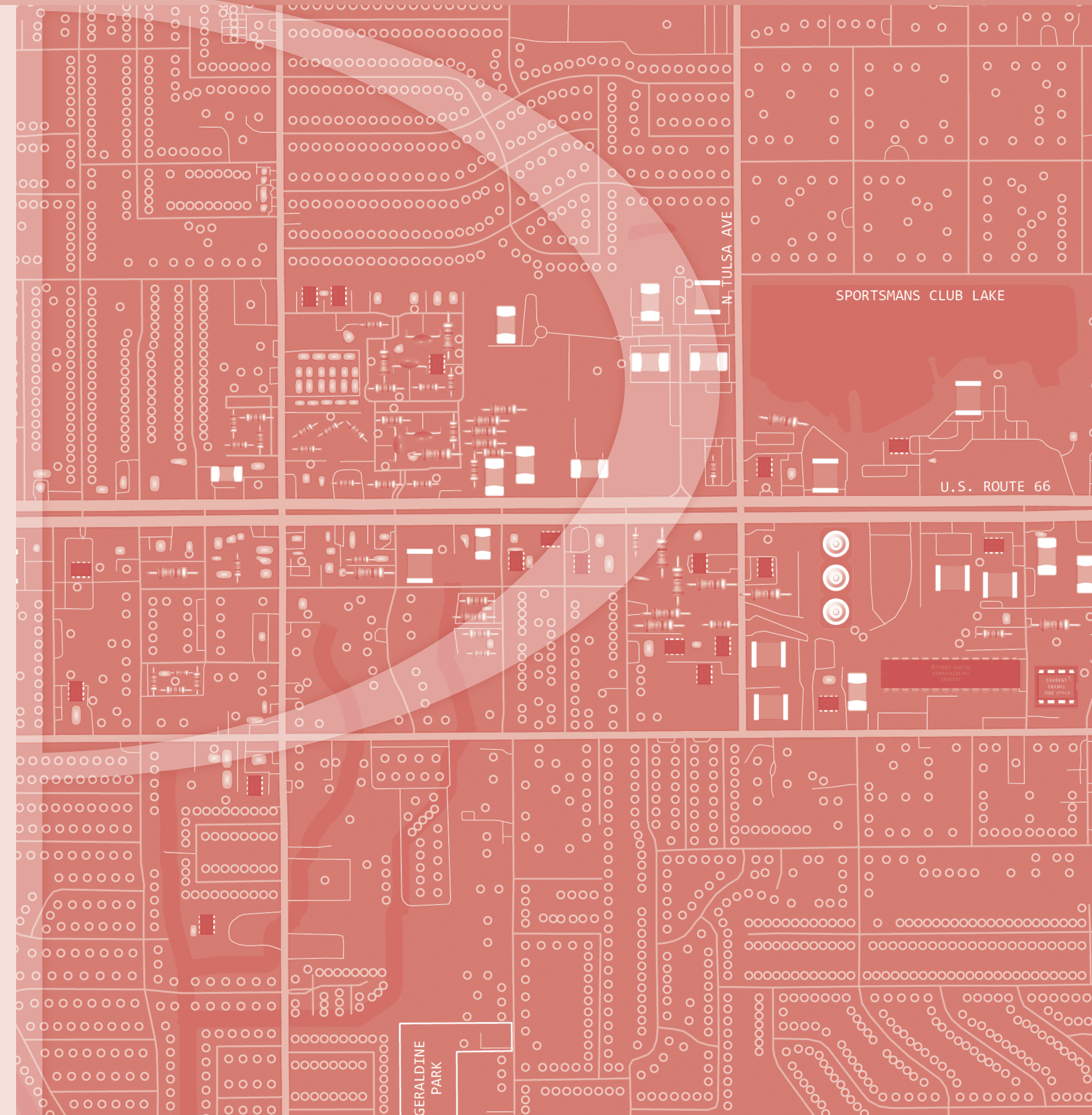
Cartographic Perspectives

The Journal of nacis

Number 103, 2024



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IN THIS ISSUE

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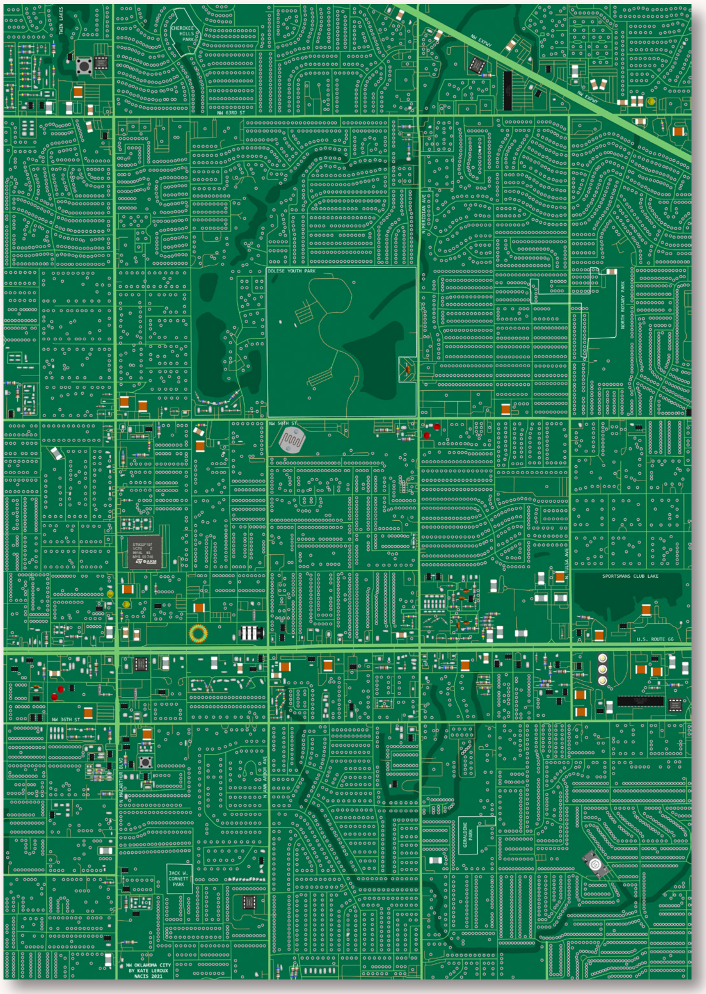
ABOUT THE COVER



Our cover this month shows part of a map of Oklahoma City, by Kate Leroux. Styled as a circuit board, it was part of the NACIS 2021 Map Quilt and pays homage to the city's role in the growing Silicon Prairie. You can find more of Kate's work at mynameiskate.com.

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LETTER FROM THE EDITOR

It is, once more, my great honor and privilege to write the editorial introduction for this 103rd issue of *Cartographic Perspectives*. An increase in the number of articles submitted to the journal has yielded a particularly long issue at 114 pages, one that features three research articles, entries in the *Practical Cartographer's Corner* and *Visual Fields* sections, and an assortment of book reviews from across the spectrum of cartography. It is my hope that any reader can find one (or hopefully several) topics of interest in this issue.

Before introducing the specific entries, I'd like to take a moment to mention a few changes coming to *Cartographic Perspectives* in the near future. First, we have developed and are currently finalizing a policy on the use of generative artificial intelligence tools when writing, reviewing, and editing for our journal. Second, in light of the tragic and much too soon passing of NACIS board member and **regular CP contributor**, Carl Sack, we are in the process of developing a policy for how memorial pieces for members of our community can be published. Finally, a formal policy on retractions and corrigenda is in the works. Assistant Editor Daniel Huffman and I have been working on these policies with the input and approval of the Editorial Board and they are intended to bring *Cartographic Perspectives* in line with other journals which have formal policies on these matters; these policies will help ensure that CP continues to serve the entire NACIS community moving forward. If you have any questions, concerns, or contributions related to the above, please do reach out to me directly. As soon as each policy is finalized, it will be added to our website.

In this issue, the first of our research articles, by Krisztián Kerkovits, is a wonderfully technical exploration of minimizing distortion for oblique map projections. Building on the work of Frank Canters (2002), Kerkovits walks readers through both the underlying math and the design choices that went into the production of a new map projection. In the issue's second article, A. Terry Bahill works to date a series of maps depicting the route Sir Francis Drake took when circumnavigating the globe in the sixteenth century. In addition to a fascinating, exhaustive exercise in deductive reasoning and historical map analysis, what Bahill has written is also "an experiment" in which he details how papers like his "could be written based solely on information shown on charts and maps that are freely available on the Internet" (18). The implications of this moving forward are fascinating and worth considering as we increasingly access archives digitally in a post-pandemic era. Finally, our third research article, by Chrisopher H. Roosevelt, is another historical examination of maps, this time of the US Navy's aerial photography in Türkiye during the Cold War. Roosevelt blends historical maps with flight logs and available technologies to recreate and examine a set of recently discovered aerial photographs, tying them to the interests and intents of the US and Türkiye during that period. The differences in approaches taken between Roosevelt and Bahill speak to the breadth and value of CP as a journal. Whereas Bahill writes that he and his collaborators strictly avoided papers that "tried to interpret maps as vehicles for the exercise of power" like "the plague" (46), Roosevelt, drawing on Harley (2001), begins from the perspective that "cartography and its products have always been potent discursive tools in politics and power" (53). While I think any reader with a passive familiarity with my own work will know that my personal views lie with the latter, I call attention to this difference because—to me—it speaks to the vibrancy and importance of CP as the journal of NACIS. *Cartographic Perspectives* represents the full spectrum of cartography and cartographic interest and, within that, there will be disagreement, different focuses, and debates. These make our journal, our community, and our field stronger.

In the *Practical Cartographer's Corner*, Bernhard Jenny offers a guide to using Eduard for ambient occlusion, along with some general tips for when, and how, to use the technique. The appendix to this entry may be of particular interest to some readers as it walks through the algorithm used to prevent "valley bottoms from becoming excessively dark" in flat areas (81). Meanwhile, our *Visual Fields* entry this issue is a reflection upon and recounting of the development of Eric Theise's *A Synesthete's Atlas*. While the technical side and developments behind Theise's performance are fascinating, I was personally struck by the influence of experimental film on the project; a connection I had previously not made, perhaps to my own detriment. Book reviews this issue include volumes 2 and 3 of *Women and GIS*, *Airline Maps: A Century of Art and Design*, *The Lost Subways of North America: A Cartographic Guide to the Past, Present*, *and What Might Have Been*, and the fourth edition of *Thematic Cartography and Geovisualization*. Rebecca Ramsay finds the *Women in GIS* collections engaging and insightful, helping to highlight not only that GIS is hardly a field set in stone, but that the many trailblazers that have come before us have built a "welcoming and supportive professional community" for women (98). Lily Houtman is more torn on *Airline Maps*, on the one hand finding it a potentially a source of "unique cartographic inspiration" (102); but, on the other, wishing for a more in depth engagement with the topic. Reviewing *The Lost Subways of North America*, Matthew Buchanan calls attention to the "compelling and interesting" (103) color maps of subways—built and imagined—that support each chapter of the work; while noting that the book lacks coverage of *all* of North America, instead focusing only on the United States and Canada. The last entry of this issue finds Daniel. G. Cole recommending Slocum et al.'s new edition of *Thematic Cartography and Geovisualization* as "required reading for every GIS/cartographic program across academia" (111). I'm not sure I've seen such a ringing endorsement in a book review previously.

As I conclude this introductory letter, I want to once more thank everyone who has contributed to this issue—the authors, the reviewers, the editorial team, and the NACIS community for its continued support. *Cartographic Perspectives*, a truly open-access journal covering the breadth of cartography, remains a gem. I am thankful to have been entrusted with its care.

Best,
Jim Thatcher
Oregon State University

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PEER-REVIEWED ARTICLE

A Low-Distortion Oblique Map Projection of the World's Landmasses

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This study presents the development of a world map projection intended to minimize distortion of all continents. I begin by reviewing a very similar map projection developed by Canters (2002), and address its shortcomings by carefully fine-tuning the initial constraints and the method of optimization, while retaining the most useful ideas of this earlier map. Most notably, the method described in this paper puts a great emphasis on the outline of the map, so that its aesthetics make it more suitable for atlases; the method also exclusively uses reproducible, deterministic methods. Finally, I compare the resulting world map to the original one of Canters in terms of map distortions and practical usefulness. The method presented here should work without changes if a low-distortion map of any other global-scale area is needed.

KEYWORDS: world map; map projections; numerical optimization; polynomial approximation; Airy–Kavrayskiy criterion

BACKGROUND

"A map projection is the mapping of a curved surface, especially a sphere or ellipsoid, into a plane" (Lapaine 2017). It is evident that map projections distort our view of the Earth, but their application is inevitable. On one hand, when compared to a physical or virtual globe, flat maps are easier to store (or are easier displayed on a flat screen) and provide an easier overview of relations covering more than a hemisphere. On the other hand, the distortions of map projections are generally a disadvantage that we need to eliminate as much as possible.

We should note that although the reduction of map distortion is a traditional approach in cartography, it is not the only meaningful workflow. Some maps are intentionally distorted to visualize a particular dataset, such as showing the areas of political units in proportion to their populations, or by spacing locations not by their physical distance, but based on the travel time between points. The reader may find further information on the theory and mathematics behind such intentionally distorted map projections (known as cartograms) in Gastner, Seguy, and More (2018). In this paper, however, the aim will be to minimize distortion with respect to the geographic reality.

The theory of Meshcheryakov (1968) states that for each area there exists an "ideal projection" that has the lowest amount of distortion possible for that area. The exact solution is still an open problem for general areas, but there are plenty of methods to approximate this map projection by polynomials or similar series. The ideal projection is strongly coupled to the region it was optimized for: each subset of the sphere will have a different ideal projection.

Although this paper deals with world maps, I will not minimize distortion for the full globe; apart from a few exceptions, a map's primary theme is usually confined to either the continents or the world ocean. As I have already previously investigated a low-distortion map of the world ocean (Kerkovits 2022), the domain of the optimization in this paper will instead be the landmasses of the earth. As the result will be a world map, the ~20 km difference between a sphere and the actual shape of the earth will not be considered; this difference diminishes to insignificance at the smaller map scales usually used for world maps.

Most world maps are plotted in a normal aspect. However, the distribution of the continents is highly asymmetrical about the equator, leading to an imbalance of distortion. Landmasses near the poles, such as Antarctica, are often distorted into unrecognizable shapes. This means that in the optimal map, the aspect of the projection (Lapaine and Frančula 2016) should be rotated, so that continents are far from the new "poles," which are called *metapoles* or *pseudopoles*. This is just a spatial rotation of the sphere, and it allows us to move our area of interest into the most advantageous parts of the projection. The most general aspect of a map projection (i.e., neither angle of rotation is a multiple of 90°) is called a *plagal aspect* by Wray (1974). Applying of plagal aspect mappings makes the most sense if Antarctica is important in our map (this is the weak point of most normal aspect world maps), and the optimization in this study will consider Antarctica as important as any other continent.

AN EARLIER, SIMILAR WORK

Canters (2002, 209–212) has already proposed a world map in plagal aspect with similar design principles to the one I will present here. Canters used random pairs of points and compared their mapped distances to their original ones. He adjusted the parameters of the map projection using the downhill simplex method until the average difference in distance could not be reduced further. However, his resulting map has several shortcomings:

- The methodology of Canters is reproducible only in a statistical sense. Furthermore, the consideration of such finite elements inevitably suffers from the "edge effect" (Albinus 1981; Laskowski 1997; Kerkovits 2019), so the peripheral parts of continents (i.e., areas near the coasts) have less weight during the optimization. The method I will present uses a deterministic method to determine the best fitting parameters, which also resolves the edge effect.

- Canters did not find the optimal aspect parameters for his oblique maps. I experimented with the downhill simplex method using different initial values and found that the arrangement of Canters is only a local minimum with respect to the distortion. In most cases, the downhill simplex method converged to a neighborhood of another minimum described later in this paper. That one has a lower distortion value, and so it is a more likely candidate to be the global minimum.

- The outline of a map projection is irrelevant for regional maps, where the cartographer may crop the map by a frame of arbitrary shape. However, it is a crucial aesthetic point for world maps, where the map frame is exactly the border of the map projection. Apparently, Canters did not consider this; therefore, his map has a very unusual shape (Figure 1). It bends concave near the metaequator (pseudoequator) and has sharp concave corners at the metapoles. My proposed projection puts a great emphasis on the outline of the final map.

Thus, one may consider this paper as an attempt to improve the methods and the map of Canters, while trying to keep the advantages of the original design.

DESIGN CONSIDERATIONS

The map presented in this paper has been designed to show continents with low distortions. However, these distortions must be measured on an infinitesimal scale: distortion measurements of finite shapes are all based on random samples, and thus are not reproducible in a strict sense. Deterministic methods are preferred. Furthermore, random samples are not distributed uniformly; due to the edge effect they are a bit sparser near the boundaries of the area. In this study, coastal regions are regarded as equally important compared to inland parts. Therefore, the Airy–Kavrayskiy criterion described later in Equation 14 was chosen to be the distortion value of the optimization.

Ideal map projections, despite their name, are not necessarily the "best" mappings. They have unusual properties that can hinder their aesthetic value. Most prominently, as the distribution of continents is asymmetrical on the earth, it is obvious that their ideal map is also asymmetrical. However, the map frame should be symmetrical

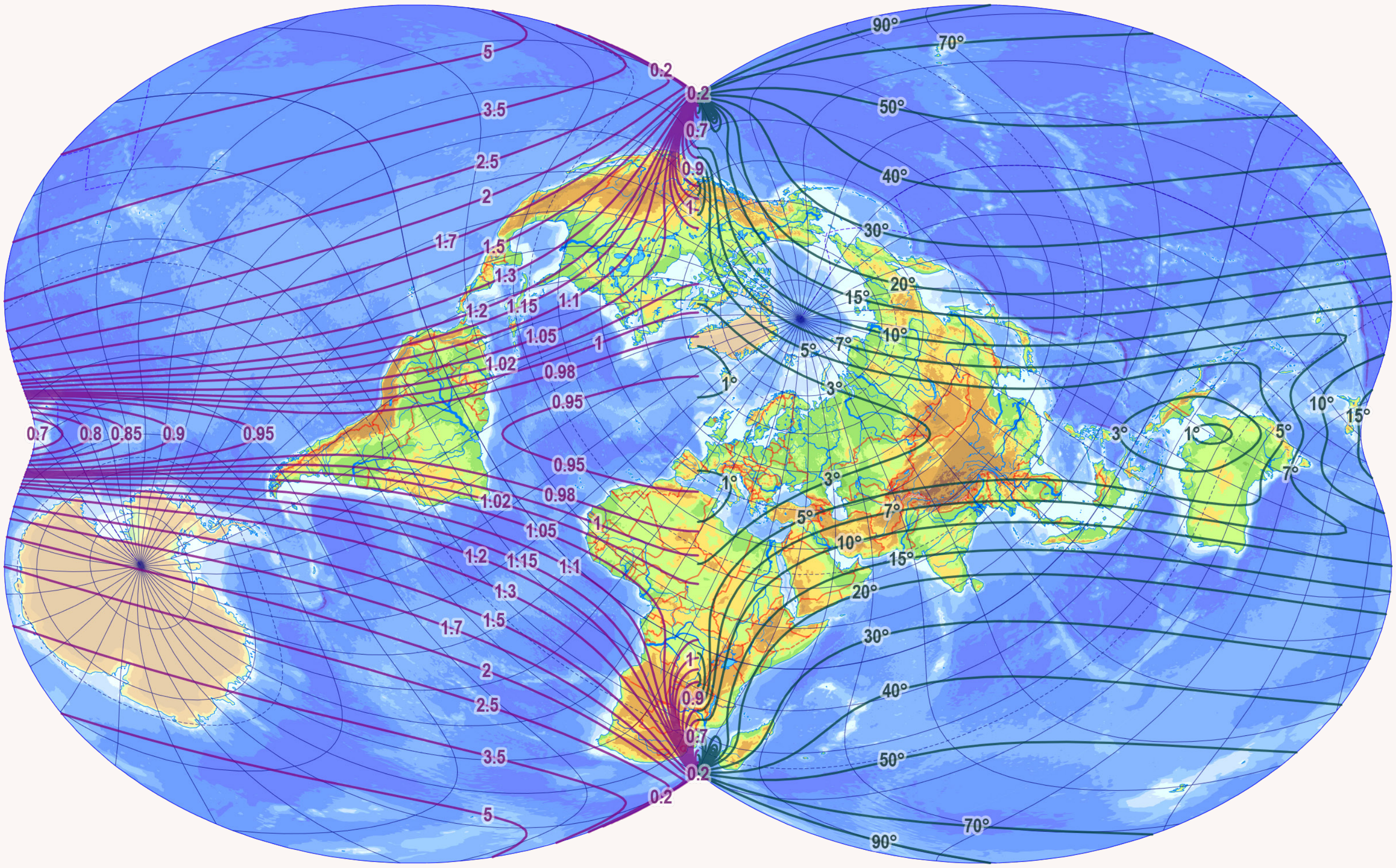

Figure 1. The plagal map projection of Canters (2002, 213) Purple lines: areal scale, green lines: maximal angular deviation.

to resemble the symmetries of the underlying sphere. Therefore, the map projection developed here will be symmetrical about both the metaequator and the prime metameridian. This ensures the symmetry of the map frame and the distortion distribution. Nevertheless, the map graticule will be asymmetrical due to the plagal aspect.

It is well known that flat-polar maps can have, in general, lower distortions than pointed-polar ones (Snyder 1985, 124). However, flat-polar oblique world maps are not encountered in serious publications, and oblique world maps of established authors (e.g., Bartholomew, Briesemeister) are all pointed-polar. A possible reason is that while map readers are accustomed to seeing the true pole represented by a pole line, the same is not accepted in the case of an arbitrary metapole. It's worth noting that there *are* some oblique flat-polar maps, by authors such as Winkel and Wagner, but these have their metapoles placed outside the map frame. Consequently, the map projection developed here will be pointed-polar.

We must also observe that in oblique world maps, such as previous examples like the Atlantis or the Bertin projections, the metapole is never cusped (like in the sinusoidal projection), but the map frame is smooth. Assuming that this decision comes from aesthetic consideration, this study will prescribe that the map frame must be smooth at the metapoles. Furthermore, metameridians (except the prime metameridian) will also pass through the metapole without a cusp, so that graticule lines will continue smoothly (an example of such a map is that of Mollweide).

FORMULAE OF THE MAP PROJECTION

In the mathematical development of the new map, we will assume that the earth is a sphere of unit radius. Following the usual convention, φ will stand for latitude and longitude will be denoted as λ. Unless explicitly marked by a degree symbol, all angles are in radians. The image of the map projection is on the plane parametrized by a usual Cartesian coordinate system. Planar coordinates are denoted by x and y.

The formulae of the map projection must be developed with due care. The exact formulation influences the result of the optimization significantly (Canters 2002). We must allow the map projection to take any possible shape permitted by the prior constraints. Assuming that the optimal projection is smooth (analytical), a polynomial can approximate it to arbitrary precision. On the other hand, simple polynomials permit flat-polar projections. A map projection symmetrical about its mid-meridian is pointed-polar if

$$x|_{\varphi=\pm\frac{\pi}{2}} = 0 \quad \text{and} \quad \frac{\partial y}{\partial \lambda}\bigg|_{\varphi=\pm\frac{\pi}{2}} = 0 \tag{1}$$

Bimeridians will cross the pole without a cusp if they are perpendicular to the vertical axis:

$$\lim_{\varphi\to\pm\frac{\pi}{2}} \frac{\partial x}{\partial \varphi} = \pm\infty \tag{2}$$

The simplest function that satisfies the constraints of x is achieved by transforming the equation of a circle:

$$x = P_x(\varphi,\lambda)\sqrt{1-\left(\frac{2\varphi}{\pi}\right)^2} \tag{3}$$

where $P_x(\varphi, \lambda)$ can be any polynomial of φ and λ.

The constraint on y is less specific, as it only requests that its derivative must be zero at two points. It may either be achieved by a quadratic function or a cosine function. Testing both ideas, it turned out that the latter one behaved better (allowed for more flexibility during optimization) when being multiplied by the polynomial, so $\partial y/\partial\lambda$ was chosen to be $P_y'(\varphi, \lambda)\cos\varphi$. Integrating it with respect to λ yields

$$y = P_y(\varphi,\lambda)\cos\varphi + P_c(\varphi) \tag{4}$$

where $P_c(\varphi)$ is a constant of integration, which is a polynomial of φ, and $P_y(\varphi, \lambda)$ is the antiderivative of polynomial $P_y'(\varphi, \lambda)$. Namely, $P_y(\varphi, \lambda)$ can be almost any polynomial, but it must not contain terms constant in λ.

Symmetry about the mid-meridian and the equator can be achieved by constraining the parity of functions x and y. In our case, P_x must be an even function of φ and an odd function of λ, P_y must be an odd function φ of and an even function of λ, and P_c must be an odd function of φ. Putting this together:

$$x = (A_{01}\lambda + A_{03}\lambda^3 + A_{21}\varphi^2\lambda + A_{05}\lambda^5 + A_{23}\varphi^2\lambda^3 + A_{41}\varphi^4\lambda + \cdots)\sqrt{1-\left(\frac{2\varphi}{\pi}\right)^2} \tag{5}$$

$$y = (B_{12}\varphi\lambda^2 + B_{32}\varphi^3\lambda^2 + B_{14}\varphi\lambda^4 + \cdots)\cos\varphi + B_{10}\varphi + B_{30}\varphi^3 + B_{50}\varphi^5 + \cdots \tag{6}$$

The polynomials were truncated at the fifth degree. A major problem was that even with fifth-degree polynomials, I found seemingly completely different sets of coefficients as local minima with different starting values, but there was absolutely no visual difference in the resulting maps, and their estimated distortion value was different by less than 0.0001%. This experience suggests that a better approximation might be meaningless.

Additionally, I examined seventh-degree polynomials. However, the computation time was more than 10 hours on a modern desktop computer, compared to the more reasonable 20–30 minutes needed for optimizing the fifth-degree polynomial. This made it cumbersome to check different starting values, although the downhill simplex method seemed to be very sensitive to them: it reported local minima very far from each other, none of which could be responsibly reported as a global minimum. Nevertheless, the resulting maps were close in appearance to the result of the fifth-degree polynomial, so that there appeared to be no practical benefit from using higher-degree polynomials.

This resulting map projection can then be applied in the plagal aspect to further minimize distortion. Namely, the metapole is rotated to a point at φ_0, λ_0, and the prime metameridian has azimuth λ_p'. In this case, the metalatitude φ' and metalongitude λ' becomes (Snyder 1987):

$$\varphi' = \arcsin[\sin\varphi_0\sin\varphi + \cos\varphi_0\cos\varphi\cos(\lambda-\lambda_0)] \tag{7}$$

$$\lambda' = -\lambda_p' + \arctan\frac{\sin(\lambda-\lambda_0)}{-\cos\varphi_0\tan\varphi + \sin\varphi_0\cos(\lambda-\lambda_0)} \tag{8}$$

but it should be noted that the *arctan* function should actually be implemented as *atan2* in many conventional programming languages.

When applying Equations 5 and 6, the metacoordinates obtained in Equations 7 and 8 should be substituted for φ and λ.

OPTIMIZATION OF COEFFICIENTS

Coefficients A_{ij}, B_{ij} and parameters φ_0, λ_0, λ'_p of the aspect were optimized against the Airy–Kavrayskiy criterion (denoted as E) calculated as (Györffy 2018):

$$h = \sqrt{\left(\frac{\partial x}{\partial \varphi}\right)^2 + \left(\frac{\partial y}{\partial \varphi}\right)^2} \tag{9}$$

$$k = \frac{1}{\cos\varphi}\sqrt{\left(\frac{\partial x}{\partial \lambda}\right)^2 + \left(\frac{\partial y}{\partial \lambda}\right)^2} \tag{10}$$

$$\cot\vartheta = \frac{\frac{\partial x}{\partial \lambda}\frac{\partial x}{\partial \varphi} + \frac{\partial y}{\partial \lambda}\frac{\partial y}{\partial \varphi}}{\frac{\partial x}{\partial \lambda}\frac{\partial y}{\partial \varphi} - \frac{\partial y}{\partial \lambda}\frac{\partial x}{\partial \varphi}} \tag{11}$$

$$a = \frac{\sqrt{h^2 + k^2 + 2hk\sin\vartheta} + \sqrt{h^2 + k^2 - 2hk\sin\vartheta}}{2} \tag{12}$$

$$b = \frac{\sqrt{h^2 + k^2 + 2hk\sin\vartheta} - \sqrt{h^2 + k^2 - 2hk\sin\vartheta}}{2} \tag{13}$$

$$E = \sqrt{\frac{1}{S}\iint_S \frac{\ln^2(ab) + \ln^2\frac{a}{b}}{2}\,\mathrm{d}S} = \sqrt{\frac{1}{S}\iint_S \ln^2 a + \ln^2 b\,\mathrm{d}S} \tag{14}$$

where S is the surface of continents.

The surface integral in Equation 14 should be calculated over irregular spherical polygons. It was, in fact, evaluated numerically using the two-point Gaussian quadrature generalized for spherical polygons (Kerkovits 2020). Optimal parameters were found by a more robust variant of the downhill simplex method as designed by Kaczmarczyk (1999).

Simultaneous optimization of the aspect parameters and coefficients made the method unstable, converging into various local minima. Therefore, in the first step, only the aspect parameters were optimized, trying a few starting values. Most runs resulted in $\varphi_0 \approx 37.8711°$, $\lambda_0 \approx 168.0160°$, $\lambda'_p \approx -140.8168°$, which is quite far from what Canters (2002) reported: $\varphi_0 \approx 30°$, $\lambda_0 \approx -140°$, $\lambda'_p \approx 150°$ using the notation conventions of this study. Furthermore, a few starting values led the downhill simplex to other local minima: notably, one of the local minima was pretty close to the values Canters reported and showed only slightly bigger distortion values (see exact values in the next section) after optimizing the coefficients: $\varphi_0 \approx 19.1366°$, $\lambda_0 \approx -118.2273°$, $\lambda'_p \approx 140.1385°$. Some selected starting values that I tried can be checked in Table 1. Minima were considered identical if they resulted in the same map upside down.

It seems that Canters only found a local minimum for the aspect parameters. Although Canters excluded Antarctica from the optimization, the optimal map projection has circa 3.27% less distortion if we use the aspect parameters developed here instead of Canters's one, even if Antarctica is excluded from the calculation. The result of this correction is that Antarctica will be moved from the bottom right corner to the bottom left one, and the antimeridian cut will go through the Drake Passage instead of passing by the Kerguelen Islands. Cartographic effects of this change are discussed at the end of the paper.

In the second step, the aspect parameters were fixed and only coefficients were optimized. Allowing the aspect parameters to change, distortions would have been decreased

Starting value			Terminated at
φ_0	λ_0	λ'_p	
90°	0°	0°	Global minimum
90°	0°	90°	Other local minimum
90°	0°	180°	Canters's minimum
90°	0°	-90°	Canters's minimum
45°	0°	0°	Global minimum
45°	90°	-90°	Global minimum
45°	-90°	90°	Global minimum
-45°	0°	0°	Other local minimum
0°	0°	0°	Global minimum
0°	90°	0°	Global minimum
0°	180°	0°	Canters's minimum
0°	-90°	0°	Other local minimum
0°	0°	90°	Canters's minimum
0°	0°	180°	Global minimum

Table 1. Influence of starting values on the result of aspect parameter optimization.

further, but the map frame would have cut into the middle of South America, which is clearly unacceptable for a map projection that is themed around continents. As an aesthetic consideration, angles of the aspect parameters were rounded to the nearest 5° so that the graticule lines of the map would symmetrically "snap" to the map frame. The starting projection was the Apian II ($A_{ij} = B_{ij} = 0$ but $A_{01} = B_{10} = 1$), but in order to avoid reporting local minima, the downhill simplex method was restarted near the result of the last run and the result was accepted only if two successive runs reported the same minimum.

THE RESULTING MAP PROJECTION

As mentioned previously, two sets of aspect parameters were tried. The first, $\varphi_0 = 20°$, $\lambda_0 = -120°$, $\lambda'_p = 140°$ (close to Canters's original suggestion) resulted in $E \approx 0.186371$, while the new parameters of $\varphi_0 = 40°$, $\lambda_0 = 170°$, $\lambda'_p = -140°$ lead the optimization to $E \approx 0.178772$. Therefore, the previous set of parameters were discarded. Finally, the calculated coefficients are: $A_{01} \approx 0.843705$, $A_{03} \approx 0.009100$, $A_{21} \approx 0.028176$, $A_{05} \approx -0.001242$, $A_{23} \approx -0.001448$, $A_{41} \approx 0.063196$, $B_{10} \approx 0.953366$, $B_{30} \approx 0.033826$, $B_{12} \approx 0.015131$, $B_{50} \approx -0.006287$, $B_{32} \approx -0.025215$, $B_{14} \approx 0.008227$.

Substituting this into Equations 5–8, one gets the map displayed in Figures 2–4. The reader is advised to compare the distortion isolines to that of Canters's original map (Figure 1). It can be observed that both angular and areal distortions decreased significantly at most places. The biggest winner is, of course, Antarctica, where areal inflation decreased from 150% to only 10%, and the angular deviation was changed from 20° to 7°. Other regions gaining much better representation include South Africa (inflation: 100% → 50%; angular deviation: 40° → 25°) and Mexico (inflation: 50% → –2%; angular deviation: 25° → 12°). Weak points of the new mapping are in Australia (inflation almost unchanged; angular deviation: 3° → 12°) and Chile (inflation: 0% → 12%; angular deviation effectively the same). In general, the new projection surpasses Canters's one.

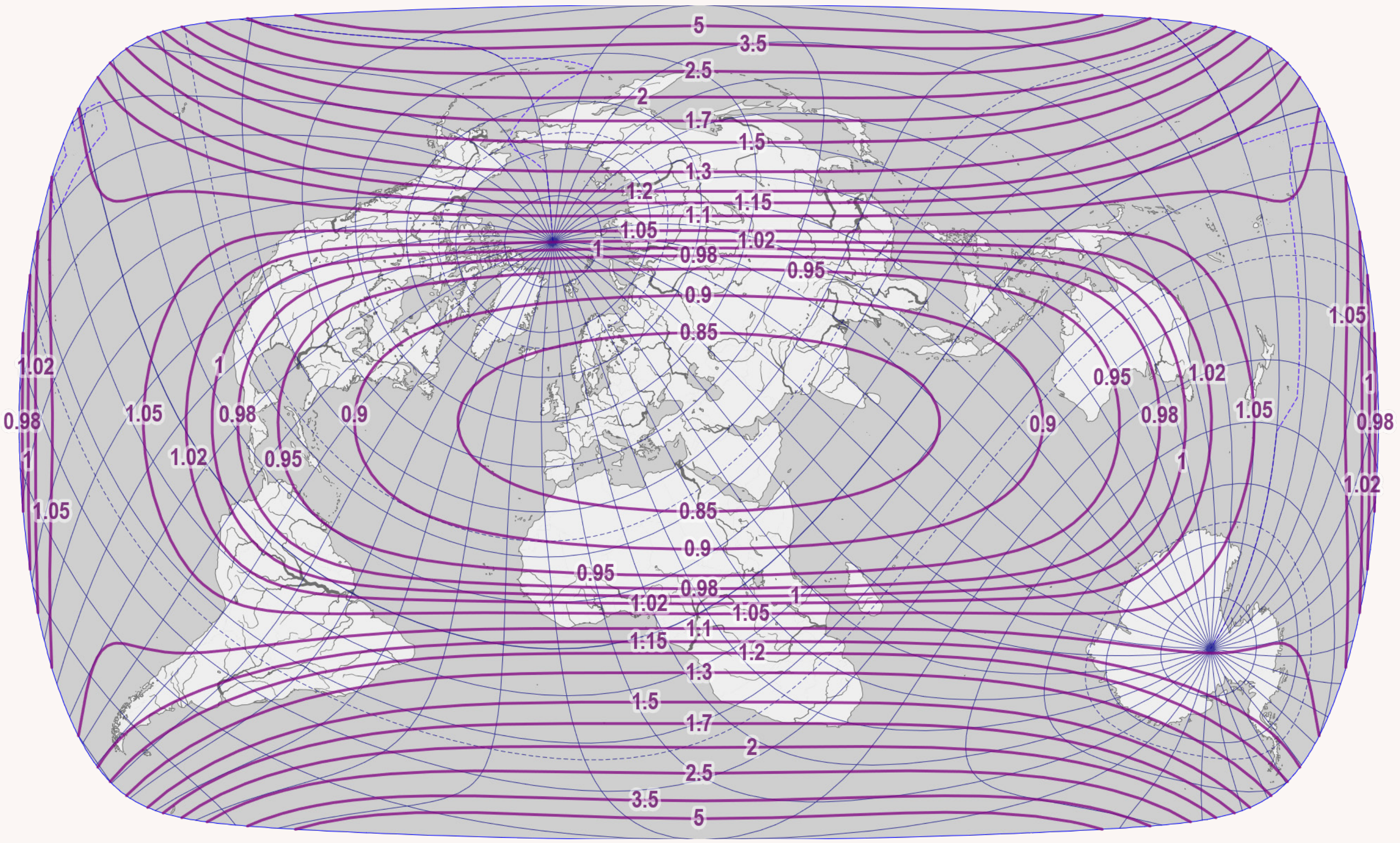

Figure 2. The new map projection developed in this paper (isolines of areal scale).

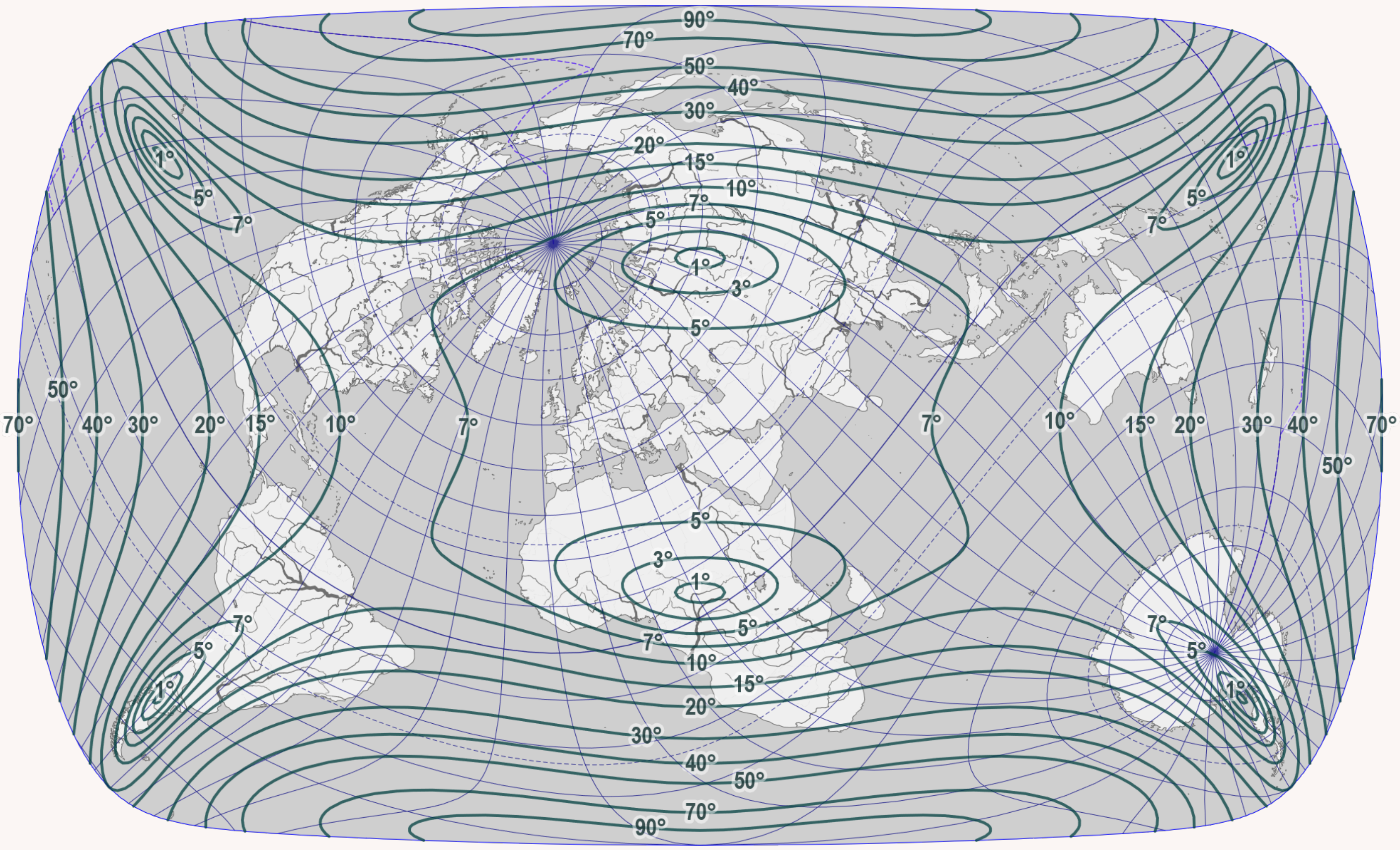

Figure 3. The new map projection developed in this paper (isolines of maximum angular deviation).

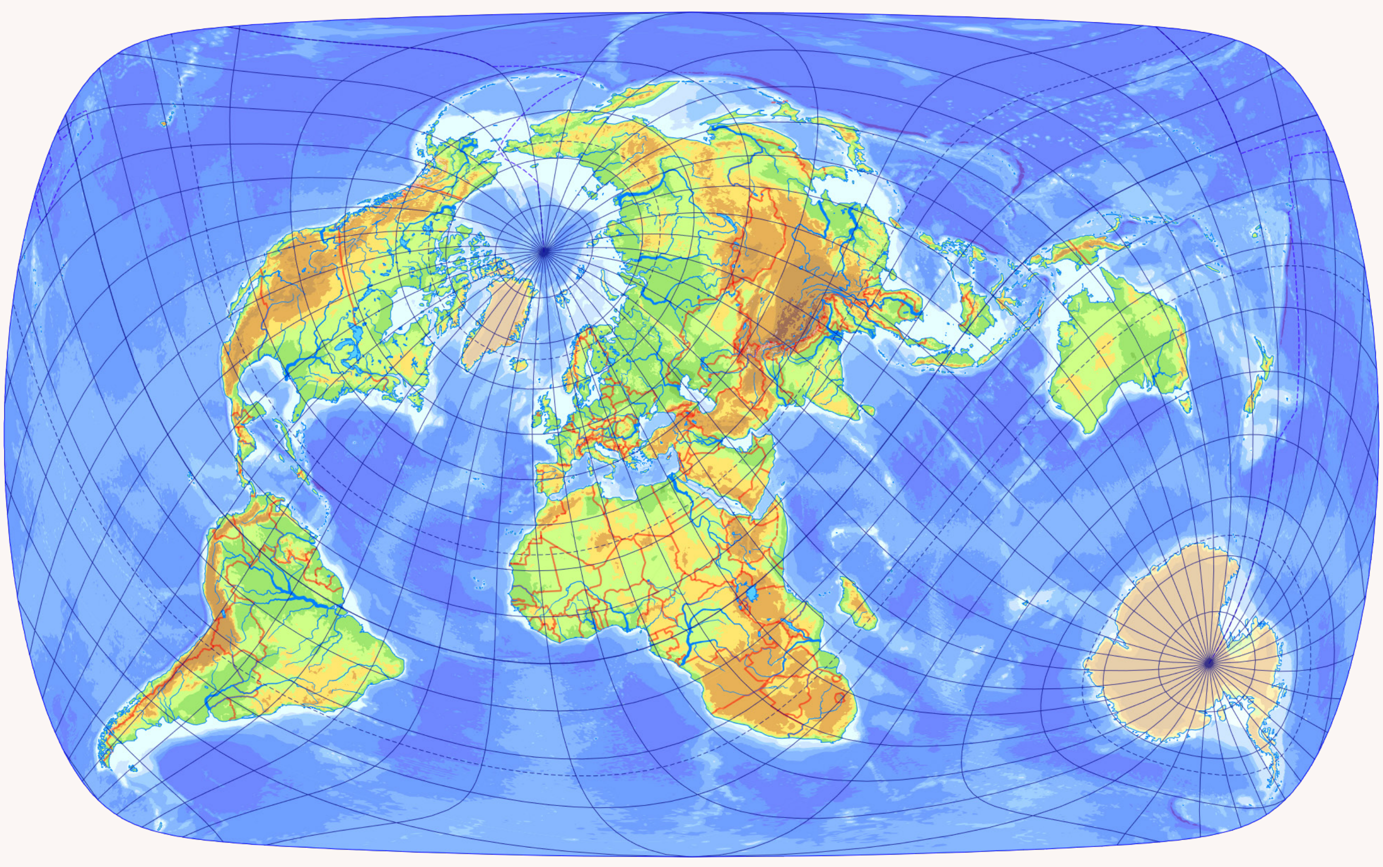

Figure 4. The new map projection developed in this paper (without isolines)

CONCLUSIONS

Comparing the overall texture of the new map to that of Canters, the map presented here is significantly more compact. Continents appear to be closer to each other, emphasizing their global connections. However, the different placement of the discontinuity at the antimeridian has stretched the southern tip of Africa slightly away from South America, and the connection between Antarctica and South America is lost. These disadvantages are, however, not so large: South Africa and Argentina are quite far from each in reality, and one can hardly find a map theme in which global connections between South America and Antarctica would be crucial. However, for situations where such proximities do matter, the present map can show the proximity of New Zealand to Antarctica or even to its outlying islands, which is a feature absent from Canters's map.

The amount of distortion was already quite low, but it could even be reduced further by trying to avoid local minima and carefully selecting the functions used in the development. This paper used fifth-degree polynomials for the approximation, as the computation technology has not advanced enough since Canters to allow for a better approximation.

The frame of the resulting map looks like a rounded rectangle. This might be considered as an advantage, as it fits well in a rectangular screen or a rectangular sheet of paper. However, this shape has very low resemblance to the near-spherical shape of the Earth. Nevertheless, it still fills a typical page better than Canters's apple-shaped frame, and the lack of the concave bends make it a more reasonable solution for practical cartography. Although according to my own aesthetic taste, further correction of the outline is unnecessary in this case; if one needs a more "elliptical" outline, it should be possible to combine the method presented in this paper with the outline reshaping method of Györffy (2018).

As a final thought, the present study shows that after a wise choice of design criteria, optimal map projections of the earth do not always look unnatural. The results of the optimization presented here may be used as-is in practical cartography.

REFERENCES

Albinus, Hans-Joachim. 1981, "Anmerkungen und Kritik zur Entfernungsverzerrung." *Kartographische Nachrichten* 31 (5): 179–183.

Canters, Frank. 2002. *Small-scale map projection design*. London: CRC Press. **https://doi.org/10.4324/9780203472095**.

Gastner, Michael T, Vivien Seguy, and Praytush More. 2018. "Fast flow-based algorithm for creating density-equalizing map projections." *Applied Mathematics* 115 (10): 2156–2164. **https://doi.org/10.1073/pnas.1712674115**.

Györffy, János. 2018. "Minimum distortion pointed-polar projections for world maps by applying graticule transformation." *International Journal of Cartography* 4 (2): 224–240. **https://doi.org/10.1080/23729333.2018.1455263**.

Kaczmarczyk, Grzegorz. 1999. "Downhill simplex method for many dimensions." Accessed March 16, 2002. **http://paula.univ.gda.pl/~dokgrk/simplex.html**.

Kerkovits, Krisztián. 2019. "Comparing finite and infinitesimal map distortion measures." *International Journal of Cartography* 5 (1): 3–22. **https://doi.org/10.1080/23729333.2018.1500255**.

———. 2020. "Quadrature Rules to Calculate Distortions of Map Projections." *The Cartographic Journal* 57 (3): 249–260. **https://doi.org/10.1080/00087041.2020.1714278**.

———. 2022. "A Low-Distortion Map of the World Ocean Without Discontinuities." *Kartografija i Geoinformacije* 21 (special issue): 80–90. **https://doi.org/10.32909/kg.21.si.6**.

Lapaine, Miljenko. 2017. “Definicija kartografske projekcije [Map Projection Definition].” *Kartografija i Geoinformacije*. 28 (16): 136–137. English translation is available at **https://kig.kartografija.hr/index.php/kig/article/view/795**.

Lapaine, Miljenko, and Nedjeljko Frančula. 2016. “Map projection aspects.” *International Journal of Cartography*. 2 (1): 38–58. **https://doi.org/10.1080/23729333.2016.1184554**.

Laskowski, Peter. 1997. “Part 1: Distortion-spectrum fundamentals a new tool for analyzing and visualizing map distortions.” *Cartographica* 34 (3): 3–18. **https://doi.org/10.3138/Y51X-1590-PV21-136G**.

[Meshcheryakov, German A.] Мещеряков, Герман А. 1968. Теоретические основы математической картографии [Theoretical bases of mathematical cartography]. Москва: Недра.

Snyder, John P. 1985. *Computer-assisted map projection research*. Washington, DC: US Government Printing Office. **https://doi.org/10.3133/b1629**.

———. 1987. *Map projections: A working manual*. Washington, DC: US Government Printing Office. **https://doi.org/10.3133/pp1395**.

Wray, Thomas. 1974. “The Seven Aspects of a General Map Projection.” *Cartographica* 11 (2): 1–72. **https://doi.org/10.3138/E382-8522-4783-28K5**.

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Dating Maps with Sir Francis Drake's Route of Circumnavigation

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This paper describes the nine sixteenth-century maps, texts, and globes that showed Sir Francis Drake's route of circumnavigation of the world. It shows the relationships between these nine artifacts and suggests the year of disclosure for each. The oldest of these is the Whitehall map, which was the direct or indirect precursor of the Drake-Mellon map, the French-Drake Van Sype map, the Dutch-Drake map, and the Hondius Broadside map. Most world maps published between 1561 and 1588 have a huge bulge on the coast of Chile. However, eight of the maps discussed in this paper shrank the bulge and moved it to the southern tip of Chile, using updated information from Drake's voyage.

KEYWORDS: *Whitehall* map; Nicola van Sype; nautical charts; Sir Francis Drake; circumnavigation; bulge on the coast of Chile; *Drake-Mellon* map; *Silver* maps; Spanish Armada; sixteenth century

INTRODUCTION

Sir Francis Drake (ca. 1541[1]–1596) was an English admiral, ship captain, naval navigator, world explorer, war hero, and privateer. The Spanish, however, viewed him as a ruthless pirate and called him *El Draque, The Dragon*. Drake commanded the second ship to circumnavigate the earth. This paper is about the first descriptions of Drake's route of circumnavigation.

Drake sailed from England in December of 1577 with a fleet of five ships and headed southwest across the Atlantic through storms, starvation, and mutiny. His purpose may have been to recover his losses to King Phillip II of Spain, to avenge his grievances against this king, or maybe it was to seize Spanish treasures. He passed through the Strait of Magellan and reached the Pacific Ocean in September 1578 with one remaining ship, the *Golden Hind*. Then, as he sailed north, he plundered Spanish ships and ports along the west coast of South America.

In June of 1579, he gave up pirating and searching for the Northwest Passage and spent five weeks onshore on the northwest coast of America repairing his ship and preparing for a long voyage west across the Pacific Ocean. Then he sailed perhaps 10,000 miles non-stop in 100 days, an unprecedented feat, and arrived at his intended destination without running out of food or water. This was an unparalleled feat of navigation.

Drake sailed through the Spice Islands (the Moluccas or Maluku Islands) in November 1579 and then around the Cape of Good Hope. On the unremarkable final leg of his journey northwards up through the Atlantic Ocean, he stayed far away from Spain. He returned to England in September of 1580. His ship was bulging with stolen gold and silver from Spanish ships and ports, rare porcelains and silks from China, and spices from islands of the East Indies.

When he met with Queen Elizabeth on his return to England, Drake presented to her a map of the world with his route of circumnavigation drawn on it. She hung this map on a wall of her private quarters in her Whitehall Palace, hence its name, the *Whitehall* map. In honor of his circumnavigation of the world, in 1581 she knighted him.

1. Drake was born in the 1540s. The Library of Congress states 1543. Wagner (1926, 457) states between 1541 and 1545. Drake (1854, vi) states 1544. A quick survey of Internet sources with Drake's birthdate yielded $\bar{x}$ = 1540.9, σ = 1.4, n = 33, and range = 1540 to 1545. We will use 1541. The reader can ignore all footnotes in this paper without a lack of continuity.

About eight years later, world maps showing his route suddenly appeared. The purpose of these maps was presumably to honor Drake's achievement and show his route of circumnavigation. The following contemporary maps, globe, and book describe Drake's general route of circumnavigation.[2] No papers in the literature describe these nine artifacts as a group. In this list, we also give our final determination of their years of disclosure.[3]

- The *Whitehall* map 1580, burned in the seventeenth century.
- *Drake-Mellon* map 1589, ***Vera descriptio expeditionis nauticae*** . . . .
- Drake ***Silver* maps** 1589; see also **hdl.loc.gov/loc.rbc/rbdk.d058**.
- Richard Hakluyt 1589, "The famous voyage of Sir Francis Drake . . ." in ***The Principall navigations*** . . . , text only, no map.
- *French-Drake Van Sype* map 1589, ***La Herdike Enterprinse*** . . . .
- *Dutch-Drake* map 1594, ***La Heroike Interprinse*** . . . .
- Emery Molyneux 1592, ***Petworth House Globe***.
- Jodocius Hondius 1595 map, ***Vera Totius Exbitionis Nautica***, (*Broadside* map).
- Theodor de Bry 1599 map, ***America Pars VIII***, a copy of the Hondius *Broadside*.

In this paper, these nine descriptions of Drake's route of circumnavigation will collectively be called the C9. The C9 without the *Whitehall* map will be called the C8. We recommend that the readers look ahead in this paper and familiarize themselves with Figures 2–8, which show the C8. URLs for these and all other maps mentioned in this paper are given in our list/database located at **sysengr.engr.arizona.edu/URLsForSixteenthCenturyMaps.xlsx**.

Why was there a gap of over eight years between the completion of Drake's voyage and the first public descriptions of his route? Probably because Queen Elizabeth wanted to keep all of Drake's discoveries secret from the despised and feared Spanish. This included where Drake had been, the fact that he had circumnavigated the world, how much gold and silver he had brought back, and most importantly his route of circumnavigation. The Queen forbade her subjects to disclose these state secrets *under pain of death* (de Mendoza 1896; Colthorpe 2017, 29).

As will be shown below, four of the C9 (the *Drake-Mellon*, the *French-Drake*, the *Dutch-Drake,* and the Hondius *Broadside* maps) were certainly based on the *Whitehall* map, either directly or indirectly: it was their common precursor. Figure 1 shows, with black arrows, information flows between the C9; grey arrows indicate uncertain information flows. This figure summarizes the literature about sixteenth-century maps that contain the route of Drake's circumnavigation of the world. While our general principle in this paper it to use only information contained on the maps themselves, this figure is an exception. It instead uses information from historical texts, sixteenth-century family, friendship, and religious relationships, language, geographical location of the cartographers, and chronology of the maps.

2. We have found no other sixteenth-century maps or texts that show or describe the route of Drake's circumnavigation of the world, except possibly for the following four. The John Blagrave 1596 *Nova Orbis Terrarum Descripto* map has the routes of circumnavigation of Drake and Cavendish (Shirley 1983, entry 191; Wallis 1984, 155). However, it uses a unique projection, featuring a north polar stereographic for the northern hemisphere, with the southern hemisphere added in four corner pieces to extend the map into the shape of a square. It is mathematically elegant but practically useless for our purposes because Drake's path cannot be readily followed into the corners. Gastaldi & De Jode's 1600 *Nova Totius Orbis Descriptio* map also had Drake's path but we did not include it in this paper because its origin is obscure and it was published too late to have affected the maps discussed in this paper (Shirley 1983, entry 174). It can be seen at **https://objects.library.uu.nl/reader/img.php?obj=1874-12850&img=/11/77/86/1177862914752773823854090279879699329 09.jpg**.

Bawlf (2015, 33) and Wallis (1984, 132) each show a copy of Ortelius's 1579 *Typus Orbis Terrarum map* from the British Museum that has Drake's route drawn on it. However, because Drake did not return to England until 1580, this route must have been added by an unknown person at an unknown later date. Furthermore, no other copies of the *Typus Orbis Terrarum* have Drake's route. Crispin de Passe in his 1598 *Effigies Regum ac Principum* has a portrait of Drake along with a simplified miniature of the Hondius 1595 *Broadside* map. However, it adds nothing new to our discussion. Of course, there may have been other maps with Drake's route that have simply disappeared over the last five centuries.

3. The years of disclosure mean when the creator first made the maps, etc. available for others to view. These dates are probably accurate to the year, not the month (Thrower 1984, 36). Our years of disclosure are usually the year after an enabling event. For example, Rumold Mercator first published his double-hemisphere equatorial stereographic map projection in 1587. We think that it would take a year to learn a new technique, make a new map or write a text, and then publish it. Therefore, the earliest year of disclosure we give for maps using that projection is 1588. In a similar way, the Spanish Armada was destroyed in August 1588. So, we state that maps and texts that depend on that event could have first been made public in 1589.

When we began this research, the state of knowledge about the information sharing between these sources was as shown in Figure 1. However, no previous papers have shown all of this in an integrated form. Although the Ortelius *Typus Orbis Terrarum* does not contain Drake's route of circumnavigation, it is included in Figure 1 because it is central to late sixteenth-century nautical world maps. Figure 1 foreshadows the findings of this paper, suggesting the incipient relationships between the C9 that will be revealed. Two purposes of the research presented in this paper are to find the relationships and the years of disclosure of these maps, globes, and books. We will start at the top of Figure 1 with the *Whitehall* map.

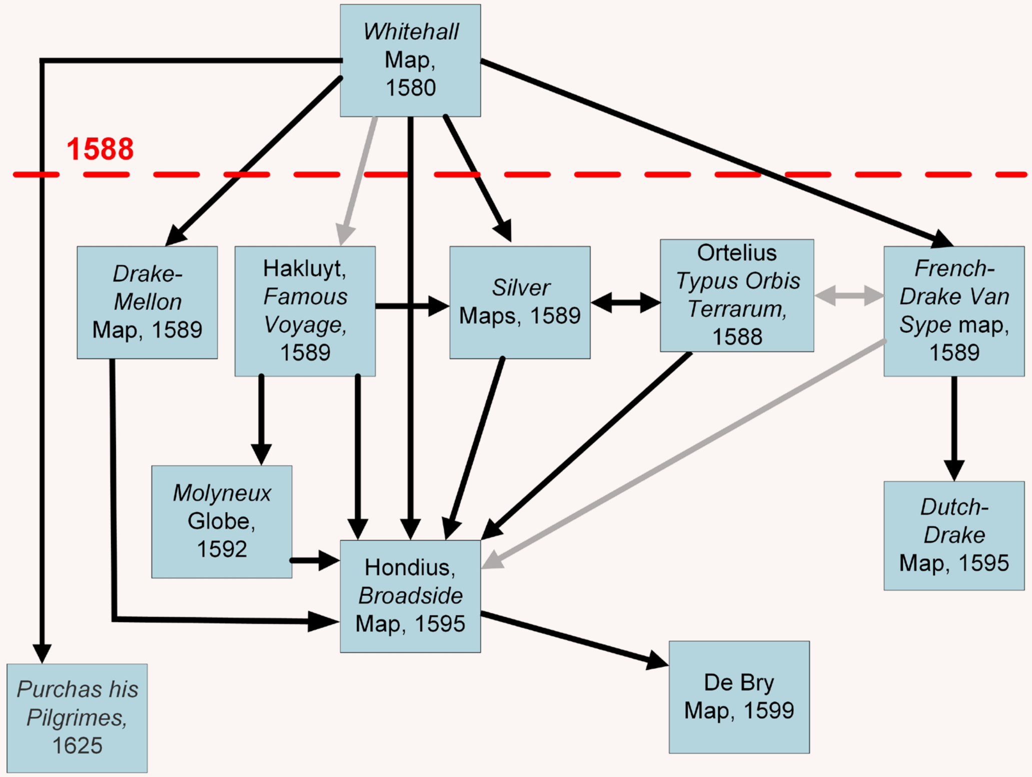


Figure 1. A flashforward suggesting the derivation and chronology of the first descriptions of Drake's route of circumnavigation of the world shown in this paper. Time runs roughly from the top to the bottom.

METHODS

This paper analyzes the relationships of the sixteenth-century C9 that show Drake's route of circumnavigation of the world, based only on information shown on the maps themselves. My colleagues and I inspected over 2,000 sixteenth-century nautical charts and maps[4] that were available on the Internet. We downloaded 500 of these maps and examined them in detail. Of these, we recorded the 180 most relevant to Drake's route in our database, which is located at **sysengr.engr.arizona.edu/URLsForSixteenthCenturyMaps.xlsx**. Then the C9 were studied and dated in this paper.

This is not a traditional history paper as is commonly found in the fields of cartography. Instead, this paper introduces a new genre of research writing about sixteenth-century nautical charts, by being based *only* on material contained in those charts and not modern interpretations of them. We do not make a statement about a map and then reference an earlier paper that made a similar statement. Rather we make a statement and then point to a feature on a map that supports that statement. We do not arrange the maps in chronological order. This paper does not present the religious, familial, or nationality relationships of the cartographers, or try to analyze their thinking or what their motives were. Nor does it present their ages, native languages, educations, or alma maters. In general, we do not use manuscript maps because the date can never be ascertained with certainty. We do not interpret our maps as

4. What is the difference between a nautical chart and a map? In general, a nautical chart is designed for navigation on the water. They emphasize oceans, seas, bays, and rivers and islands and shoals within them. Depending on the scale, they might give water depth. They show features along the coasts, like lighthouses and harbors, but do not emphasize inland features, like roads. An example would be a chart of the Pacific Ocean. In contrast, several types of land maps show mountains and their elevations, cities, political boundaries, railroad tracks, and other inland features. A map of Portugal would not be a nautical chart (Gaspar and Leitão 2019).

vehicles for the exercise of power to effect social-political ends as was done by Harley (1988 and 1989) and Edney (2019). This paper is an experiment. We wanted to show that research papers like this could be written based solely on information shown on charts and maps that are freely available on the Internet. Long trips to libraries are no longer necessary.

After we wrote this paper and ushered it through four rounds of reviews, we discovered the David Rumsey Map Center at Stanford University (**davidrumsey.com**). It is the perfect solution for what we are trying to do. This online digital database contains over 125,000 maps and related images dating from the sixteenth to the twenty-first century, and can be read by anyone, anywhere. Rumsey has said that he wanted to provide "open access to all art . . . freely available via the Internet" (Hessler 2023). The David Rumsey Map Collection's capabilities exceeds our needs: "It allows searching maps by toponyms and text on the maps" (Hessler 2023). This database should further enable the new genre of map research we are suggesting here.

Of course, there are limitations to using only information on digitally published maps in research on nautical world maps. These are presented in the Limitations section of this paper.

PURPOSES & ASSUMPTIONS

The purposes of this paper are to

- identify and describe all of the sixteenth-century maps, globes, and texts that describe Drake's route of circumnavigation;
- use the information on these "maps" to adjust and justify the relationships and years of disclosure shown in Figure 1;
- describe the *Whitehall* map that Drake presented to Queen Elizabeth in 1580; and
- introduce a new genre of research papers about sixteenth-century nautical charts, ones based only on material contained on the maps themselves and not interpretations of them.

We made many assumptions while researching and writing this paper, and we continually checked their validity. These are some of the initial assumptions that were, in the end, deemed important and valid.

- The C9 were made in the last two decades of the sixteenth century.
- The C9 were made by different people.
- The *Whitehall* map was the first to shrink the large bulge on the west coast of Chile and move it to the southern tip of South America.
- Some of the C8 cartographers saw the actual *Whitehall* map and some did not.
- Queen Elizabeth's ban on disclosing the details of Drake's circumnavigation was effective for eight years, until the defeat of the Spanish Armada in 1588.
- We have found all of the sixteenth-century nautical maps that contain Drake's route of circumnavigation.

One initial assumption that was discarded was that the *Whitehall*-derived maps were made in southern England.

SIXTEENTH-CENTURY MAPS WITH DRAKE'S ROUTE OF CIRCUMNAVIGATION

In this section, we give general descriptions of the C9. Details will be added in later sections.

WHITEHALL MAP

On his voyage of circumnavigation, Drake had with him maps and charts, along with paint brushes and pens for embellishing them. Furthermore, he took the maps from every Spanish ship he seized. We speculate that during the voyage, he and his cousin John drew his route of circumnavigation on one of them. Then on his return to England in 1580, he presented it to Queen Elizabeth (Colthorpe 2017, 27). This map then joined the royal map collection in her "Majesties Gallerie at Whitehall, neere the Privie Chamber" (Purchas 1625).[5] No modern cartographer has seen the *Whitehall* map because everything in the royal

5. This map might have been put on public display in the Whitehall Palace after 1589 (MacGregor 2013).

map collection at Whitehall was presumably destroyed in fires in the seventeenth century. The only known first-hand visual description of this map was made by Samuel Purchas (1625).

DRAKE-MELLON MAP

The *Drake-Mellon* map (Figure 2) was made with pen, ink, and watercolors on vellum. This manuscript map is held in the Paul Mellon Collection, Yale Center for British Art at Yale University Library, **collections.britishart.yale.edu/catalog/orbis:9579023**. It is not attributed to any particular cartographer or artist (Wallis 1984, 141–145). Its text is in Latin. Wallis (1984) dates it as "after 1586" (138) and "not later than 1590" (141). It includes Drake's Caribbean voyage of 1585–86. Because it is a manuscript map, it is hard to be sure of its cartographer and date.

This map has flags with the cross of St. George planted four places in the Americas. This map also contains the names Virginea [*sic*] and California.

This map shows the general route that Drake took during his circumnavigation. However, the route is not detailed enough to be used for navigation. Presumably, the purpose of this map was to document Drake's unique feat, not to give directions for replicating it. It might have never been put on public display.

DRAKE SILVER MAPS

The Drake *Silver* maps are 68 mm (2.7 in) diameter sterling silver disks with maps of the known world in the sixteenth century, featuring Drake's route of circumnavigation stamped on them (Christy 1900; Hague 1908; **hdl.loc.gov/loc.rbc/rbdk.d058**). The nine existing medallions have weights from 260 to 424 grains (0.6 to 1 oz, 17 to 27 g) (Kraus 2022a, item 58). Each of these medallions has a diameter that is about the same as that of a tennis ball. The variation in weight is due to differences in thickness: the lightest one is as thin as a thumbnail (0.46 mm) and the heaviest one is as thick as a credit card (0.76 mm) (Bahill 2022b). Christy (1900) emphatically states that they were created in 1581. MacGregor (2013) states 1589.

Figure 2. The *Drake-Mellon* map (*Vera descriptio expeditionis nauticae Francisci Draci Angli . . .*) shows Drake's approximate route of circumnavigation of the world in 1577–80 with black dots on brown lines and his Caribbean voyage of 1585–86 with black lines. This manuscript map uses an equirectangular map projection.

RICHARD HAKLUYT'S BOOK

"The famous voyage of Sir Francis Drake into the South Sea, and there hence about the whole Globe of the Earth, begun in the yeere of our Lord, 1577," is a section that comprises twelve unnumbered pages in Richard Hakluyt's 1589 volume ***The Principall navigations, voiages and discoveries of the English nation***, which he self-published.

The content of these pages is also given in *The World Encompassed* (Drake 1854, 92–93), *The Anonymous Narrative* (Wagner 1926, 277–285), and *The English Hero* (R. B. 1695).

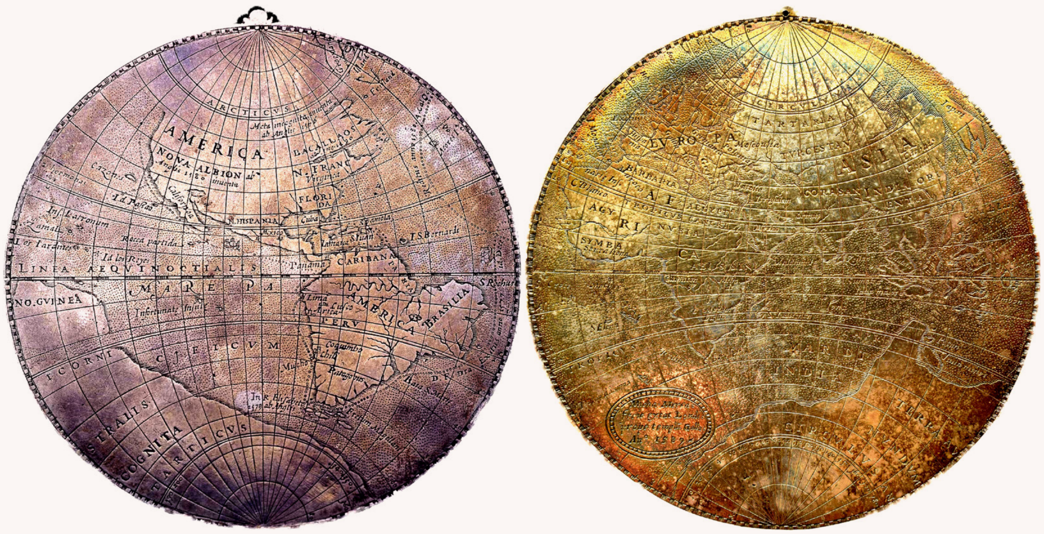


Figure 3. Drake *Silver* maps. The medallion on the left, showing the western hemisphere is from the British Museum (2024). On the right, the eastern hemisphere is from the Library of Congress. These medallions are 68mm in diameter and are shown at their actual size. Each medallion uses a Mercator double-hemisphere equatorial stereographic map projection. The maps have parallels and meridians every ten degrees.

This summary of Drake's voyage was corroborated and elaborated by John Drake, Sir Francis Drake's cousin (sometimes mistakenly called his nephew), who was on the voyage of circumnavigation, in his testimony before the Spanish Inquisition in March 1584 and January 1587 (Nuttall 1914). However, these declarations were presumably not seen by an Englishman

Figure 4. *French-Drake Van Sype* map, *La herdike enterprinse faict par le Signeur Draeck D'Avoir cirquit toute la Terre*. This is on an equirectangular map projection. Note the cartouches.

for a long time, because they were state secrets of the Spanish Inquisition.

FRENCH-DRAKE VAN SYPE MAP

The *French-Drake Van Sype* map, *La herdike enterprinse faict par le Signeur Draeck D'Avoir cirquit toute la Terre*, is seen in Figure 4 (Shirley 1983, entry 149). This map is attributed to Nicola van Sype (or van Sÿpe), whose name is engraved to the right of the distance scale in the lower right-center. Most assume that this was the name or pseudonym of the cartographer, the engraver, or a friend of theirs. However, nothing is known about Nicola van Sype (Wallis 1984). The *La Herdike Enterprinse* map, shown in Figure 4, was written in French, and is usually called the *French-Drake* map (Wagner 1926, 427–434). It was printed from an engraved copper plate. The Kraus Collection at the Library of Congress **dates it to 1581**. Wallis (1984) dates it as "1582–83 or later" (143) but "not later than 1590" (141). Aker (1970, 70) wrote a "date not later than c. 1585."

DUTCH-DRAKE MAP

The ***Dutch-Drake* map**, *La heroike interprinse faict par le Signeur Draeck D'Avoir cirquit toute la Terre*, was a copy of the *French-Drake Van Sype* map. It uses French for the title, a mixture of Early Modern Dutch and French for the cartouches, and Latin and Spanish for the toponyms. See Figure 5 (Shirley 1983, entry 151). Wagner (1926, 424–426) dates it as 1641.[6] Aker (1970, 77) opines that the *Dutch-Drake* map was published after the *French-Drake* map, but he estimates the *Dutch-Drake*'s date of publication as 1581.

6. Wagner (1926) has two mistakes. On page 424 the heading has the word *Enterprinse* whereas it should be *Interprinse* and on page 427 the heading has *Interprinse* which should be *Enterprinse*. Aker (1970, 68; 77) caught one of these mistakes but left the other. He called both the *French-Drake* and the *Dutch-Drake* maps *La Heroike Enterprinse*.

Figure 5. *Dutch-Drake* map *La heroike interprinse faict par le Signeur Draeck D'Avoir cirquit toute la Terre.* This map is on an equirectangular projection.

MOLYNEUX PETWORTH HOUSE GLOBE

Emery Molyneux's *Petworth House Globe* was made in 1592 (Figure 6). It has the routes of circumnavigation of both Sir Francis Drake (1577–80) in red and Sir Thomas Cavendish (1586–88) in blue (Wallis 1951; Wallis 1984; Dekker 2007; Blundeville 1613). This may be the first public display of Cavendish's route of circumnavigation.

JODOCIUS HONDIUS BROADSIDE MAP

The Jodocius Hondius 1590 and 1595 map *Vera Totius Exbitionis Nautica* (Figure 7) is commonly known as the *Broadside* map. Generally, a broadside was a large sheet of paper having words and graphics printed on one side only, such as a poster or handbill. This particular broadside has

Figure 6, right. Molyneux's 1592 *Petworth House Globe*. It is about two feet one inch (63.5 cm) in diameter.

Figure 7, below. Hondius 1595 *Broadside* map. This piece is on a Mercator double-hemisphere equatorial stereographic projection. For convenience, it uses a ten-degree graticule.

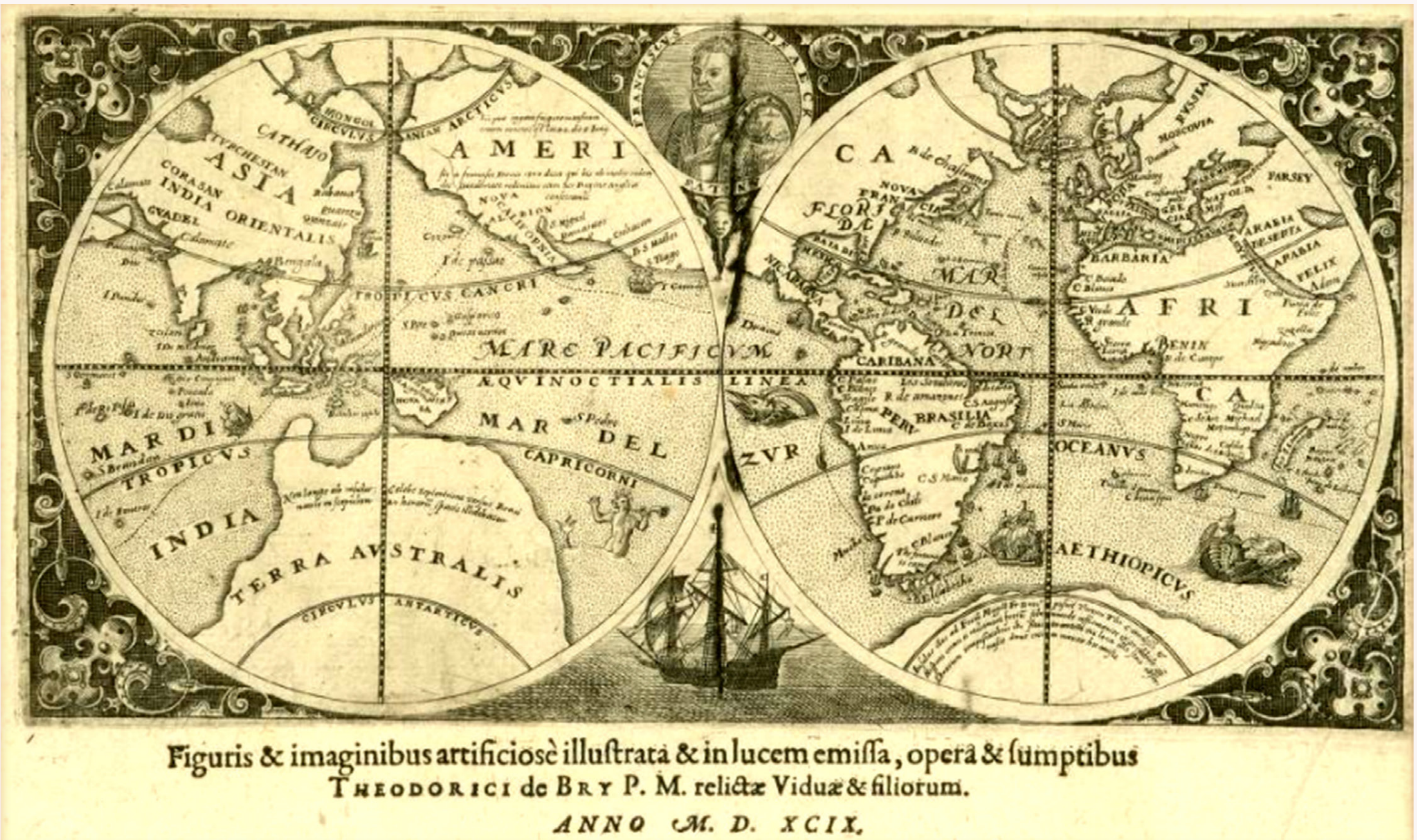


Figure 8. The De Bry 1599, *America Pars VIII* map, like the Hondius *Broadside* map, is a Mercator double-hemisphere equatorial stereographic projection.

the routes of circumnavigation of both Drake (1577–80) and Cavendish (1586–88). See Shirley (1983, entry 188) and **lccn.loc.gov/92680608**.

Hondius lived in London from 1584 to 1593. Wallis (1984, 145) states that of the six surviving copies of the Hondius *Broadside* map, three were issued in London in 1590 and the other three in the Netherlands in 1595. Wallis (1984, 145) and Aker (1970, 102) both mention the "Jodocus Hondius fecit Londini" written on the back of one of these maps. Wagner (1926 239) states that the Hondius *Broadside* map was engraved in 1595.

THEODOR DE BRY MAP

The De Bry map *America Pars VIII* (Figure 8) is nearly the same as the Hondius *Broadside* map (Shirley 1983, entry 219; van Groesen 2007), and is viewable at **jcb.lunaimaging.com/luna/servlet/s/j4s58c**.

We have found no other sixteenth-century maps or texts that show or describe the route of Drake's circumnavigation of the world; however, see footnote 2.

TEXT IN BOTTOM CENTER CARTOUCHES

The texts in the cartouches of the *Drake-Mellon*, *French-Drake*, and *Dutch-Drake* maps (Figures 2, 4, and 5) are surprisingly similar and are consistent with the description of the *Whitehall* map given by Purchas (1625, 461–462). We will now compare Purchas's comments about the *Whitehall* map to the texts in the bottom center cartouches of the other three maps.

PURCHAS' COMMENT ABOUT THE WHITEHALL MAP

This is the complete comment by Purchas (1625, 461–462) about the *Whitehall* and *Silver* maps.

> . . . I adde their New Straights Southwards from those of Magelane were discovered before by Drake, as in the Map of Sir Francis Drakes Voyage presented to Queene Elizabeth, still hanging in His Majesties Gallerie at White Hall, neere the Privie Chamber, and by that Map (wherein is Cabotas [Sebastian Cabot's] Picture, the first and great Columbus for the Northerne World) may be seene. In which Map, the South of the Magelane Straits is not a Continent, but many Is[l]ands, and the very same which they have stiled in their Straits. Barneuels Is[l]ands had long before been named by the most auspicate of Earthly Names (and let themselves be Judges, with which the other is as little worthie to be mentioned, as a kind Mother, and an unkind Traitor. The name Elizabeth[c] is expressed in golden Letters, with a golden Crowne, Garter, and Armes affixed: The words ascribed there unto are these, Cum omnes feré hanc partem Australem Continentem esse putent, pro certo sciant Insulas esse Navigantibus periuias, earumqum australissimam ELIZABETHAM à D. Francisco Draco Inventore dictam esse. The same height of 57. degrees, and South-easterly situation from the Magelan Westerne Mouth give further evidence. And my learned friend Master Brigges told me, that he hath seene this plot of Drakes Voyage cut in Silver by a Dutchman (Michael Mercator, Nephew to Gerardus) many years before Scouten or Maire [Williem Schouten and Jacques Le Maire] intended that Voyage. As for Nova Zemla by Stephen Burrough, and others, long before discovered, they also have given new names, which, I envie not: only I feare a vae soli [being alone] and hate ingratitude both ours and theirs. But too much of this. Next to this more generall Discourse shall follow the Dutch Northerne Voyages, and the English North-easterne: after which wee will take a more complementall leave of that Continent, and from thence visite the Northerly and North-westerne Discoveries; at once hunting for a New World and a New passage to This
>
> [c] [footnote in original] In the [s]aid Map is Queene Elizabeths Picture, with Neptune yielding his Trident, and Triton sounding her Fame, with these Verses, Te Deus aequoreus donat Regina Tridente, Et Triton laudes esslat ubique tuas.

The following is our summary of the comments by Purchas (1625) about the *Whitehall* map.[7]

- The *Whitehall* map was hung next to a map by Sebastian Cabot that had Cabot's picture on it.
- It was hung in the Whitehall Palace near the Privy Chamber (the private apartment of the sovereign).
- It had the name Elizabeth in gold letters. It had Queen Elizabeth's coat of arms encircled with a garter belt and topped with a crown.
- It had Queen Elizabeth's picture with Neptune yielding his trident.
- It shows or reports that Drake was at 57° S latitude, southeast of the western mouth of the Strait of Magellan.
- There was not a continent south of the Magellan Straits, but, rather, there were many islands.
- Latin was used for all text.
- These words were inscribed on it (our translation): "Since almost all think that south of this part is a Continent, let them know for certain that the islands are passable by those sailing on it, and that the southernmost part of them is named ELIZABETH by the discoverer Francis the Dragon."

COMPARISON OF TEXT IN THE BOTTOM-CENTER CARTOUCHES

We will now use this quotation to examine maps that were clearly copied from the *Whitehall* map, Table 1. Purchas did not specify where on the *Whitehall* map the Latin inscription appeared. But a similar sentence appears in the bottom center cartouche of the *Drake-Mellon*, the *French-Drake*, and the *Dutch-Drake* maps shown in Figures 2, 4, and 5, respectively.

7. Please note that *Purchas, his pilgrimage* . . . 1613, *Purchas, his Pilgrim* . . . 1619, and *Purchas his Pilgrimes* . . . 1625 are three entirely different books written by Samuel Purchas (1577–1626).

Whitehall map, Purchas (1625, 461–462)	Translation by the author
Latin Cum omnes feré hanc partem Australem Continentem esse putent, pro certo sciant Insulas esse Navigantibus periuias, earumqum australissimam ELIZABETHAM à D. Francisco Draco Inventore dictam esse.	**English translation** Since almost all think that south of this part is a Continent, let them know for certain that the islands are passable by those sailing on it, and that the southernmost part of them is named ELIZABETH by the discoverer Francis the Dragon.
***Drake-Mellon* map, Figure 2**	**Translation by the author**
Latin Cum omnes feré hanc partem australem continente esse putent, pro certo sriant insulas esse earugum australissimam ELIZABETHAM dictam esse, a Francisco Draco eiusde inventore	**English translation** Since almost everyone thinks that this southern part is the continent, for certain they must be the southernmost of the islands, ELIZABETH, that it was said to have been discovered by Francis the Dragon.
***French-Drake* map, Figure 4**	**Translation by Mike Horner**
French Combien que l'on pense que la partie meridionale du destroit soit terre ferme chÿ et ce qu'elle est tres certain que ne sont gillas la prochain de midi à l'este nommé Elisabete par le dirt sig drack qui pmier la descouverte.	**English translation** However much one may think, that south of the strait is terra firma it is very certain that [these are islands] of which the next from South to East named Elizabeth by the said Seigneur Drake who first discovered it.
***Dutch-Drake* map, Figure 5**	**Translation from Aker (1970, 80)**
Dutch Dat Suÿderste deel van Mageliano den. Draeck eerst Ontdaen en Sin niet đan Eÿlande. Waer af tsuÿderste bÿ hem gename .S. Elisabet. La Partie m̄eridionalle Magellánes ne Sont qù isles. [This sentence is in French.]	**English translation** The southern part of the Magellanes, which Drake first discovered, are not but isles of which the most southern was named by him S. Elizabeth. The southernmost part of the Magellanes are nothing but islands.

Table 1. Comparison of texts on the *Whitehall*, *Drake-Mellon*, *French-Drake*, and *Dutch-Drake* maps.

These four descriptions of the southern tip of South America are remarkably similar. From these wordings, we should assume that the *Drake-Mellon*, *French-Drake,* and *Dutch-Drake* maps were derived from the *Whitehall* map.

Earlier researchers, for example, Shirley (1993, entries 149 and 151), have further concluded that the *Dutch-Drake* map is a copy of the *French-Drake* map. We agree with this conclusion.

TEXT IN THE UPPER-LEFT CARTOUCHES

The *Drake-Mellon*, *French-Drake,* and *Dutch-Drake* maps also have cartouches in their upper left, and the texts in these are also similar to each other. And in this case, a fourth map, the Hondius *Broadside,* contains a title box with similar text, as shown in Table 2.

Using these translations for the text in the cartouches, we can easily infer the flow of information from the *Whitehall* map to the Hondius *Broadside* map indicated in Figure 1.

Moreover, all four of these maps have cartouches in the bottom corners. Those in the bottom-right represent the *Golden Hind* being aground on a shoal off of Celebes island in January of 1580. The cartouches in the bottom-left corners show the *Golden Hind* being triumphantly towed into Ternate, one of the Moluccas islands. We now wish to offer evidence for the information flow arrows from the *Whitehall* map to the Hakluyt text, to the *Silver* maps, and thence to the Hondius *Broadside* map.

Drake-Mellon map, Figure 2	Translation by the author
Latin Vera descriptio expeditionis nauticae, Francisci Draci Angli, equitis aurati, qui quinq[ue] navibus probe instructis, ex occidentali Anglia parte anchoras soluens, tertio post decimo Decembris An[n]o MDLXXVII, terraru[m] orbis ambitum circumnavigans, unica tantu[m] navi reliqua (alijs fluctibus, alijs flamma correptis) redux factus, sexto supra vigesimo Sep. 1580.	**English translation** A true description of the naval expedition of Francis Drake, Englishman and Knight, who with five ships departed from the western part of England on 13 December 1577, circumnavigated the globe, and returned on 26 September 1580, with one ship remaining, the others having been destroyed by waves or fire.
***French-Drake* map, Figure 4**	**Translation by Mike Horner**
French La vraie description du vojage du sr fransoys draeck Chevalier lesquel estant acompaigne de cing navires deux desquel il brula ung aultre sen retourna et la quarter fuit peris il partit d'Angleterre le 13 desembre 1577 passa oultre et fit le sirquit de toute la terre et retourna audict royame le z6 Septembre 1580	**English translation** The true description of the journey of Seigneur Francis Drake Knight who is accompanied by five ships two of which he burned another returned and the fourth perished. He left from England on 13 December 1577, passed beyond and made the circuit of all the earth and returned to the said kingdom 26 September 1580
***Dutch-Drake* map, Figure 5**	**Translation from Aker (1970, 79)**
Dutch Beschriuinge vãn Reÿse gadaen by Francoÿs Draek met 5 schepen. Waer af .2. Verbrande eeniuce derkē en een vergink if Seÿlende Vÿt Engelant den: 13 dissember .7.7. Naeden westen om die Ganse Cloot des Aertricx int Onsl wederom opcomende eade Alsoo In Engelant Den. 26. September 1580. Comme le Cap. ne Draeck Singlant d'Angleterre a, cercui Entre'lan '77. et 80 Toute la terre. [This sentence is probably in French.]	**English translation** Description of the journey made by Francis Drake with 5 ships of which 2 burnt down, one returned and one was wrecked sailing off from England the 13th of December '77 in west direction around the whole Globe of the earth, in the east coming up again and on this way back in England the 26 September 1580. Captain Drake sailing from England, has circumscribed between the years '77 and 80 all of the earth.
Hondius 1595 *Broadside* map, Figure 7. The contents of the title box are equivalent to the upper-left cartouches of Figures 2, 4, and 5.	**Translation by the author**
Latin Descriptio D. Franc Draci qui 5, navibus probé instructis, ex Anglia solvens 13 Decembris anno 1577, terrarum orbis ambitum circumnavigans, unica tantum navi, ingenti cum gloria, ceteris partim flammis, partim fluctibus correptis, in Anglim 27 Septembris 1580.	**English translation** The description of D. Francis Drake who with 5 ships properly equipped, departing from England 13 December 1577, circumnavigating the compass of the world only one boat returned with great glory in England 27 September 1580, some of the others burned, some were caught by the waves.

Table 2. Comparison of texts in the upper-left cartouches of the *Drake-Mellon*, *French-Drake*, and *Dutch-Drake* maps and the title box of the *Broadside* map.

FROM WHITEHALL TO HAKLUYT TO THE SILVER MAPS TO THE HONDIUS BROADSIDE

Isla Mocha, off the central Chilean coast (38° S, 74° W), was a significant stop for Drake and his men. Two of his crew were killed and Drake was shot with arrows. This island is shown as a stop and is labeled as Mucho on the *Drake-Mellon* map, the *Silver* maps, and the Hondius *Broadside* map and is described in detail in the text “The famous voyage of Sir Francis Drake . . .” (Hakluyt 1589; Drake 1628). Therefore, Isla Mocha is a link between these sources of information. The *French-Drake* and *Dutch-Drake* maps did not label the island. Therefore, they are more distant from the Whitehall map.

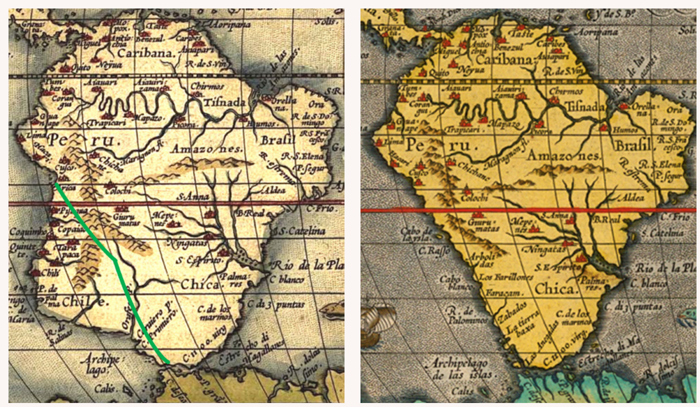
The *Silver* maps and the Hondius *Broadside* map show a large inland lake, the precursor of the Salton Sea in southern California. The *Drake-Mellon*, *French-Drake*, and *Dutch-Drake* maps do not show this lake. The *Silver* and *Broadside* maps also show and label the Pacific Ocean islands named Rocca Partida, Cazones, I. de Pasiao, and Ambon. The *Drake-Mellon*, *French-Drake*, and *Dutch-Drake* maps might show these islands but they do not label them. Again, this shows the affinity of the *Silver* maps and the Hondius *Broadside* map and their detachment from the *Drake-Mellon*, *French-Drake*, and *Dutch-Drake* maps.

The *Drake-Mellon*, *French-Drake*, and *Dutch-Drake* maps draw Japan as a horizontal oval centered on 155° W latitude. The *Silver*, Broadside, and de Bry maps orient it vertically centered on 175° E.

These paragraphs suggest that there was an information flow from the Whitehall map to the Hakluyt text to the Silver Maps and finally to the Hondius Broadside map. The *French-Drake* and *Dutch-Drake* maps were not a part of this flow.

THE BULGE ON THE COAST OF CHILE

Girolamo Ruscelli, in his *Orbis Descriptio* map in his 1561 atlas *La Geografia di Claidio Tolomeo Alessandrino*, put an enormous bulge on the coast of Chile. This bulge is more than four times the size of Spain. He was followed by Pablo Forlani in 1562, Giacomo Gastaldi circa 1561 and 1565, Diogo Homen in 1565, and many others. This bulge lies between the Tropic of Capricorn (23.4° S) and 45° S latitude as shown in the lefthand portion of Figure 9 (Bahill 2022a).



Abraham Orteius 1587 (P2S2) Abraham Orteius 1588 (P2S3)

Figure 9. Parts of *Typus Orbis Terrarum* by Ortelius 1587 (P2S2) (left) and 1588 (P2S3) (right). Land to the west of the green line is the bulge (Bahill 2022a). The only differences between the two maps are to the left of the green line. To the right of the green line, land, rivers, mountains, and other toponyms on these maps can be superimposed. The abbreviations P2S2 and P2S3 stand for plate-2 state-2 and plate-2 state-3, respectively. It is shorthand to distinguish maps with small variations (Shirley 1983). These are in Ortelius oval map projections. Parallels of latitude and meridians of longitude are spaced ten degrees apart.

Abraham Ortelius published his atlas *Theatrum Orbis Terrarum* in 1570. Then he updated and reissued it just about every year. The *Typus Orbis Terrarum* maps in his atlases from 1570 to 1587 had this enormous bulge on the coast of Chile, as he was (along with Mercator in 1569) an early adopter of this feature. Others followed Ortelius by adding bulges to their coasts of Chile, for example, André Thevet 1575, Francisco de Belleforest 1575, Gerald de Jode 1578, Joan Martines 1582 and 1587, Rumold Mercator 1587, Urbano Monte 1587, Sebastian Munster 1580 and 1588, Cornelius De Jode 1589, Theodor de Bry 1592, Michael Mercator 1595, and Arnoldo di Arnoldi, 1600. Note that URLs for these maps (and others mentioned without a formal reference in this paper) are available in our database at **sysengr.engr.arizona.edu/URLsForSixteenthCenturyMaps.xlsx**.

Drake was known to have taken maps with him on his trip of circumnavagation. Furthermore, whenever he seized a Spanish ship, he took their maps and navigation charts. He may have had some of the above-mentioned maps with him. However, no known European explorer or cartographer had been to this section of the coast of Chile before Drake in 1578.[8] Therefore, when Drake followed existing, unfounded maps, he got lost.

8. Magellan sailed through this area. Albo’s log of Magellan’s route (Albo 1874) lists him as cruising northward along the Chilean coast from 48° S latitude up to 36° S latitude where he headed west out into the Pacific Ocean. But Magellan left no maps. Ribero made an accurate map in 1529, but it only went up as far as 52° S.

Several textural descriptions of Drake's voyage describe his sailing from the southern tip of South America. Nuño da Silva's[9] deposition to the Spanish Inquisition (Wagner 1926, 342; Moreno Madrid 2022) stated that from November 1 to 5 they sailed northwest. This is four-plus days. Assume they sailed at a slow 50 miles (80 km) per day. This would give them over 200 miles (320 km). The protrusion on the Wright-Molyneux 1599 map (Gitzen, 2014) of Figure 10 is about 220 miles (350 km) at 49° S latitude. Da Silva continued, then they changed direction to the northeast for a few days and then to the north for 20 days: finally, they landed at Isla Mocha (Mucho Island). This meandering is described by the red track at the southern end of South America in Figure 10. The above synopsis is from Nuño da Silva's deposition. However, there are several similar descriptions.[10]

This Chile bulge mistake in the maps seems to have vexed Captian Drake, who wrote:

> . . . we continued our course, *November* 1, [1578] still North-west, as wee had formerly done, but in going on we soone espied, that we might easily have beene deceived; and therefore casting about and steering upon another [compass] point, wee found, that the general mappes did erre from the truth in setting downe the coast of *Peru*,

Drake refers to the whole South American coast as Peru, not differentiating between Chile and Peru. After describing the section of the coast between 52° S and 40° S latitude, he continues:

> . . . perceiving hereby that no man had ever by travell discovered any part of these 12. deg., and therefore the setters forth of such descriptions are not to be trusted, much less honored, in their false and fraudulent coniectures which they use, not in this alone, but in divers other points of no small importance. (Drake 1854, 92–93)

At the end of his circumnavigation of the world, Drake returned to England in 1580. We conjecture that he expressed his displeasure to some cartographers and presumably he corrected the coast of Chile on his *Whitehall* map because afterwards, there was a proliferation of changes to this coastline. When the changes appeared, there were three distinct manifestations: one group of cartographers omitted the bulge entirely (Figure 9), a second group shrunk the bulge and made it a small protrusion between 52° S and 44° S latitude (Figures 2, 4, 5, 7, 8, and 10) and finally a third group fell behind the times and continued to publish maps with the big bulge on the coast of Chile.

Ortelius omitted the bulge on his *Typus Orbis Terrarum* map that was printed in 1588 (Figure 9, right). He did the

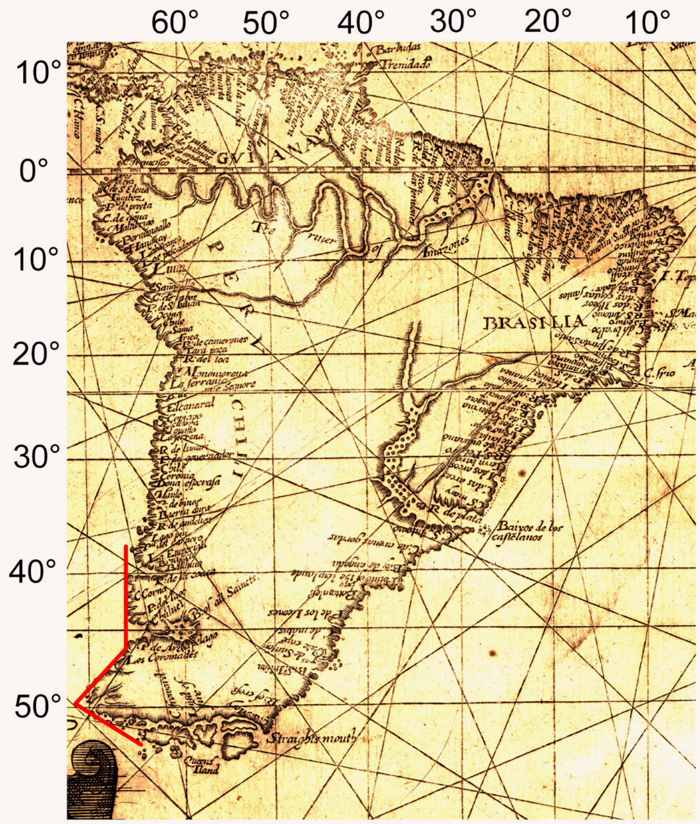


Figure 10. A section of the Wright-Molyneux 1599 map showing South America with a part of Drake's path shown in red. Other cartographers probably used this description (in red) to fill in the land behind it. This is a Mercator projection map. However, this does not preclude wind roses with correctly interconnected rhumb lines throughout the whole map. Parallels of latitude and meridians of longitude are spaced ten degrees apart.

9. Nuño da Silva was a Portuguese pilot. He was captured by Drake in the Cape Verdes in January of 1578 and was released in Mexico in May 1579. He served as Drake's pilot along both sides of South America.

10. This same description is given in *The World Encompassed* (Drake 1854, 92–93), "The famous voyage of Sir Francis Drake" (Hakluyt 1589), *The Anonymous Narrative* (Wagner 1926, 277–285), *The English Hero* (R. B. 1695), and John Drake's testimony before the Spanish Inquisition (Nuttall 1914).

same on his *Americae Sive* 1587,[11] and his *Maris Pacifici* 1589. For the most part, these maps were all contained in his atlases: they were not published individually. This, therefore, makes their dating fairly certain. However, we do not know the month in 1588 when he published his map. So, we do not know if he had a head start on the other C8 cartographers.

Ortelius and his followers constituted the first group of cartographers who either removed the bulge on the southern coast of Chile after 1588 or had never put it there in the first place. These cartographers included: the *Silver* maps 1589, Plancius 1590 and 1594, C. de Jode 1593 (*Brasilia et Peruvia*), Vrients 1596, Lavanha & Teixeira 1597, Hondius 1592 and 1597, and Ricci 1602 (Bahill 2022a).

Our second and most important group of cartographers did not omit the bulge but instead shrunk it and made it a small, protrusion between 52° S and 44° S latitude with a peak at 49° S (see Figures 2, 4, 5, 7, 8, and 10). They moved it around a thousand miles (1600 km) down the coast. The average area of the bulge on these maps is 10% of that of the large bulges on pre-1588 maps (Bahill 2022a). Maps and other artifacts that have this small protrusion at the very southern end of South America include the 1580 *Whitehall* map (probably), the 1589 *Drake-Mellon* map, the 1589 Hakluyt text, the 1589 *French-Drake* map, the 1594 *Dutch-Drake* map, the 1592 Molyneux globe, the 1595 Hondius *Broadside* map, the 1599 Theodor de Bry map, and the 1599 Wright and Molyneaux map of Figure 10; but not the 1589 *Silver* maps. This group is the C9 plus the Wright and Molyneaux map but without the *Silver* maps.

The red path shown in Figure 10 was constructed from descriptions given in "The famous voyage of Sir Francis Drake" (Wagner 1926, 277–285; 342; Moreno Madrid 2022; Drake 1854, 92–93; Hakluyt 1589; R. B. 1695). It outlines the small protrusions that are seen on the maps of the second group of cartographers. These protrusions are almost the same among the C8-minus-Silver-maps and no other maps have this protrusion.[12] This is strong evidence of a common ancestor for these maps, shown in Figure 12—namely the *Whitehall* map or "The famous voyage of Sir Francis Drake" text.

We speculate that cartographers started with this description of Drake's path (in red in figure 10) and filled in the land behind it. In Figure 10 and the C8, toponyms are dense along the whole coast of South America, except along this fictitious peninsula. Cartographers typically invented toponyms to fill in empty space. But they did not do that here. This must mean that they had no information and, in this case, they did not want to invent any.

This description of the Chilean coast of South America was probably one of the Queen's most prized secrets because at the time there were no good maps of this region and the undocumented maps that Drake had on board got him lost.

The third, and least important, group of cartographers did not get the word and continued to publish maps with the bulge on the southern coast of Chile; for example, Munster 1588, C. De Jode 1589, Theodor de Bry 1592, M. Mercator 1595, and Ruscelli 1599.

Because this section is so important, it merits a summary. Starting in 1561 several cartographers drew their nautical world maps with a huge bulge on the coast of Chile. Within the next dozen years, many cartographers followed suit. It is quite likely that the maps Drake had with him on his voyage of circumnavigation had this incorrect bulge, causing him difficulty navigating the southern coast of Chile. When Drake returned to England, we speculate that he had stern words with cartographers about their "false and fraudulent coniectures" (Drake 1854, 92–93). Speculating again, we suggest that this caused them to correct their mistakes in one of two ways. The maps show that one group of cartographers omitted the bulge completely and the second group shrunk the bulge and moved it to the southern tip of Chile. Most of our C9 were in the second group (all except for the *Silver* maps). This shows a previously unnoticed commonality of the C9 that is not described in the literature.

11. This map is dated 1587. So, it seems to have an earlier date than the 1588 Ortelius *Totius Orbis Terrarum*. In addition, the *Novus Orbis* map that was published in Paris and is dated 1587 and was included in Hakluyt's text of 1587 also seems to have a confusingly earlier date.

12. The 1602 LeClerc and Hondius *Orbis Terrae Novissima Descriptio* also has this protrusion (Shirley 1983, entry 233) but it is not included in our C9 because it does not have Drake's route of circumnavigation and it was published in the seventeenth century.

SIMILARITIES AND DIFFERENCES BETWEEN THE MAPS

The main purpose of this section is to show the relationships between the C9 as shown in Figure 1. We will start with the *Drake-Mellon*, *French-Drake*, and *Dutch-Drake* maps. These relationships, shown in Table 3, help derive the years of disclosure of these maps and they help show who copied from whom.

IMPORTANT SIMILARITIES OF THE WHITEHALL-DERIVED MAPS

The comparisons in Table 3 imply that, first, the *Drake-Mellon*, the *French-Drake*, and the *Dutch-Drake* maps without a doubt drew information from the same common precursor, either directly (black arrows in Figure 1) or indirectly (grey arrows). Second, the *Dutch-Drake* map was derived from the *French-Drake* map (Shirley 1983). It probably did not draw information directly from the *Whitehall* map. It drew information from other contemporaneous maps. We can assume that the *Drake-Mellon*, the *French-Drake*, and indirectly the *Dutch-Drake* maps were derived from the same common precursor, the *Whitehall* map. Therefore, in this section, we will call these collectively the Whitehall-derived (WHD) maps. These three WHD maps look generally alike.

Aspect	Feature	Drake-Mellon map	French-Drake map	Dutch-Drake map
Route Similarities	**Drake's route of circumnavigation is**	**almost the same on all three maps**		
Text Similarities	Words in the title	none	La **Herdike Enterprinse** Faict Par Le Signeur Draeck D'Avoir Cirquit Toute La Terre	La **Heroike Interprinse** Faict Par Le Signeur Draeck D'Avoir Cirquit Toute La Terre
			the difference is **Herdike Enter** versus **Heroike Inter**	
	Language of the title	none	French	
	The contents of the five cartouches describe	**the same events**		
Text Differences	The engraver's or cartographer's name	none	Nicola van Sype?	none
	Note in the lower-right	none	map seen and corrected by the said signeur Drack	none
	The language used in cartouches is	Latin	French	Dutch and French
	The number 2 is represented by	2's and z's	the letter z	the number 2
	Text in cartouches have	different handwriting		
	Compare the handwriting of	"Reditus" below the Cape of Good Hope	"Route De retour" below the Cape of Good Hope	"Route de retour," Nicaragua, and Guatemala
	Font labeling oceans	simple	simple	fancy

Table 3. Similarities and differences between the *Drake-Mellon* map, the *French-Drake* map, and the *Dutch-Drake* map. Cells in a **boldface** font are especially important. Table continues on following pages.

Aspect	Feature	Drake-Mellon map	French-Drake map	Dutch-Drake map
Ornament Similarities	**Galleon icons showing the number of major ships in Drake's fleet at that location**	**are the same**		
	Shadows on cartouches	are correct (Bahill 2021)		
Ornament Differences	Portrait of Drake	none	oval containing an engraving of Drake stating his age as forty-two	circular ring with lettering and a different engraving of Drake
	Coats of arms of Queen Elizabeth	instead, it has flags with the cross of St. George	one in Nova Albion and one below the Strait of Magellan	none
	Has sea monsters	no	yes	no
Land Similarities	Latitude of islands off the NW coast of America	**39°**, boldface indicates a landing site	38°, **40°**, 41°, 43°	39°, **40°**, 42°, 45°
	Drake's maximum north latitude	39°	45°	47°
	North America, South America, Europe, and Asia	are similar		
	Bulges on the southern coast of Chile are	**the same unusual size, shape, and southern position (49° S)**		
	Shape and position of Japan	the same shape (horizontal oval) and position (155° W)		
Land Differences	Isla Mocha is labeled (as Mucho)	yes	no	no
	The land above Europe and the Arctic Circle	none is shown		Terra Forma, Nova Zembla
	Newfoundland is	a peninsula		an island
	The shape of the Black Sea is	good	rudimentary	basic
	The shape of the Mediterranean Sea between Italy and Spain is	good	grossly wrong	good
	The position of the Azores Islands is	west of the zero-longitude meridian		Incorrectly east of this meridian

Table 3, continued.

Aspect	Feature	Drake-Mellon map	French-Drake map	Dutch-Drake map
Land Differences	The shape of Madagascar is	one large island	many islands near the coast	One large island
	Unique mid-ocean islands	none	huge imaginary island between India and the Red Sea	Saint Helena in the South Atlantic
	The Pacific coast of North America has labels for	California	no toponyms	Quivira, California Nicaragua, and Guatemala
	Florida is labeled	yes	no	yes
	Virginia is labeled	yes	no	
	Has Terra Australis	no	yes	
	The Amazon River is	shaped like a giant snake	Straight and wide	
	The Nile River	connects the Mediterranean Sea to the Atlantic or the Indian Ocean in South Africa		
Cartographic Similarities	**Mapping projection is**	**equirectangular**		
	The maps have a prominent equator and linearly gradated central meridian	yes		
	The zero-longitude (central) meridian is	Cape Verde Islands, 23° W	25° W	28° W
Cartographic Differences	Meridians of longitude are numbered 10, 20, 30, etc. from the central meridian going	**east**ward		**west**ward!
	Materials	drawn with pen and ink and watercolors on vellum	printed on paper from engraved copper plates	
	The Tropics of Cancer and Capricorn	are labeled		are shown but are not labeled
Other	Size (width by height) cm	43 by 22	44 by 24	44 by 24
	Estimated year of disclosure	1589	1589	1594

Table 3, continued.

In addition, the following specific features from Table 3 and earlier sections strongly suggest that these three maps had a common precursor.

- All three WHD maps have a cartouche in the bottom center-left with near-identical text, which is almost the same as that described by Purchas (1625) as being on the *Whitehall* map.
- The five cartouches on each of these three WHD maps describe the same items and events. The top-left corner cartouches describe the overall voyage. The bottom-left corner cartouches show the *Golden Hind* being towed ceremoniously into Ternate in the Moluccas Islands. The bottom left-center cartouches describe land south of the Strait of Magellan. The bottom right-center cartouches contain the scale of distance. The cartouches in the bottom-right corner show the *Golden Hind* grounded on a reef near Celebes Island. (The Hondius 1595 *Broadside* map, has similar drawings in similar cartouches.)
- All of the WHD maps used the equirectangular projection, which was antiquated and uncommon in the late sixteenth century. For maps published in Shirley (1983) and dated between 1587 and 1607, 31% used the Ortelius oval projection, 26% used the Mercator double-hemisphere equatorial stereographic projection, only 8% used an equirectangular projection and the rest used one of a dozen other projections.
- All three of these maps have a prominent equator and central meridian. Their graticules are evenly spaced labeled in degrees. The spacing confirms that the maps use an equirectangular projection.
- They each feature the Arctic Circle, the Tropic of Cancer, the Equator, the Tropic of Capricorn, and the Antarctic Circle. Their spacings further confirm the equirectangular projection.
- These maps are in a landscape orientation and all have an approximate size of 44 cm width by 24 cm height (17.3 by 9.5 in).
- The Rio de la Plata is immense on all of these maps.
- They all have the Nile River with connections extending from the Mediterranean Sea to oceans near the Cape of Good Hope.
- The shadows on the cartouches (Bahill 2021) are consistent between all three WHD maps.
- They have the Pacific Coast of North America at least up to 50° N latitude.
- Zero-longitude meridians on the three are 23° W, 25° W, and 28° W of Greenwich.
- All three of these maps have Drake's general route of circumnavigation with only minor differences. Most of these differences are ports and islands where he landed.
- Aside from landing point differences, these three routes are almost the same. There is one feature in particular that shows a good knowledge of Drake's route. That is the place south of the Strait of Magellan where a huge storm blew his ship backward down to 55°–57° S latitude. At this point, Drake named the southernmost island Elizabeth.[13] Purchas (1625) refers to Drake being at 57° S latitude, southeast of the western mouth of the Strait of Magellan. All three of our WHD maps have this detail the same.
- All three of the WHD maps have galleon icons showing the number of major ships in Drake's fleet at various locations. However, from time to time, Drake captured and released Spanish ships, barks, and pinnaces.
- The three WHD maps have the same shape and position for Japan.

Besides the maps mentioned in this paper, no other maps have all of the above features. Most assuredly, the three WHD maps had a common precursor, and that precursor was the *Whitehall* map.

13. Wagner (1926, 91) quotes an account that states that Drake "going ashoare, carried a Compasse with him, and seeking out the Southermost part of the Iland, cast himselfe downe upon the uttermost point groveling, and so reached out his bodie over it. Presently he imbarked, and then recounted unto his people, that he had beene upon the Southermost knowne Land in the World, and more further to the Southwards upon it, then any of them, yea, or any man as yet knowne." Francis Fletcher, however, wrote the same story but claimed that it was *he* (Fletcher) who performed this dramatic act (Drake 1854, 88).

THE NILE RIVER

The three WHD maps in Figures 2, 4, and 5 have the source of the Nile River in South Africa, as most other sixteenth-century nautical world maps. This model for the Nile River originated with Ptolemy in the Second Century AD.

The *Drake-Mellon*, *French-Drake,* and *Dutch-Drake* maps have simplistically drawn river systems. The *French-Drake* and *Dutch-Drake* maps, however, each have a river flowing out of the more southern of the Nile River source lakes going to the Atlantic Ocean near the Cape of Good Hope. In a similar way, the *Drake-Mellon* map, and some other sixteenth-century maps have a river flowing from one of these lakes to the Indian Ocean. Thus, many maps have a continuous, but non-navigable, waterway from the Mediterranean Sea to the Atlantic and/or the Indian Ocean in Southern Africa.

IMPORTANT DIFFERENCES BETWEEN THE WHD MAPS

The handwriting in the cartouches is different in the three WHD maps. See in particular the handwriting in the upper-left cartouche. These differences suggest that these three maps had different illustrators/engravers.

Both the *French-Drake* and the *Dutch-Drake* maps mistakenly label the Moluccas Islands at 20° N latitude. However, these are the Mariana Islands. The Moluccas Islands are on the equator. The *Drake-Mellon* map correctly labels these Mariana Islands as Ini Ladrones.

UNIQUE FEATURES ON THE DRAKE-MELLON MAP

Between 1545 and 1600, most maps that included South America represented the Amazon River shaped as a giant snake, as in Figures 2, 3, 9, and 10 (Bahill and Gitzen 2021). Of our three WHD maps, only the *Drake-Mellon* map has this feature. We do not know about the *Whitehall* map but it might have been influenced by the Sebastian Cabot map of 1544 and that map does represent the Amazon River shaped as a giant snake.

The *Drake-Mellon* manuscript map was made with pen, ink, and watercolors on vellum. As a result, only one copy was probably made, unlike the *French-Drake* and *Dutch-Drake* maps, which were printed from engraved copper plates. That one copy is now in the Yale University Library. It is an undated manuscript map. Below the label for VIRGINEA is this text (originally in Latin): "VIRGINEA Colony was led into this part of the continent by Walter Raleigh knight in 1583." Therefore, this map was surely finished after 1583. Raleigh was knighted in 1585. If the labeling of Virginia and the route of Drake's Caribbean voyage were added to this map at a later date (for example after 1586), then the *Drake-Mellon* map could be the original *Whitehall* map!

UNIQUE FEATURES OF THE FRENCH-DRAKE MAP

A grossly incorrect feature on the *French-Drake* map is a peninsula protruding from Marseille, France almost to Africa. The western Mediterranean Sea had been drawn accurately on many fourteenth- and fifteenth-century portolan charts. Therefore, the introduction of such a careless error is surprising. Greg McIntosh (in a personal communication) wrote that this appears "to be an area of the plate that was left unengraved by mistake, then made into a coastline. Very strange. Most likely an error of the engraver, not of the cartographer."

Another mistake on this *French-Drake* map was drawing Madagascar as several small islands close to the coast of Africa. From Gemma Frisius's 1544 *Charta Cosmographica* and afterward, almost everyone drew Madagascar as one large island quite detached from Africa. One final mistake is the huge island (the size of Great Britain) between India and the Horn of Africa. Wallis (1984) suggested that the cartographer of the *Drake-Mellon* map had more time to study the *Whitehall* map than the cartographer of the *French-Drake* map and therefore was more correct.

The following two items are unique to the *French-Drake* map, but they do not help us to differentiate or date the maps. In some Medieval and Renaissance styles of writing, the letter z stood for the number 2. This evaluation criterion differentiates maps from the first and second halves of the sixteenth century, with earlier maps more likely to use z=2. In concurrence, the last map we have found with this is the D. Teixeira 1573 *World* map (Bahill 2021). The *French-Drake* map is anomalous in this respect because it consistently used z=2. This could hint at an earlier year for the *French-Drake* map. The *French-Drake* map had two icons of Queen Elizabeth's coat of arms, one below Terra del Fuego and the other west of Nova Albion. This also did not help date this map.

DRAKE PASSAGE

The bottom center cartouches on all three WHD maps state that below the Strait of Magellan, there are many islands and not a large continent. Earlier maps, for example, by Mercator in 1569 and Ortelius in 1570, show a southern continent (Terra Australis) close to the South American mainland, so that the Strait of Magellan is the only route between the Atlantic and Pacific Oceans. However, the *French-Drake*, *Dutch-Drake*, Hondius *Broadside,* and *Silver* maps have their southern continent around 500 to 700 miles away from the South American mainland. This is the Drake Passage.

The *Drake-Mellon* map, the J. S. G map in Hakluyt (1587) (sometimes called the Martyr-Hakluyt map), the Molyneux globe, the De Bry map, and the Wright-Molyneux map do not have this southern continent at all. Therefore, they also have ample room for the Drake Passage below South America. Most other maps of this era have Terra Australis close to the South American mainland. This wide passage was touted by many as an important discovery by Drake. All of the C8 have this wide Drake Passage.

Drawing Terra Australis on a sixteenth-century map was certainly not new. The first such representation may have been on the Piri Reis 1513 map (McIntosh 2000). Later cartographers who did this included Cabot in 1544, Mercator in 1569, and Ortelius in 1570. What was unique about the *French-Drake*, *Dutch-Drake*, Hondius *Broadside,* and *Silver* maps was leaving a large expanse of open ocean south of mainland South America and north of Terra Australis.

The C8 correctly did not put toponyms on Terra Australis. Sixteenth-century maps with toponyms on the Terra Australis are pure fantasy. These can be found, for example, in Gutiérrez & Cock 1562, G. Mercator 1569, Ortelius 1570 to 1587, Thevet 1575, R. Mercator 1587, Plancius 1590 and 1594, De Jode 1593, and Van Langren 1596.

UNIQUE FEATURES OF THE DUTCH-DRAKE MAP

The *Dutch-Drake* map cleaned up some of the *French-Drake* map's mistakes by (1) removing the peninsula protruding from Marseille, France almost to Africa, (2) drawing Madagascar as one large island well separated from Africa, (3) removing the huge island between India and the Horn of Africa, and (4) adding land above Europe, north of the Arctic Circle. It left some mistakes, and it added some of its own, such as moving the Azores east of the zero-longitude meridian.

The *Dutch-Drake* map uses Dutch and French for the cartouches, Latin and Spanish for toponyms, and French for the title. The *Dutch-Drake* map shows a wide Northwest passage. This passage looks similar to those of Gerald Mercator 1569, Ortelius 1570–1587, Belleforest 1575, Urbano Monte 1587, and Rumold Mercator 1587. It has also added the Northeast Passage and Florida.

There are two versions or states of the *Dutch-Drake* map. The one in the Huntington Library has the letters MA RE O C CE AN US spread out across the Atlantic and Indian Oceans. The copies at Christie's (since sold, but an image can still be reviewed) and Daniel Crouch Rare Books (Figure 5) instead spell out MAR DEL NORTE, OCEANUS AETIODICUS, and MAR INDICUM (Aker 1970, 77).

A very strange feature of the *Dutch-Drake* map is that it labels the meridians of longitude starting with zero and increasing going *westward* to 360°. The only other cartographer that we know of who consistently followed this practice was Herman Moll, who published in the eighteenth century. We have no conjecture about this very odd feature.

UNIQUE FEATURES ON THE SILVER MAPS

The *Silver* maps were commissioned by Drake. We assume that he gave the cartographer directions and maybe a map with his route of circumnavigation. Therefore, the cartographer would not have needed to see the *Whitehall* map. Thus, the arrow from the *Whitehall* map to the *Silver* maps has been diminished going from Figure 1 to Figure 12. The cartographer of the *Silver* maps was not Michael Mercator. Born in 1567, he was probably too young. He was the engraver of only the cartouche and the maker of only one of the silver medallions. The handwriting in the cartouche is different than the handwriting on the rest of the medal (Bahill 2022b).

The *Silver* maps label the landing at Mucho island (the *Drake-Mellon* map, the *Broadside* map, and the Hakluyt text also do) and do not have the landings at Río de la Plata, S. Julian, Pe lima, and Sierra Leone as the *French-Drake* and *Dutch-Drake* maps do.

The *Silver* maps are the only constituents of the C8 that *removed* the bulge on the coast of Chile, like the Ortelius 1588 *Typus Orbis Terrarum* (Figure 9), unlike the other C8 that shrank it and moved it to the southern tip of Chile as shown in Figure 10. Hence the *Silver* maps have minimal relationships with the three WHD maps.

Another unique feature is that only the *Silver* maps, the *Drake-Mellon* map, and the Molyneux globe label Virginia. The *Silver* maps label Terra Australis and place it far away from South America, so that there is plenty of room for the Drake Passage. Only the *French-Drake*, *Dutch-Drake*, Hondius *Broadside,* and *Silver* maps have this feature.

The *Silver* maps do not have the cartouches that (1) state "Since almost all think that south of this part is a Continent . . . ," (2) show the *Golden Hind* being towed ceremoniously into Ternate, or (3) show the *Golden Hind* grounded on a reef near Celebes island.

These features emphasize that the *Silver* maps are different from the WHD maps. The *Silver* maps have greater affinity with the Hakluyt text and the Ortelius *Typus Orbis Terrarum* map. We conclude that the cartographer of the *Silver* maps received his information from Drake himself, whereas the cartographers for the Whitehall-derived maps received their information from the *Whitehall* map.

FEATURES OF THE MOLYNEUX GLOBE

The Molyneux Globe 1592 has the routes of circumnavigation of both Sir Francis Drake 1577–80 and Sir Thomas Cavendish 1586–88. The Molyneux globe has the distinctive bulge at the southern tip of Chile (Wallis 1984, 152).

UNIQUE FEATURES ON THE HONDIUS BROADSIDE MAP

The Jodocius Hondius 1595 map, *Vera Totius Exbitionis Nautica*, nicknamed *Broadside*, is similar to the *Drake-Mellon*, *French-Drake*, and *Dutch-Drake* maps, with respect to Drake's route of circumnavigation and the cartouches at the bottom of the maps.[14] Its major difference is that it uses the Mercator double-hemisphere equatorial stereographic projection instead of an equirectangular. However, numbers along the equator indicating longitude in the western hemisphere are all ten degrees too large. This map is 56 cm wide and 41 cm high.

FEATURES ON THE DE BRY MAP

The 1599 De Bry map is a copy of the 1595 Hondius *Broadside* map, except that it has no cartouches or graticule. The De Bry map has the distinctive small bulge on the southern coast of Chile. Although it is not as distinctive as the other C9 maps, it does complete the collection of sixteenth-century maps with Drake's route of circumnavigation. There are many copies of this map in varied sizes. The map on the front cover of his book is about 23 cm wide and 12 cm high.

WHO COPIED FROM WHOM?

One of our not-very-speculative conclusions is that the *Dutch-Drake* map was copied from the *French-Drake* map. This is also the conclusion of Shirley (1983) and of many others. The *Dutch-Drake* map was made in a later year by a mapmaker different than the one that made the *French-Drake* map. The general route of Drake's circumnavigation is the same on both maps. However, the *Dutch-Drake* map has many additional toponyms that are not on the *French-Drake* map, such as California, Guatemala, Nicaragua, and Saint Helena; no toponyms from the *French-Drake* map were removed. Secondly, the *Dutch-Drake* map more accurately depicts the shapes of the Black Sea, the Mediterranean Sea, Madagascar, Newfoundland, and all lands north of the Arctic Circle. As expected, new knowledge made the copy more correct than the original. Third, the handwriting in the cartouches is different between the two maps. The original and the copy were engraved by different hands. Figure 1 shows the *Drake-Mellon* and *French-Drake* maps being derived from the *Whitehall* map and the *Dutch-Drake* map being derived

14. This map has an additional inset in the upper-left corner labeled "Portus Novae Albionis" that describes the place where Drake spent five weeks in the summer of 1579. However, this is not useful for us, because in 1700 AD the magnitude 9 Cascadia Earthquake and its resulting 40 foot (12 m) tsunami wave resculpted the Pacific northwest coast (Schulz 2015; Williams, Marken, and Peterson 2017). Therefore, the bay shown in the inset in the upper-left corner of the map and the place where Drake spent those five weeks, if it still exists, would be completely unrecognizable today.

from the *French-Drake* map. There is no evidence that the creator of the *Dutch-Drake* map used any information directly from the *Drake-Mellon* map or the *Whitehall* map.

Our second conclusion about copying is that the *French-Drake* map was *not* copied from the *Drake-Mellon* map. One piece of evidence for this is the shapes of the Amazon River. Between 1545 and 1600, most maps that included South America represented the Amazon River as a giant snake, as in Figures 2, 3, 9, and 10 (Bahill and Gitzen 2021). The *Drake-Mellon* map has this feature, but the *French-Drake* map does not. Drake's maximum northern latitude is 39° on the *Drake-Mellon* map and 45° on the *French-Drake* map. This was a key point that was widely discussed, as it would help determine how much land the English could claim from the Spanish along the Pacific coast of North America. On the *Drake-Mellon* map, the shape of Madagascar is correctly shown as one large island, whereas the *French-Drake* map shows it as many small islands near the coast of Africia. The *Drake-Mellon* map labeled three regions in North America, namely California, Florida and Virgina. If the cartographer of the *French-Drake* map had seen this he surely could have remembered them and put them on his map. These two maps were both disclosed in 1589, so there was not enough time for either to copy from the other. Finally, the *Drake-Mellon* map is a manuscript map: we speculate that it was hidden in the privy chamber of the Queen's palace to shield it from the prying eyes of the despicable Spanish.

The purpose of these last two sections has been to show the relationships between the C9. These relationships were applied to Figure 1 to produce Figure 12. No one fact is responsible for any one arrow, but taken together, all of these facts constitute evidence for the arrows. The next section will derive the dates shown in Figure 12.

DATING THE C9 MAPS

Our earliest disclosure dates are usually a year after the event that precipitated them. For example, Queen Elizabeth's ban on disclosing details of Drake's circumnavigation ended in August of 1588. It is unlikely that some cartographer had a map all ready to go when the ban on disclosure evaporated, so that they could quickly release it in the last months of 1588. Therefore, our earliest dates of disclosure are 1589.

Furthermore, we think that it would take around a year to learn a new map projection, engrave a new map or set of dies, and then publish the map or stamp the medallions. For example, the Mercator double-hemisphere equatorial stereographic map projection was first published in 1587 by Rumold Mercator. So, maps that used this projection were certainly made years after 1587. Indeed, the first maps adopting this map projection were the 1589 *Silver* maps and the Plancius 1590 map. Similarly, the name Virginia originated in 1584, but it did not appear on a known map until the 1587 Hakluyt-Martyr map (Hakluyt 1587, 19).

The purpose of this section is to present evidence for the years of disclosure given in Figure 12. For maps that were printed, this would be the year of publication, if this were known. For one-of-a-kind objects, like the *Whitehall* map, the *Drake-Mellon* map, or the Molyneux globe, this would be the year the creator gave the object to its recipient or made it open for public view. Thus, these would be the years that:

- The *Whitehall* manuscript map was presented to Queen Elizabeth.
- The *Drake-Mellon* manuscript map was drawn.
- The *Silver* maps were stamped into silver disks.
- The Richard Hakluyt text was published.
- *The French-Drake* maps were printed.
- *The Dutch-Drake* maps were printed.
- The Emery Molyneux *Petworth House Globe* was unveiled.
- The Jodocius Hondius *Broadside* map was published.
- The Theodor de Bry map was published.

This section breaches our general principle of using only information printed on maps.

GENERAL CONSIDERATIONS

Extinction of the Ban on Disclosure

Drake's route of circumnavigation was kept secret for over eight years. Queen Elizabeth wanted to keep all of Drake's discoveries secret from the Spanish, whom she loathed.

Therefore, in 1580, she forbade Drake's crew from revealing any of these state secrets *under pain of death*.

Here is a review of the extinction of the Queen's ban. "Drake had been given express orders that 'none shall make any charts or descriptions of the said voyage,' a prohibition of publication that was to remain in force until 1588" (Harley 1988, 61). "Secrecy about the Drake voyage was kept through the decade. When the new edition of Holinshed's *Chronicles* was published in 1587, it was immediately recalled and censored" (Kelsey 1990, 448). "A further prohibition of any publication giving details of the route and reports of the discoveries appears to have been in force until at least 1588" (Wallis 1984, 136). In 1589 four important descriptions of Drake's route of circumnavigation were published (Toppin 2013), namely: (1) *Vera descriptio expeditionis nauticae Francisci Draci Angli*, colloquially called the *Drake-Mellon* map; (2) Richard Hakluyt, "The famous voyage of Sir Francis Drake. . ." in *The Principall navigations, voiages and discoveries of the English nation,* (text only, no map); (3) the *Silver* maps; and (4) the *French-Drake*, *La Herdike Enterprinse Faict Par Le Signeur Draeck D'Avoir Cirquit Toute La Terre*. Because of Queen Elizabeth's ban on disclosing information, we think that all of the *Whitehall* map derivatives were first disclosed in 1589.

In August of 1588, the English navy and a fierce storm in the North Sea destroyed almost all of the Spanish ships, sailors, and soldiers of the Armada. After this calamity for her enemies, the Queen no longer feared the Spanish, and thus her ban on disclosing details of Drake's circumnavigation faded away. Thomas Cavendish completed the third circumnavigation of the world just a month after the defeat of the Spanish Armada and his maps and journals were not subjected to the secrecy that Drake's were.

If the *French-Drake* and the *Dutch-Drake* maps were printed on the European continent, then they may have escaped the Queen's ban on divulging information. But then, how did the cartographers get their information? The Queen's ban seems to have been highly effective for eight years: there were no documented leaks.

The prohibition of disclosing information about Drake's circumnavigation is our strongest evidence for dating all of the C8 as after 1588. In the following paragraphs, we will abbreviate this as "QueensBanEnded1588."

Bulge on the Coast of Chile

Our policy is that we try to only use information contained in maps. We prefer not to rely on (1) historical texts, (2) family, friendship, and religious relationships, (3) geographical location of the cartographers, or (4) present-day human biases, speculation, and mistranslations. In this subsection, we will break with this policy and offer speculation based on historical texts.

Maps of South America were becoming common in the first half of the sixteenth century. However, in the middle of the sixteenth century, on the west coast of Chile, cartographers introduced a large bulge, a bulge three times the size of Chile itself. These are probably the maps that Drake had with him when he rounded the bottom of South America. He started following these maps, but their inaccuracy, along with severe weather, left him wandering the South Pacific. He was angry with the cartographers who provided such lousy maps. On his voyage home he and his cousin John made some good world maps that included the South and North American Pacific Ocean coasts. When he returned to England, he gave an accurate world map to Queen Elizabeth. She loved it, but she did not want the dirty-rotten Spanish scoundrels to profit from knowledge about Drake's voyage. So, she forbade Drake's crew from disclosing any details. It worked. Everyone kept silent.

About eight years later, after the English navy and a horrendous storm demolished the Spanish Armada, the Queen stopped fearing the Spanish and her ban on disclosing details of Drake's circumnavigation faded away. During those eight years, many cartographers evidently began to doubt the existence of the great bulge on the coast of Chile.

Ortelius had been updating his *Typus Orbis Terrarum* map annually for twenty years. Suddenly, in 1588, he dramatically removed the bulge on the coast of Chile on his *Typus Orbis Terrarum* and two other maps. What followed was a mad scramble by other cartographers to publish their maps without this bulge. A large group of cartographers simply chopped off the bulge, as shown in Figure 9. However, the C8 (without the *Silver* maps) shrank it and moved it down a thousand miles (sixteen hundred km) to the southern tip of Chile (see Figure 10).

Cartographers who had seen the *Whitehall* map or had heard Drake's complaints had a head start on fixing the bulge on their maps. This likely applies to Ortelius, *Drake-Mellon*, *French-Drake*, the *Silver* maps, the Hakluyt text, and Hondius. They may have even secretly started revising their maps earlier. Thus, they were able to get their maps out in 1588–90. For those who did not see the *Whitehall* map, it took longer for them to get their maps published. However, we date all of the C8 as after 1588. In the following paragraphs, we will abbreviate this as "ChileBulgeRemoved1588."

Equirectangular Map Projection

The equirectangular map projection was used almost exclusively by European cartographers in the fourteenth and fifteenth centuries. All three of the Whitehall-derived maps (the *Drake-Mellon*, *French-Drake,* and *Dutch-Drake*) used this projection, which by the late sixteenth century had become antiquated and uncommon. For maps published in Shirley (1983) between 1587 and 1607, less than ten percent used an equirectangular map projection; between 1620 and 1650, none did. These WHD maps were likely some of the last equirectangular maps made in the sixteenth century.

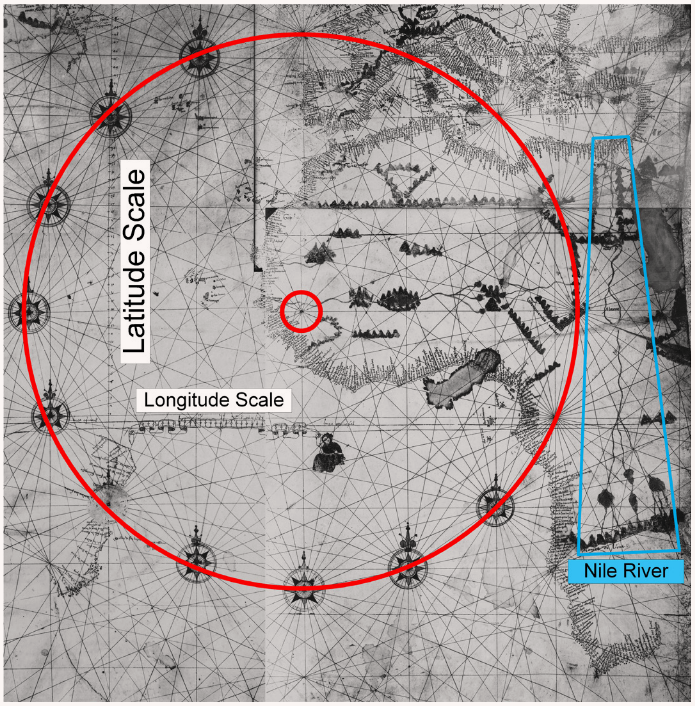


Figure 11. The Kunstmann III 1501–02 map. See also McIntosh and Gaspar (2021, 164). This is an equirectangular latitude chart. It has a latitude scale on the upper-left side. Numerous toponyms arranged perpendicular to the coasts, rhumb lines emanating from the compass/wind roses, and the red circle through them emphasize the map's portolan chart roots. However, the large amount of inland detail and the latitude scale belie its portolan chart origins.

Mercator Double-hemisphere Equatorial Stereographic Map Projection

The 1589 *Silver* maps, the 1590 and 1595 Jodocius Hondius *Broadside* map, the Plancius 1590 map, and the 1599 Theodor de Bry map used a Mercator double-hemisphere equatorial stereographic projection. This map projection was developed by Rumold Mercator and was first published in 1587. This fixes the earliest creation year for these three maps as 1588. This is compelling evidence for dating these maps. In the following paragraphs, we will abbreviate this as "MapProjectionInvented1587."

The Nile River

The three WHD maps in Figures 2, 4, and 5 use the **Ptolemaic model** for the Nile River system. This model originated with Ptolemy in the second century CE, and began to spread to European maps once his *Geographica* was translated into Latin in the late fifteenth century. In the basic model there are four (or possibly two) lakes around 10° S latitude. Their inputs come from a range of mountains to the south known as the *Montes Lunae* or Mountains of the Moon. The outputs of these lakes feed the White Nile going north, which merges with the Blue Nile to form the Nile River that flows north to the Mediterranean Sea. From the late fifteenth century, this model remained the standard up through the mid nineteenth century.

The 1501–02 Kunstmann III map (Figure 11) was a watershed in African cartography (McIntosh and Gaspar 2021). It was the first sixteenth-century map with this model of the Nile River, though not the first map to show the sources of the Nile in the Mountains of the Moon. The contemporary world maps of Cantino 1502 and Juan de la Cosa 1500 do not have use the Ptolemaic model for the Nile River, though Waldseemüller 1507 and later sixteenth-century maps do (Van Duzer 2020). The Kunstmann III is also the first of the portolan latitude maps. It has a scale of latitude and a rudimentary scale of longitude, as shown in Figure 11. The Kunstmann III map is the predecessor for sixteenth-century maps of Africa.

The Amazon River

Between 1545 and 1600, most maps that included South America represented the Amazon River shaped as a giant snake, as in Figures 2, 3, 9, and 10 (Bahill and Gitzen, 2021). The first exploration of the Amazon River by Europeans occurred in 1541–42. For the next 60 years, few Europeans explored the Amazon, so the information about it remained static. Then around the turn of the seventeenth century, many explorers and proselytizers traversed South America. Knowledge about the shape of the Amazon River became better. This new knowledge instigated the creation of better models with straight lines rather than snake-like undulations. Of our three WHD maps, only the *Drake-Mellon* map has this snake-like river model. The *Broadside* map does not have the Amazon River at all. Strangely, the *French-Drake* and *Dutch-Drake* maps represent the Amazon as a straight, wide river: this suggests that they were made later.

Virginia

In the sixteenth century, *Virginia* referred to the east coast region of North America not occupied by Spain or France, roughly present-day North Carolina. In 1584, Sir Walter Raleigh sycophantically suggested the name Virginia for this region in honor of Queen Elizabeth, who was known as the Virgin Queen. Later in that same year, Arthur Barlowe, in "The First Voyage to Roanoke" (Hakluyt 1589), lavishly described "the country now called Virginia." The next year Raleigh established a colony on Roanoke Island in this region.

The earliest use of this name on a map was likely in Hakluyt's publication of Peter Martyr's *De Novo Orbe* on a map dated 1587 (Hakluyt 1587; Verner 1950).[15] The *Drake-Mellon* map, the *Silver* maps, and the Molyneux globe have the label "Virginia" (or "Virginea"). Therefore, they were probably made after 1587. In the following paragraphs, we will abbreviate this as "NameVirginaUsed1587."

DATING THE WHITEHALL MAP

Drake returned to England in September 1580. In his first meeting with Queen Elizabeth, Drake presented her with a large map. There is no doubt about when Drake gave the *Whitehall* map to Queen Elizabeth. Thus, we assign it a year of disclosure of 1580.

DATING THE DRAKE-MELLON MAP

The *Drake-Mellon* map has Drake's route of circumnavigation and his Caribbean Sea voyage of 1585–86. Therefore, this map must have been made after the Caribbean trip ended in 1586, assuming that this route was not added later to the finished map. Therefore, this map was certainly created after 1586. This map represents the Amazon River shaped like a giant snake; therefore, it was surely made before 1600.

For the above reasons and because of the factors of the QueensBanEnded1588, the ChileBulgeRemoved1588, and the NameVirginaUsed1587, we date the *Drake-Mellon* map as 1589.

DATING THE DRAKE SILVER MAPS

There are nine known existing medallions with the Drake *Silver* map. The Library of Congress has two of them and gives the location of the others (Kraus 2022b, item 58). One of these has a cartouche on the old-world side that reads "Micha Merci: fiat extat Londi: prop tempt ũ Gallo: Ano 1589." We translate this as "Made in London by Michael Mercator . . . 1589 CE." Therefore, there is no controversy about when this particular medallion was made. Because this cartouche was engraved on the die, this has to be the last of the known medallions made with this die (Christy 1900). The others were made before it, as they feature no cartouche, which is the only known difference between the nine existing medallions. We date the *Silver* maps as 1589.

There are other points in favor of this year. These medallions used the Mercator double-hemisphere equatorial stereographic map projection that was first published in 1587 by Rumold Mercator. So, they were certainly made after 1587 (Bahill 2022b). *This is our strongest point*.

Probably sometime after the destruction of the Spanish Armada in 1588, Drake commissioned these remarkable silver medallions with his route of circumnavigation engraved upon it. We think that it would certainly take more

15. This map is titled *Novis Orbis*. It is signed F. G. S. and is dated 1587. It is contained in Hakluyt's revised edition of Peter Martyr's *De Novo Orbe* which was published in Latin in Paris in 1587. Two 1889 copies of the original 1587 map are available online, one in the David Rumsey Map Collection at (**www.davidrumsey.com/luna/servlet/s/98740o**) and one at the Art Institute of Chicago (**www.artic.edu/artworks/152508/novus-orbis**).

than a quarter of a year to engrave a set of dies and stamp medallions.[16] Therefore, this further supports the notion that the earliest year of disclosure should be 1589.

For the above reasons but mostly because the QueensBanEnded1588, the ChileBulgeRemoved1588, the MapProjectionInvented1587, and the NameVirgina-Used1587, we think that the Drake *Silver* map with Michael Mercator's cartouche was made in 1589. The other *Silver* medallions were most likely made earlier in that same year.

DATING THE HAKLUYT TEXT

A thousand copies of Richard Hakluyt's *The Principall navigations, voiages and discoveries of the English nation*, were printed in London in 1589. A hundred dated copies are still in existence. Therefore, there is little doubt about the year of publication. This assumes that the twelve-page unnumbered section entitled "The famous voyage of Sir Francis Drake into the South Sea, and there hence about the whole Globe of the Earth, begun in the year of our Lord, 1577" was inserted in the original printing of the book and not in a later printing that surreptitiously kept the original publication year.[17] There is no reason to doubt that Hakluyt's text was published in 1589 and that the insert was published with it (Hakluyt 1589, between 643–644). For these reasons and because the QueensBanEnded1588 and the ChileBulgeRemoved1588, we date the Hakluyt text as 1589.

DATING THE FRENCH-DRAKE MAP

In the upper-left cartouche, this map calls Drake a *Knight* (Chevalier), so this map must have been printed after Queen Elizabeth knighted him in 1581.

Drake was born around 1541 (see footnote 1). The *French-Drake* map has a portrait of Drake in an oval frame stating that he was 42 years old when the portrait was painted. The original portrait, from which the image on the map came, had to be painted before the map was printed. Therefore, this map must have been printed after 1583.

Wagner (1926, 427–434) dates this map as 1641 because five of the six *French-Drake* maps that he examined were bound in 1641 French translations[18] of "The famous voyage of Sir Francis Drake. . .." However, this does not preclude the possibility of an earlier publication. The *French-Drake* map treats California as a peninsula, not as an island. Sixty percent of the maps made between 1625 and 1650 that are in Shirley (1983) treat California as an island. None of those published before 1625 do. This is a weak suggestion that the *French-Drake* map was published before 1625.

The *French-Drake* map has the statement, "A map seen and corrected by the aforesaid Sir Drake." It is highly doubtful that his portrait and this statement were on the *Whitehall* map: it just does not fit the character of Drake (Wallis 1984, 143). Therefore, the *French-Drake* map might not have been copied from the *Whitehall* map, but rather from some apocryphal missing copy of it (Wallis 1984, 143): hence the grey dashed arrow in Figure 1. Because of the "A map seen and corrected by the aforesaid Sir Drake" and the fact that Drake died in 1596 means that the *French-Drake* map must have been made in 1596 or before.

For the above reasons but mostly because the QueensBan-Ended1588 and the ChileBulgeRemoved1588, we date the *French-Drake* map as 1589.

DATING THE DUTCH-DRAKE MAP

The *Dutch-Drake* map is a copy of the *French-Drake* map. Therefore, it must have been made after the French-Drake map. The version in the Huntington Library is bound in with Bigges (1586) but Stephen Tabor, Curator of Rare Books, has suggested that this is a mis-binding. Furthermore, the Library of Congress's version of Bigges has no maps. Wagner (1926, 424–426) dates the Dutch-Drake map as after 1587.

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16. Unless the cartographer was Rumold Mercator, who had already engraved the plates for his *Orbis Terrae Compendiosa Descriptio* map using his Mercator double-hemisphere equatorial stereographic map projection.

17. We assume that Hakluyt collected the 800-plus pages that he wanted in his book. He arranged them in sequence and numbered the pages. Then after the defeat of the Spanish Armada, he added the twelve unnumbered pages in between the pages numbered 643 and 644. These are images 661 and 674 in the **Library of Congress copy**, and images 684 and 697 in the **Hathitrust copy**.

18. Translation usually refers to translations of the text of an atlas not of text on the maps. In an atlas a single map might have up to a dozen pages of text associated with it. The translation would be of the text pages and perhaps the text on the verso side of the maps. They probably did not change the maps or the words on them.

The *Dutch-Drake* map has a peninsula coming down from the North Pole near Russia that is labeled Nova Zembla. The Ortelius *Typus Orbis Terrarum* 1570 to 1595, R. Mercator 1587, Plancius 1594 *Orbis Terrarum Typus . . .*, Hondius 1597, and Van Langren 1596 maps also label this area but they spell it Nova Zemla. The *Dutch-Drake* map spells it Nova Zem***b***la. Plancius and Waghenaer first used the Zembla spelling on maps in 1592. Therefore, the Dutch-Drake map was surely made after 1592. Nova Zembla on the Dutch-Drake map is drawn as a peninsula of one of the giant circumpolar islands. But in 1594 cartographers started correctly showing it as a discrete island far away from the North Pole. After 1598 almost everyone drew it as a discrete island. After 1603 no one showed it as a peninsula.

Our strongest evidence for dating the Dutch-Drake map as 1594 is its labeling of Nova Zembla and drawing it as a peninsula. It had to be after Plancius and Waghenaer first used the spelling Zembla on a map in 1592 and before everyone started drawing it as an independent island in 1598.

For the above reasons and also because the QueensBanEnded1588 and the ChileBulgeRemoved1588, we date the *Dutch-Drake* map as 1594.

DATING THE EMERY MOLYNEUX GLOBE

The Emery Molyneux *Petworth House Globe*, which was unveiled in 1592, is displayed in the Petworth House (Wallis 1951). An early draft of it was shown to Queen Elizabeth in 1591. A copy of it, the Molyneux *Middle Temple Globe* that is kept in the Middle Temple, was printed from the same plates. This revision was made public in 1603.

DATING THE HONDIUS BROADSIDE MAP

The Jodocius Hondius map, *Vera Totius Exbitionis Nautica* (colloquially called the *Broadside* map) shows the circumnavigation routes of Sir Francis Drake 1577–80 and Sir Thomas Cavendish 1586–88. Therefore, it had to have been made after 1588. The the Library of Congress, dates its copy as around 1595 (**lccn.loc.gov/92680608**). However, some authors (e.g., Wallis 1984, 145; Toppin 2013, 4) speculate that Hondius might have published some of his *Broadside* maps while he was still in England around 1590. Daniel Crouch Rare Books dates it from 1589 to 1595 (**crouchrarebooks.com/maps/the-drake-map**).

For the above reasons and also because of the QueensBanEnded1588, the ChileBulgeRemoved1588, and the MapProjectionInvented1587, we date the Hondius *Broadside* map as after 1588, with 1590 likely and 1595 a sure thing.

DATING THE DE BRY MAP

The Theodor de Bry map was on the cover of his book *America Pars VIII*, which was published in 1599: **library.princeton.edu/visual_materials/maps/websites/pacific/drake/map-world-drake-1599.jpg**.

YEAR OF DISCLOSURE

Table 4 lists the C9 along with their previously proposed publication years and our new years of disclosure. For maps that were printed, this would usually be the year of publication, if this were known. For one-of-a-kind objects, like the *Whitehall* map, *Drake-Mellon* map, or the Molyneux globe, this would be the year the creator gave the object to its recipient or made it open for public view.

The *Whitehall* map was not published. Only one copy of this map was made and it was presented to Queen Elizabeth by Francis Drake in 1580.

- The *Drake-Mellon* map was not published. It was a manuscript map and most likely no copies of it were made. It was created in 1589.
- The *Silver* maps were stamped into silver disks in 1589.
- The Richard Hakluyt text was published in 1589.
- *The French-Drake* maps were first printed using engraved copper plates in 1589. Many copies were probably made.
- *The Dutch-Drake* maps were first printed using engraved copper plates in 1594. Many copies might have been made.
- The Emery Molyneux *Petworth House Globe* was unveiled in 1592.
- The Jodocius Hondius *Broadside* map was printed by 1595 and probably in 1590. Many copies were probably made.

Name	Previously estimated years of publication	Year of disclosure determined in this paper	Approximate number of existing copies
Whitehall map	1580	Presented in 1580	0
Drake-Mellon map, *Vera descriptio expeditionis nauticae . . .*	1587, 1588	Drawn in 1589	1
Drake *Silver* maps	1581, 1589, 1589, 1585–95, 1580–86	Stamped in 1589	9
Richard Hakluyt, "The famous voyage of Sir Francis Drake . . ." in *The Principall navigations . . .*	1589	Published in 1589	100
French-Drake map, *La Herdike Enterprinse . . .*	1580–84, 1581, 1581, 1583, 1583, before 1585, 1627, 1641, 1641	Printed in 1589	7
Dutch-Drake map, *La Heroike Interprinse . . .*	1581, 1585, 1587, after 1587, 1589, 1590	Printed in 1594	4
Emery Molyneux, *Petworth House Globe*	1592	Unveiled in 1592	2
Jodocius Hondius, *Vera Totius Exbitionis Nautica, (Broadside)*	1590, 1595	Printed in 1590 and 1595	2, Wallis (1984, 145) wrote six.
Theodor de Bry, *America Pars VIII*	1599	Published in 1599	Many

Table 4. Years of disclosure for the C9.

- The Theodor de Bry map was published in 1599.

While Table 4 lists the previous estimates of the year of publication of the C9, we are not in a position to specifically refute each of these. Many scholars did not give detailed reasons for their speculation about creation dates. In any case, our fundamental guiding principle has been to use only the information on the maps themselves in making our arguments. We wanted to show that research papers could be written relying only on information available on the Internet.

CONTINENTAL THEORY

So far in this paper, most statements have been based on the maps themselves. Now, however, in this section we switch to speculating that the *French-Drake* and *Dutch-Drake* maps were made on the European continent (Wagner 1926). This would mean that they would not have been subjected to the Queen's prohibition on revealing details of Drake's voyage and they, therefore, might have been printed before her ban lapsed in 1588. But then, what would have been their source of information? Such foreigners certainly would not have had access to the *Whitehall* map in the Queen's privy chamber. Some authors speculate that Drake might have discussed his findings with these foreigners, given them a text with his findings, or shown (or given) them a copy of the *Whitehall* map. King Philip II's ambassador to London, Bernardino de Mendoza, wrote to his King on 20 April 1582 that Mendoza's spy, Sir James Crofts, had seen Drake's chart and discussed it with him (Wagner 1926, 89). These authors offer, as supporting evidence for a leak, speculation that Drake gave a fancy copy of this map to his friend John Foxe, the Archbishop of Canterbury (Nuttall 1914, xxvii; 357). However, John Foxe was never the Archbishop of Canterbury. Nuttall (1914, xlv) also cites a letter written in 1585 by King Henry III of Navarre (soon to become King Henry IV of France) to Sir Francis Walsingham, where he "begs the Queen to command the 'chevalier de Drac' to send him the collection [of charts?] and the discourse of his great voyage" This means that as of 1585 King Henry still did not have a copy of the map. Therefore, it is not likely that there was a description of the *Whitehall* map that the makers of the *French-Drake* and *Dutch-Drake* maps used much before 1585.

Who made the information about Drake's circumnavigation public? Drake himself was suspected of having leaked the information to someone. Could that someone have been Nicola van Sype, whoever he was? However, there is no evidence that the Queen was angry with Drake: he made her rich, she knighted him in 1581, gave him the commission to raid the Caribbean Sea in 1585–86, and made him Vice-Admiral of the fleet that destroyed the Spanish Armada in 1588. He was in her good graces

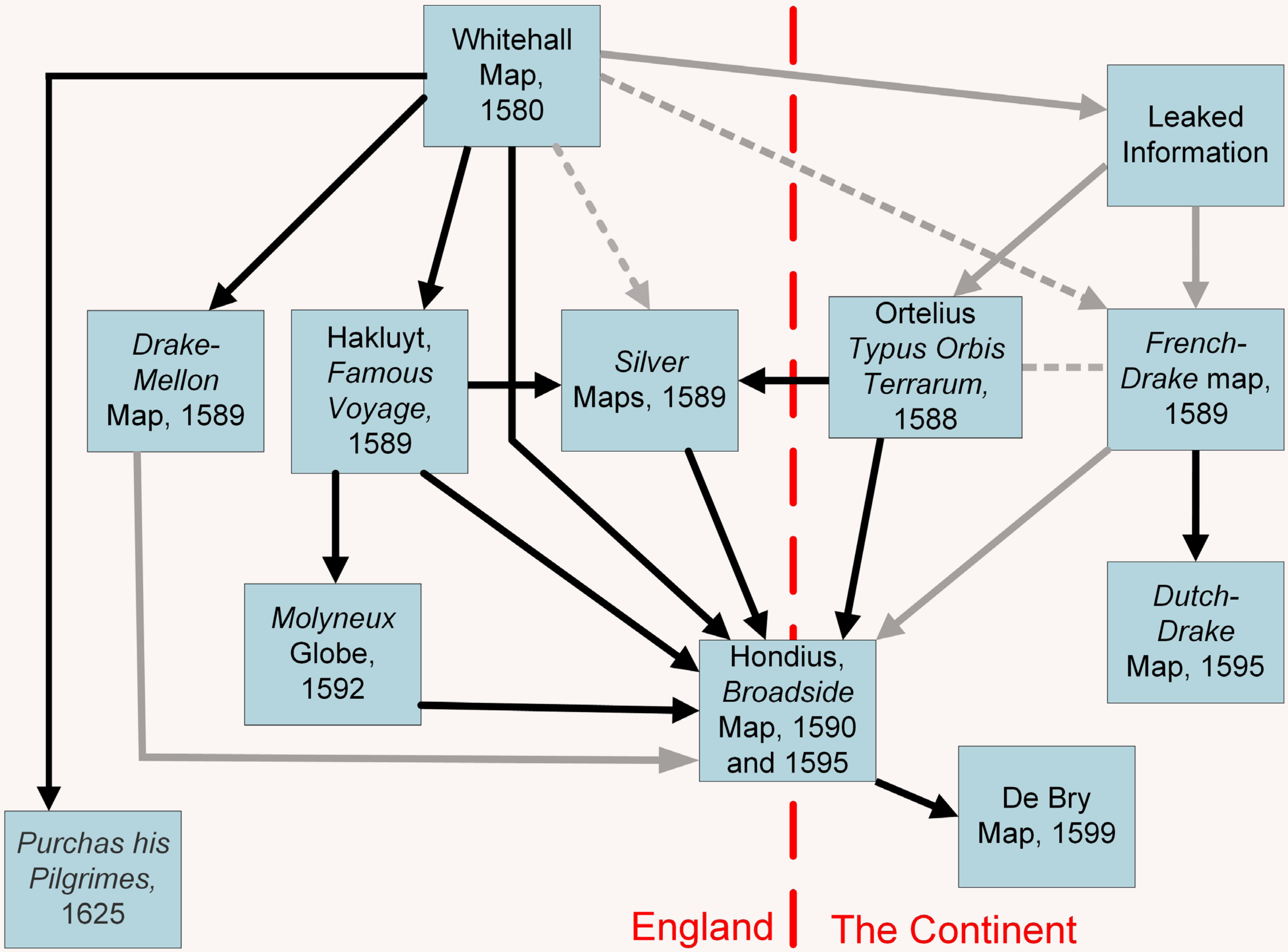

Figure 12. The Continental Theory for the relationships of the sixteenth-century objects that show Drake's route of circumnavigation. Time runs roughly from the top to the bottom. The red dashed line divides maps made in England from those made on the European continent. Black arrows show information flows. Gray arrows show suspected information flows. Dashed grey arrows show ghost connections, that is, connections that may or may not have existed.

throughout the decade. Therefore, Drake was not likely to have leaked the information.

Putting together everything presented in this paper we formulate the Continental Theory shown in Figure 12.

The fact that Ortelius chopped off the Chile bulge instead of shrinking it and moving it down to the bottom of Chile suggests that he did not see the *Whitehall* map. Instead, we speculate that he heard a discussion of it. Rather than feed information *to* the C9 cartographers of Figure 12, he mostly got information *from* them. He did not have Drake's route of circumnavigation on his maps. He is in the figure because he knew everybody and everybody knew his maps.

The theory that the *French-Drake* map was made on the continent, and out of the Queen's control, creates a puzzle as to why it sycophantically has two icons of Queen Elizabeth's coat of arms, one below South America and the other west of Nova Albion. These indicate the Queen's right of domain or authority over these regions.

The Continental Theory also requires that the Hondius 1590 and 1595 *Broadside* map be put on the dividing line between England and the Continent because much of its research and early development was done in England but it was finished and printed in Amsterdam.

LIMITATIONS

There are limitations to using only information on published maps in research on nautical world maps. In this paper, we necessarily supplemented the information found on maps with information from texts when the maps were insufficient. For example texts were used for the date and place of publication because these are seldom on the maps themselves. Of the C8, only the De Bry map is explicitly dated.

Likewise we used texts to understand Queen Elizabeth's ban on disclosing details of Drake's circumnavigation, the destruction of the Spanish Armada, and the Queen's subsequent ignoring of the ban; these facts were not on the maps.

The Whitehall Map has not been seen in five centuries. So, we used texts and maps to construct a textural and visual mental model of this map. We then compared this mental model to other maps. Secondly, some information was not put on maps, such as Drake's meanderings south of the Strait of Magellan. To construct the route shown in Figure 10, we used written texts. For this reason, the route shown is questionable. Thirdly, the Continental Theory posits that the French-Drake and the Dutch-Drake maps were made on the continent, not in England. Such information is not on the maps themselves.

Using only information on published maps limited our research to maps made by European cartographers in the fourteenth century and onward. In fact, the C9 were all made by sixteenth-century English and probably French and Dutch cartographers. We used no maps by Spanish, Portuguese, Italian, or Chinese cartographers.

We did not use manuscript maps because their dates cannot be ascertained with certainty. A manuscript map is a one-of-a-kind, hand-drawn map that was not mass-produced or published. Material can be added to an unpublished manuscript map at any later date. This is why our policy is to not use unpublished maps. Our only exception is the *Drake-Mellon* manuscript map.

We strove to have at least two sources for every fact that we presented. Often this meant using information from texts rather than from maps for our second source. The explanation of the galleon icons along Drake's route on the WHD maps fell into this category.

Finally, using only information on maps, we cannot get the opinions and feelings of people such as Queen Elizabeth. On the other hand, our database, at **sysengr.engr.arizona.edu/URLsForSixteenthCenturyMaps.xlsx**, makes extensive use of historical texts. It has a different purpose and a different result.

LESSONS LEARNED

We found three things that were particularly hard to do when looking only at maps. First, unless the date was written on the map, it was difficult to determine the date of disclosure. We think our dates, necessarily derived from information external to the map content, are correct to within plus or minus one year. Second, we found that it is difficult to translate from one language to another, especially for text that is five centuries old. Synonyms and archaic grammar can make each translation different. There is no one correct translation—a fact which is true even when converting between present day texts. Finally, it was hard to determine which map projection the cartographer used, unless he told us, which they never did.

One of the main purposes of this paper is to introduce a new genre of research papers about sixteenth-century nautical charts. With the exceptions listed above, these papers are based only on material contained on sixteenth-century nautical maps and charts and not modern interpretations of them.

DISCUSSION

We will now list milestones in the study of world maps. In the second century CE, Ptolemy wrote his books and created his world maps. A researcher could consult these on a quick trip to Alexandria. A millennium later, in the fourteenth century, the creation of portolan charts revolutionized the appearance and content of large-scale maps. A century later, Ptolemy's book *Geographica* was translated from Greek to Latin and then into other common languages. This revolutionized the world's view of the world. Also, in the fifteenth century, Gutenberg's invention of the moveable-type printing press greatly accelerated the printing of books and maps. Although woodblock printing had been used for a millennium in China it was first used in Europe for printing maps in the fifteenth century. Woodblock printing allowed multiple copies of maps to be made cheaply. The sixteenth-century invention of copperplate engraving allowed fine detail on multiple copies. This leads us up to the late sixteenth century and the events of this paper.

In 1570 Ortelius invented the atlas, which was a collection of maps with extensive text discussing those maps. The maps and text were arranged geographically, not chronologically. Atlases allowed a researcher to study scores of maps in one setting.

In the sixteenth century, for expansion and political control, many countries closely guarded their maps. The Spanish kept them in the *Padrón Real*. The Portuguese kept them in the *Padrão Real*. And the English kept them in the privy chamber in the Queen's palace. These were usually manuscript maps: meaning only one hand-made copy was produced. They contained the best geographical knowledge at the time. But only the crown and the trading companies could benefit from this valuable secret intelligence. Publicly accessible printed maps lacked detail and accuracy. Crown officials were the most common patrons of cartographers. Therefore, these public maps were laden with political and ideological messages. To get correct geographic information, cartographers had to compare several maps and filter out the propaganda.

From the seventeenth to the twentieth century research like that exhibited in this paper was done by researchers who visited libraries and other repositories of maps and charts. The researcher would spend days or weeks extracting all the knowledge he could and then he moved on to another repository.

In the twentieth century books about nautical maps appeared. They often gave great detail for one or a few maps. Atlases such as Shirley (1983) displayed hundreds of maps from a given period of time. And dozens of professional research journals published research papers about maps. In the last decades of the twentieth century the Internet evolved. Specific libraries opened their collections to online browsers, these libraries included those at the British Museum, Bibliothèque nationale de France (BnF), the Library of Congress, Brown University, Yale University, and Stanford University. This is the era in which this paper was researched and written.

This is also the era where authors tried to interpret maps as vehicles for the exercise of power and to effect social-political ends. They tried to analyze what the cartographers were thinking or what their motives were. Such speculation introduced intentional and unintentional human biases (Smith et al. 2007). We strictly avoided such papers. We shunned them like the plague.

This paper is an experiment. We wanted to show that research papers like this could be written based solely on information shown on charts and maps that are freely available via the Internet.

After we wrote this paper, we discovered the David Rumsey Map Center at Stanford University www.davidrumsey.com/luna/servlet/s/3aq715. It is the perfect solution for our problem. It contains over 125,000 maps and related images dating from the sixteenth to the twenty-first century. This online digital database was designed so that it could be read by anyone, anywhere. Rumsey said that he wanted to provide "open access to all art . . . freely available via the Internet (Hessler 2023)." The David Rumsey Map Collection ". . . allows searching maps by toponyms and text on the maps (Hessler 2023)." This database should offer a whole new genre for researching sixteenth-century nautical maps.

Present artificial intelligence (AI) systems are built upon huge libraries of text and digital data. Soon they will store maps. Using AI systems may soon be the first step in a preliminary literature review for a new study. Is this then the future of cartographic research? No. Not yet. While AI is becoming useful, these systems are built not so much with a mind toward collecting quality literature as collecting as vast a quantity of text as possible. These documents are not corrected for factual and grammatical errors. These systems lack validation. They are inherently racially biased because, for example, Black writers have historically not contributed the same quantity of classical English literature as white writers have.

At present you must already have maps to evaluate the opinions of an AI system. If you already know the answer to a question, then it is acceptable to ask an AI system the question. For then you will be able to tell when it has made a mistake. But, if you do not know the answer beforehand, then you had better not trust an AI system. They lack validation. An AI system does not know what it does not know.

Now, to conclude this section, was our novel experiment a success? We wanted to show that research papers like this could be written based *solely* on information shown on charts and maps that are currently available via the Internet. We think that we were successful, except that there were certain specific facts that we had to gather from texts.

We suggest that other authors adopt this unique approach. It eliminates intentional and unintentional human biases introduced by recent authors who tried to interpret maps as vehicles to exercise power and affect social-political ends, authors who tried to analyze what the cartographers were thinking or guess what their motives were.

Our approach was revolutionary for its time. However, it should become common now that the David Rumsey Map Center at Stanford University has greatly increased the power of using the internet. Furthermore, AI developers might invent methods for validating their systems and then they might contain the necessary power to further develop studies of sixteenth century nautical maps.

SUMMARY

From 1577 to 1580, Captain Francis Drake and his men circumnavigated the world in the *Golden Hind*. When he returned to England, he presented Queen Elizabeth with a map containing the route of his journey. She hung it on a wall of her Whitehall palace. Thus, it is called the *Whitehall* map. But, because she feared and loathed the Spanish, she did not want them to learn anything about Drake's voyage. Therefore, she forbade her subjects from disclosing any details under pain of death. Finally, after about eight years, after the defeat of the Spanish Armada and thus the Spanish threat to England, the ban faded away. Then (i.e., from 1588) a series of maps, texts, and globes were made showing Drake's route, which are described in this paper:

- *Whitehall* 1580 map,
- *Drake-Mellon* 1589 map, *Vera descriptio expeditionis nauticae . . .*,
- *Silver* 1589 maps, stamped into silver medallions,
- Richard Hakluyt 1589 text, "The famous voyage of Sir Francis Drake . . ."
- *French-Drake* 1589 map, *La Herdike Enterprinse . . .*,
- *Dutch-Drake* 1594 map, *La Heroike Interprinse . . .*,
- Emery Molyneux 1592 *Petworth House Globe,*
- Jodocius Hondius 1590 and 1595 map, *Vera Totius Exbitionis Nautica*, (*Broadside*), and

- Theodor de Bry 1599 map, *America Pars VIII*.

These nine artifacts are called the C9. The C9 without the *Whitehall* map are called the C8.

Using the C8 and the Purchas first-hand textual description, we have surmised what the *Whitehall* map must have looked like. It would have

- shown Drake's route of circumnavigation;
- contained several cartouches with text and drawings of the *Golden Hind*;
- displayed a statement in Latin relayed by Purchas, which translates as, "Since almost all think that south of this part is a continent . . .";
- revealed that there was not a continent south of the Magellan Straits, but, rather, there were many islands;
- featured the name Elizabeth in gold letters, and contained Queen Elizabeth's coat of arms encircled with a garter belt and topped with a crown;
- included galleon icons showing the number of major ships in Drake's fleet at that location;
- been rectangular with a landscape orientation;
- used an equirectangular map projection, centered on the equator;
- incorporated a prominent equator and a *linearly* numbered central meridian consistent with an equirectangular map projection;
- displayed an immense Rio de la Plata;
- indicated that Drake had reached 55° to 57° S latitude, southeast of the western mouth of the Strait of Magellan;
- had a small protrusion on the coast of Chile around 49° S latitude and no large bulge north of it;
- allowed room for the Drake Passage below Terra del Fuego;
- showed the Pacific coast of North America; and
- been written entirely in Latin.

The *Drake-Mellon*, *French-Drake*, and *Dutch-Drake* maps also had all of these features, except for the language. The *Whitehall* map might have been hand-drawn or Drake's route and important toponyms could have been drawn on a previously printed, copper plate engraved map.

The strongest evidence for concluding that the *Drake-Mellon* map 1589, the *French-Drake* map 1589, the *Dutch-Drake* map 1594, and the Hondius 1590 and 1595 *Broadside* maps were derived from the *Whitehall* map, is the similarity of the content of the cartouches. In particular, their bottom center cartouches that state:

> Since almost everyone thinks that south of the strait [of Magellan] is a Continent, let them know for certain that these are islands that are passable by sailors, and that the southernmost of them is named ELIZABETH by its discoverer Francis the Dragon.

Drake's navigation was a magnificent feat. But he could not brag about it because the Queen forbade Drake and his crew from disclosing any details, due to rivalry with the Spanish. Finally, eight years later, after the defeat of the Armada, she relented. In late 1588, we conjecture that Drake commissioned a fantastic silver medallion with his route of circumnavigation engraved upon it. The result was the nine extant Drake *Silver* medallions and probably many others. At about this same time the *Drake-Mellon* map, Hakluyt's book, and the *French-Drake* map appeared showing Drake's route of circumnavigation. The Queen's secret was no secret anymore.

Most nautical world maps published between 1561 and 1588 have an enormous bulge on the western coast of Chile as shown in Figure 9 (left) (Bahill 2022a). This mistake in the coastline of Chile seems to have caused Drake difficulty in navigating around Cape Horn. After he returned to England cartographers were probably impatient to correct this error, but for eight years the Queen's edict of secrecy prevented them from doing so. After the English defeated the Spanish Armada and her shroud of secrecy dissolved, there was a flurry of activity to change the coast of Chile on maps. One group led by Ortelius simply omitted the bulge. A second group, including our C9 (except for the Silver maps), shrunk it and moved it down to the southern tip of Chile. As noted earlier, a third group, the outsiders who did not get the word, continued with the bulge all the way up to 1600.

The 1589 *Silver* maps, the 1590 and 1595 Jodocius Hondius *Broadside* map, and the 1599 Theodor de Bry map used a Mercator double-hemisphere equatorial stereographic projection, developed by Rumold Mercator and first published in 1587. This fixes the earliest reasonable year of disclosure for these three maps as 1589.

The strongest evidence for the years of disclosure of the C8 is the use of the Mercator double-hemisphere equatorial stereographic projection starting in 1589 and the destruction of the Spanish Armada in 1588 causing the demise of Queen Elizabeth's ban on disclosing Drake's route of circumnavigation.

In the sixteenth century, Sir Francis Drake circumnavigated the world. When he returned to England in 1580, he presented a map containing the route of his journey to Queen Elizabeth. The Queen forbade publication of details of his journey with an edict that lasted for eight years. Thereafter, the C8 were published in a narrow time window, in the last decade of the sixteenth century. They were, plus the *Whitehall* map, the only sixteenth-century maps (etc.) to show Drake's route of circumnavigation of the world. They were also the only maps to reduce the size of the bulge on the coast of Chile and move it a thousand miles down the coast. No other maps did this. In this paper we have revealed the intricate set of relationships between each of these artifacts. The C8 is a remarkable collection of maps, representing a remarkable journey.

ACKNOWLEDGMENTS

We thank Mike Horner for the French-to-English translations. We congratulate the *Cartographic Perspectives* journal and its editor: that was the most thorough pair of reviews we have ever had.

REFERENCES

We have provided a list of Internet sources for the maps mentioned in this paper. This list/database is located at **sysengr.engr.arizona.edu/URLsForSixteenthCenturyMaps.xlsx**.

Aker, Raymond. 1970. *Report of Findings Relating to Identification of Sir Francis Drake's Encampment at Point Reyes National Seashore.* Point Reyes, CA: Drake Navigators Guild.

Albo, Francisco. 1874. "Logbook of Francisco Albo." In *The First Voyage Round the World*, by Antonio Pigafetta, translated by Lord Stanley of Alderley. London: Hakluyt Society. **https://en.wikisource.org/wiki/The_First_Voyage_Round_the_World/Logbook_of_Francisco_Alvo_or_Alvaro**.

d'Anghiera, Peter Martyr. 1587. Novus O*rbis.* Paris. **https://jcb.lunaimaging.com/luna/servlet/s/e1y9sq**.

Bahill, A. Terry. 2021. "The Second Engraver of the Library of Congress Mystery Map." *International Journal of Cartography* 9 (1): 29–72. **https://doi.org/10.1080/23729333.2021.1988042**.

———. 2022a. "Sixteenth Century Bulge on the Coast of Chile." *Journal of Geographical Research* 5 (2): 11–27. **https://doi.org/10.30564/jgr.v5i2.4357**.

———. 2022b. "Dating the Sir Francis Drake *Silver Maps*." *Cartographica* 57 (4): 291–304. **https://doi.org/10.3138/cart-2022-0011**.

Bahill, A. Terry, and Gary D. Gitzen. 2021. "The Amazon River Modeled as a Giant Snake," *KN – Journal of Cartography and Geographic Information* 71 (3): 173–194. **https://doi.org/10.1007/s42489-021-00082-3**.

Bawlf, Samuel. 2015. *Sir Francis Drake's Secret Voyage to the Northwest Coast of America, AD 1579.* Salt Spring Island, BC: Sir Francis Drake Publications.

Bigges, Walter. 1586. *Expeditio Francisci Draki Equitis Angli In Indias Occidentales, A. M. D. LXXXV.* Leyden: Fr. Raphelengium. **https://catalog.huntington.org/record=b1156148**.

Blundeville, Thomas. 1613. *M. Blvndevile his exercises, containing eight treatises …* London: W. Stansby. **http://hdl.loc.gov/loc.rbc/rbdk.d036**.

British Museum. 2024. Department of Coins and Medallions. Museum numbers 1882,0507.1 and 1891,0905.12. https://www.britishmuseum.org/collection/object/C_1882-0507-1. https://www.britishmuseum.org/collection/object/H_1891-0905-12.

Christy, Miller. 1900. *The Silver Map of the World*. London: Henry Stevens, Son, & Stiles. https://www.unz.com/print/ChristyMiller-1900.

Colthorpe, Marion E. 2017. "1580." *The Elizabethan Court Day by Day*. https://folgerpedia.folger.edu/The_Elizabethan_Court_Day_by_Day.

Drake, Francis (homonymous nephew). 1854. Originally published 1628. *The world encompassed by Sir Francis Drake: being his next voyage to that to Nombre de Dios; collated with an unpublished manuscript of Francis Fletcher, chaplain to the expedition*. London: Hakluyt Society. https://archive.org/details/worldencompassed16drak/page/n14.

Dekker, Elly. 2007. "Globes in Renaissance Europe." In *History of Cartography, Volume 3, Part 1: Cartography in the European Renaissance*, edited by David Woodward, 135–173. Chicago: University of Chicago Press. https://press.uchicago.edu/books/hoc/HOC_V3_Pt1/HOC_VOLUME3_Part1_chapter6.pdf.

Edney, Matthew H. 2019. *Cartography: The Ideal and Its History*. Chicago: University of Chicago Press.

Gaspar, Joaquim Alves, and Henrique Leitão. 2019. "Early Modern Nautical Charts and Maps: Working Through Different Cartographic Paradigms." *Journal of Early Modern History* 23 (1): 1–28. https://doi.org/10.1163/15700658-12342627.

Gitzen, Gary D. 2014. "Edward Wright's World Chart of 1599." *Terrae Incognitae* 46 (1): 3–15. https://doi.org/10.1179/0082288414Z.00000000027.

van Groesen, Michiel. 2007. *The De Bry collection of voyages (1590-1634): editorial strategy and the representations of the overseas world*. Ph.D. thesis, Amsterdam Institute for Humanities Research (AIHR). https://hdl.handle.net/11245/1.265995.

Hague, James D. 1908. "The Drake Medallion." *Bulletin of the American Geographical Society* 40 (8): 449–469. https://doi.org/10.2307/197325.

Hakluyt, Richard. 1589. "The famous voyage of Sir Francis Drake into the South Sea, and there hence about the whole Globe of the Earth, begun in the year of our Lord, 1577," in *The Principall navigations, voiages and discoveries of the English nation*, by Richard Hakluyt, twelve unnumbered pages between the pages numbered 643 and 644. London: George Bishop and Ralph Newberie. https://babel.hathitrust.org/cgi/pt?id=aeu.ark:/13960/t20c5qh1x&view=1up&seq=685 (images 685–696).

Harley, J. B. 1988. "Silences and Secrecy: The hidden agenda of cartography in early modern Europe." *Imago Mundi* 40 (1): 57–76. https://doi.org/10.1080/03085698808592639.

———. 1989. "Deconstructing the Map." *Cartographica* 26 (2): 1–20. https://doi.org/10.3138/E635-7827-1757-9T53.

Hessler, John. 2023. "In Conversation with David Rumsey." *The Portolan* 117: 27–29.

Kelsey, Harry. 1990. "Did Francis Drake Really Visit California?" *Western Historical Quarterly* 21 (4): 444–462. https://doi.org/10.2307/969250.

Keuning, Johannes. 1955. "The history of geographical map projections until 1600." *Imago Mundi* 12 (1): 1–24. https://doi.org/10.1080/03085695508592085.

Kraus, Hans. P. 2022a. *The Kraus Collection of Sir Francis Drake*, Library of Congress, paragraph 48, https://www.loc.gov/rr/rarebook/catalog/drake/drake-catalogue.html and at http://hdl.loc.gov/loc.rbc/rbdk.d058a. Accessed January 2024.

———. 2022b. " Catalogue of the Collection" in *Sir Francis Drake: A Pictorial Biography by Hans P. Kraus*. Accessed October 2022. https://www.loc.gov/collections/sir-francis-drake/articles-and-essays/drake-biography/catalogue-of-the-collection/.

MacGregor, Neil. 2013. *Shakespeare's Restless World: A Portrait of an Era in Twenty Objects*. New York: Penguin Books.

McIntosh, Greg C. 2000. *The Piri Reis Map of 1513*. Athens, GA: the University of Georgia Press.

McIntosh, Greg C., and Joaquim A. Gaspar. 2021. "Kunstmann III: The Oldest Known Nautical Chart Incorporating Latitudes." *Imago Mundi* 73 (2): 162–178. **https://doi.org/10.1080/03085694.2021.1960021**.

de Mendoza, Bernardino. 1896. "Simancas: October 1580," in *Calendar of State Papers, Spain (Simancas), Volume 3, 1580–1586*, edited by Martin A. S. Hume, 52–63. London: Her Majesty's Stationary Office. Item 44, letter to Philip II, 16 October 1580. **http://www.british-history.ac.uk/cal-state-papers/simancas/vol3/pp52-63**.

Moreno Madrid, José María, and David Salomoni. 2022. "Nuno Da Silva's *Third Relation*: An Unknown Report on Francis Drake's Voyage (1577–1580)." *Terrae Incognitae* 54 (1): 64–82. **https://doi.org/10.1080/00822884.2022.2048246**.

Nuttall, Zelia. 1914. *New Light on Drake, A Collection of Documents Relating to His Voyage of Circumnavigation, 1577–1580.* London: The Hakluyt Society. Page lvi has a small part of the *French-Drake* map. **https://catalog.hathitrust.org/Record/002809409**.

Purchas, Samuel. 1625. *Purchas his Pilgrimes, The Third Part*. London: William Stansby. **https://memory.loc.gov/cgi-bin/ampage?collId=rbdk&fileName=d0403/rbdkd0403.db&recNum=495**.

R. B. 1695. *The English Hero: or, Sir Francis Drake Reviv'd*. London: Nathaniel Crouch. **https://www.loc.gov/resource/rbcdrake.d045/?sp=14&st=image&r=-0.57,0.097,2.14,0.86,0**.

Schulz, Kathryn. 2015. "The Really Big One: An earthquake will destroy a sizable portion of the coastal Northwest. The question is when." *The New Yorker,* July 20, 2015. **https://www.newyorker.com/magazine/2015/07/20/the-really-big-one**.

Shirley, Rodney W. 1983. *The Mapping of the World: Early Printed World Maps, 1472–1700*. London: Holland Press.

Smith, Eric D., Young-Jun Son, Massimo Piattelli-Palmarini, and A. Terry Bahill. 2007. "Ameliorating Mental Mistakes in Tradeoff Studies." *Systems Engineering* 10 (3): 222–240.

Thrower, Norman Joseph William, ed. 1984. *Sir Francis Drake and the famous voyage, 1577-1580: Essays commemorating the quadricentennial of Drake's circumnavigation of the Earth*. Berkeley, CA: University of California Press. **https://openlibrary.org/books/OL3168378M/Sir_Francis_Drake_and_the_famous_voyage_1577-1580**.

Toppin, Martha Doerr. 2013. *Nova Albion revealed: Drake's claim of California celebrated by Hakluyt and Hondius.* Oxford University. **https://open.conted.ox.ac.uk/resources/documents/nova-albion-revealed-drake%E2%80%99s-claim-california-celebrated-hakluyt-and-hondius**.

Van Duzer, Chet. 2020. "Introduction to the *Carta Marina*." In *Martin Waldseemüller's 'Carta marina' of 1516*. Cham, Switzerland: Springer. **https://doi.org/10.1007/978-3-030-22703-6_1**.

Wagner, Henry R. 1926. *Sir Francis Drake's Voyage Around the World*. San Francisco: John Howell. **https://play.google.com/store/books/details?id=0ggIAQAAIAAJ&rdid=book-0ggIAQAAIAAJ&rdot=1&pli=1**.

Wallis, Helen M. 1951. "The First English Globe: A Recent Discovery." *The Geographical Journal* 117 (3): 275–290. **https://doi.org/10.2307/1791852**.

———. 1984, "The cartography of Drake's voyage," in *Sir Francis Drake and the famous voyage, 1577-1580: Essays commemorating the quadricentennial of Drake's circumnavigation of the Earth*, edited by Norman J. W. Thrower, 121–163. Berkeley, CA: University of California Press. **https://openlibrary.org/books/OL3168378M/Sir_Francis_Drake_and_the_famous_voyage_1577-1580**.

Williams, Scott S., Mitch Marken, and Curt Peterson. 2017. "Tsunami and Salvage: The Archaeological Landscape of the Beeswax Wreck, Oregon, USA." In *Formation Processes of Maritime Archaeological Landscapes*, edited by Alicia Caporaso, 141–161. Cham, Switzerland: Springer International Publishing. **https://doi.org/10.1007/978-3-319-48787-8_7**.

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US Navy Aerial Photography Squadrons in Türkiye: American Interests in Cold War Cartography

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This article explores a little-known archive of historical aerial photographs curated by the General Directorate of Mapping of the Republic of Türkiye's Ministry of Defense and discusses the historical context of their production by US Navy aerial photography squadrons in the 1950s. While the images themselves enable a technical analysis of the method of their collection, contemporary military manuals, domain-specific magazines and newsletters, and eyewitness accounts of how similar photographs were captured fill out the contexts of their production for cartographic purposes, with information about the aircraft involved, their cameras and camera configurations, and mission characteristics. Continuing sections situate the aerial surveys within the framework of US-led initiatives in mapping NATO territories following World War II. As one example of what must have been many special mapping agreements made between NATO countries at this time, the US cartographic surveys over Türkiye discussed here are an expression of postwar realignments of global power, put to the purposes of containment-based security preparations and infrastructure development, and neatly intertwining American military and commercial interests early in the Cold War.

KEYWORDS: historical aerial photographs; cartographic production; US Navy; Türkiye; NATO; Cold War

INTRODUCTION

When Koç University's Research Center for Anatolian Civilizations (ANAMED) embarked on the development of a project aiming to provide a resource for the study of past Anatolian landscapes, it inadvertently came across a little-known archive of historical aerial photographs. Collected for cartographic purposes, these images engage with topics including United States–led NATO security concerns, the Cold War Americanization of global geography, and the convergence of cartographic and commercial imperialism within US-led exploration and infrastructure development in the light of post-World War II realignments of global power. These realizations were not clear at the time, of course, when ANAMED's primary interests included exploring the analytical potential of sets of archival aerial images covering the entirety of Türkiye (Hong and Roosevelt 2023). A broad inquiry had been made to the General Directorate of Mapping, part of the Republic of Türkiye's Ministry of National Defense, concerning the availability of stereoscopic sets of historical aerial photographs that had continuous coverage of the country. The earliest dataset that met these criteria was from the 1950s, and the first partial-coverage orders were placed. Delivery of scanned images was accompanied by minimal metadata, including—among other baseline information—reference to it as the "Amerikan" collection. As initial processing and study of the dataset progressed, it quickly became apparent that this American collection of aerial photographs derived from an otherwise secretive cooperation between Türkiye and the US throughout the mid-1950s that involved a little-celebrated yet incredibly productive cartographic squadron of the US Navy.

Similar collections of twentieth-century aerial images have been discussed with varying cartographic approaches in mind. Critical analyses have highlighted technical, artistic, and cognitive perspectives (e.g., Sekula 1984, 33–52; Sichel 2007; Cosgrove and Fox 2010), while consideration of the role of aerial images in the social production of space has explored their totalizing, contextualizing capacity in structuring understandings of built environments (e.g., Haffner 2013). The map-like images that resulted from the coalescence of aviation and photography, and eventually their transformations into photogrammetrically corrected orthophoto mosaics (Cosgrove 2008; Dyce 2013), suggested a sense of depersonalized objectivity associated with an Apollonian or God's eye view (Virilio 1989; De Landa 1991; Cosgrove 2001; Kaplan 2018), and gave new meaning to the idea of the "high ground" in military contexts (van Crevald 1991, 120–27; 2011; Brugioni 2010; Barney 2014). Produced by the US Navy, the military nature of the current collection is implicit, even if similar collections were used for academic, civilian, and commercial purposes (Saint-Amour 2011).

Like most Cold War geospatial information and technologies, as explored by John Cloud, John Clarke, and others, the aerial photographs in this collection and the US Navy squadrons that produced them remain obscured by a lingering haze of secrecy (e.g., Cloud and Clarke 1999; Cloud 2002; Truesdell 1953). Brian Harley (2001b) demonstrated how cartography and its products have always been potent discursive tools in politics and power, and the images in this collection are no different. Imprinted with "US Navy" and "Top Secret," the photos signpost their significance early in the Cold War, at a time when concealing the technologies that underlaid geographic knowledge production was paramount.

Others have commented on the US military's assembly-line methods of geographic knowledge production during and after World War II (e.g., Sekula 1984), encapsulated in the processing of hundreds of thousands of aerial photos into usable cartographic tools with "relentless graphic uniformity" (Rankin 2016, 84). Rather than focus on their processing, this article focuses on the initial capture of aerial images in aerial surveys and the historical contexts that led the US Navy to Türkiye for this purpose. As such, the article aligns most closely with traditions Matthew Edney (2014, 94) describes as "processual map history," with coverage of both the technical aspects of aerial photographic production and the historical contexts that enabled them.

The article also follows Matt Dyce (2013), whose critical cartographic approach explored the representational, map-like nature of vertical aerial photographs, and how photogrammetric processing into depersonalized, technically objective images made them only more map-like (see also Cosgrove 2008; Daston and Galison 2007). Aerial images and maps are thus conflated in this article, and the term "cartographic" is used only in one of its traditional senses, in relating to mapmaking. "Cartographic squadron," "cartographic survey," "aerial survey," and "aerial imaging," then, all refer to the same practice: systematic aerial photographic survey conducted by specifically trained units with the aim of collecting images for photogrammetric processing into standardized and accurate maps.

Just as "maps inevitably codify the interests and worldviews of their makers" (Rankin 2016, 13; see also Woods and Fels 1992; Harley 2001a), so too are mapmaking practices imprinted with the underlying tendencies of those who commission them. In this case, the specific practices of aerial photographic surveys in Türkiye reflect postwar realignments of global power and the technocratic and imperializing military and commercial incentives that supported them (see also Immerwahr 2019). To reach this conclusion, this article works backwards, beginning with a characterization of the images based on their imprinted information. A Geographic Information System (GIS)-enabled analysis of survey missions over Türkiye is then complemented by embodied understandings deriving from archival research, US Navy aerial photography manuals, domain-specific magazines and newsletters, and eyewitness accounts. Together, these sources fill out the contexts of image production by aerial mapping squadrons in the 1950s, with information about the aircraft involved, their cameras and camera configurations, and mission characteristics. This article goes on to discuss these aerial surveys within the framework of US-led postwar initiatives in mapping that were rallied to the dual causes of security preparations and infrastructure development that neatly intertwined American military and commercial interests along NATO's Southern Flank early in the Cold War.

TECHNICAL CHARACTERISTICS OF THE PHOTOGRAPHS AND THEIR PRODUCTION

The request for historical aerial photographs described above resulted in the delivery of scanned panchromatic images by early 2021. Metadata delivered with the images themselves included spreadsheets and other files with filenames such as "Amerikan," "Amerft," or "fotoamerikan," containing a selection of information for each image including date, year, roll number, exposure number, latitude and longitude (in decimal degrees), focal length, and scale, the latter referring to photographic scale, or the ratio of camera focal length to elevation. Four additional data columns—type, size, direction, and purpose—were mostly empty, except for direction, which sometimes recorded cardinal directions, and purpose, which sometimes recorded "amerikan." It quickly became apparent that the supplied metadata represented only a selected collation of the information available in the camera-printed labels. Also apparent was an explanation for references to the collection as "American," as each image was stamped with "USN" (for US Navy), along with squadron and detachment identification, among other information (Figure 1).

Figure 1. Representative sample of the historical aerial photographs in the collection, this one captured in late June 1955 above the historical peninsula of Istanbul, and surroundings, with north near the top. Note the camera-printed label shown here along the left side of the frame.

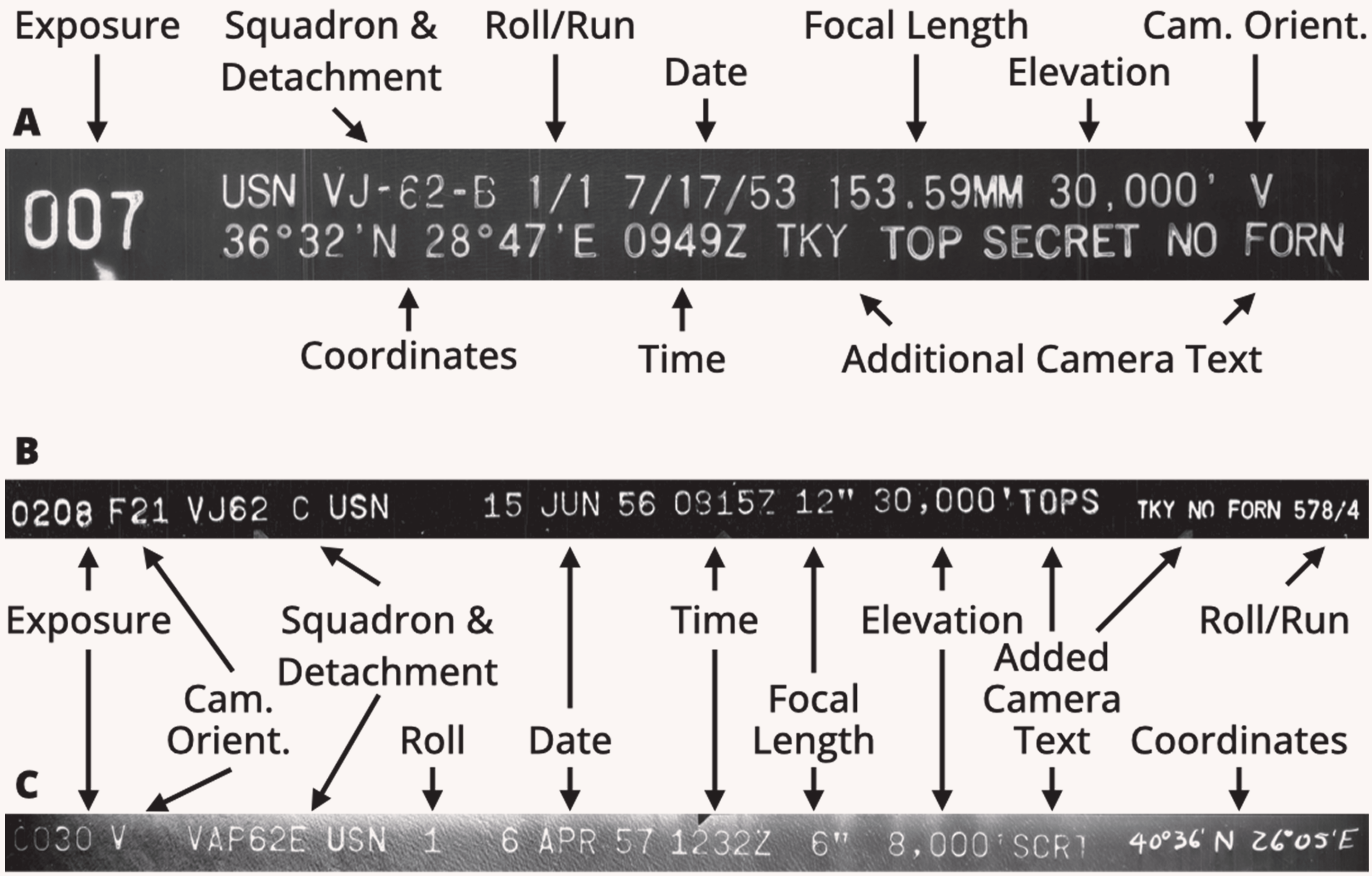

Figure 2. Examples of camera-printed labels on historical aerial photographs in the collection. A: label format used in 1953–1954; B: label format used in 1955–1956; C: label format used in 1957, including hand-annotated coordinate data.

Review of the camera-printed labels of the collection demonstrated that the images were captured between July 1953 and May 1957 by detachments of the VJ-62 and, later, VAP-62 squadrons of the US Navy, with each detachment identified by an alphabetic suffix adopted from the 1947 version of the International Civil Aviation Organization's Radiotelephony Spelling Alphabet, beginning with Able, Baker, Charlie, etc. (Ginter 1992, 70). Photographs from 1953 and 1954 share the same two-line labeling format, with the label located at the bottom of the frame with respect to the direction of flight (Figure 2). These labels usually include the following information: exposure number; squadron-detachment identification; film roll and run (transect) number; date; focal length (in mm or inches); elevation (in feet); camera orientation (V for vertical, VL and VR for vertical left and right, respectively); coordinates (in degrees and minutes); time of run start (with suffix Z); and varying additional text, usually including at least "TKY" (for "Türkiye") "TOP SECRET," and "NO FORN," for "No Foreign" access or distribution.

Similarly, photographs from 1955 and 1956 share a common single-line labeling format containing similar information, now with the label located at the top of the frame with respect to the direction of flight. Exceptions in 1955 and 1956 include coordinates that are handwritten, when included at all, and LO and RO camera orientations, for left and right oblique, respectively. Additionally, F21 and F22 sometimes replace the L- and R- camera orientations in images from 1956, respectively, "TOPS" is another abbreviation for "Top Secret," and roll and run information appears after the additional text.

Camera-printed labels from 1957 again appear at the top of the frame with respect to the direction of flight and are even more abbreviated, with "SCRT" substituting for "Top Secret" and with handwritten coordinates, if included at all.

With the additional exception of pre-printed labels on negatives that identify film manufacturer and type (often "KODAK RECON SAFETY" or "KODAK AEROGRAPHIC SAFETY FILM 1A" (or "1B")), this is the extent of the metadata available for the collection. General Directorate of Mapping sources suggest the images were scanned in its Department of Photogrammetry at a resolution of 20-microns with a positional accuracy of ±2 microns (Erbaş 2013, 28–29; HGM Hava Fotoğrafı 2023), yet no other information

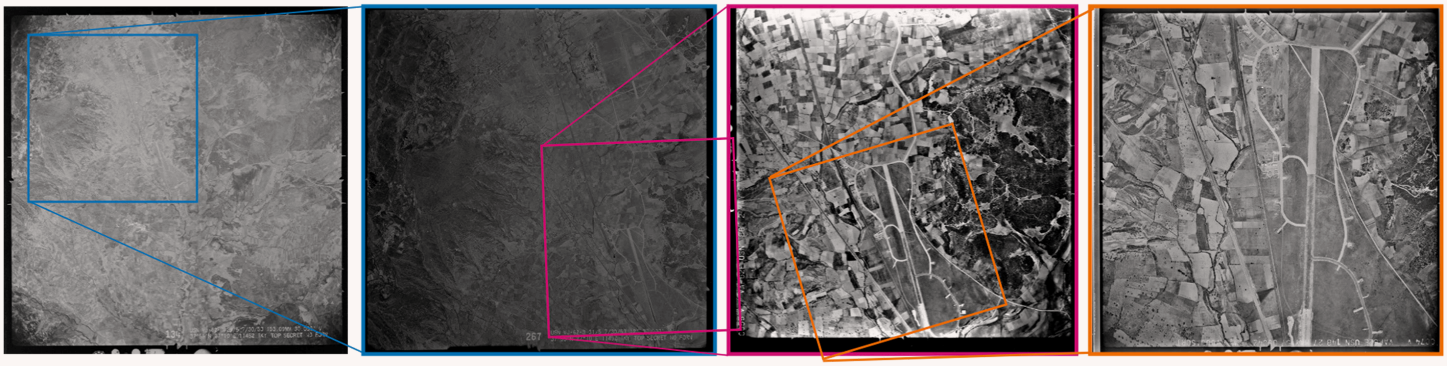

Figure 3. Examples of collection images, exhibiting different photographic scales as well as the differing quality of the image exposures. Here the focus is on the Cumaovası airfield, what later became the Izmir Adnan Menderes Airport in Gaziemir, Izmir.

Year	Squadron & Detachment	Days	Total Distance	Avg. Distance/Day	Photographic Scale	Rolls	Avg. Rolls/Day	Photos
1953	VJ-62-B (Baker)	22 (17 JUL–16 AUG)	33,196 km	1,581 km	1:60,000	29	1.38	4,203
					1:30,000	56	2.55	15,226
1954	VJ-62-F (Fox)	58 (31 MAY–29 SEP)	37,855 km	773 km	1:60,000	61	1.25	3,786
					1:30,000	85	1.93	9,016
1955	VJ-62-L (Love)	26 (9 JUN–28 SEP)	13,947 km	634 km	1:60,000	27	1.23	1,694
					1:30,000	41	2.41	4,838
1956	VJ-62-C (Charlie)	11 (9 JUN–7 JUL)	11,450 km	1,041 km	1:60,000	19	1.73	1,187
					1:30,000	33	3.00	3,974
1957	VAP-62-E (Easy)	30 (6 APR–31 MAY)	32,815 km	1,367 km	1:16,000	95	3.96	12,837
			4,494 km	346 km	1:10,000	20	1.54	2,301
			92 km	92 km	1:8,000	1	1.00	60
Totals		117	96,448 km	824 km	1:60,000	136	1.16	10,870
					1:30,000	215	1.84	33,054
		24	32,815 km	1,367 km	1:16,000	95	3.96	12,837
		13	4,494 km	346 km	1:10,000	20	1.54	2,301
		1	92 km	92 km	1:8,000	1	1.00	60

Table 1. Flight days, distances, and photographic production derived from nearly 60,000 images and their camera-printed labels.

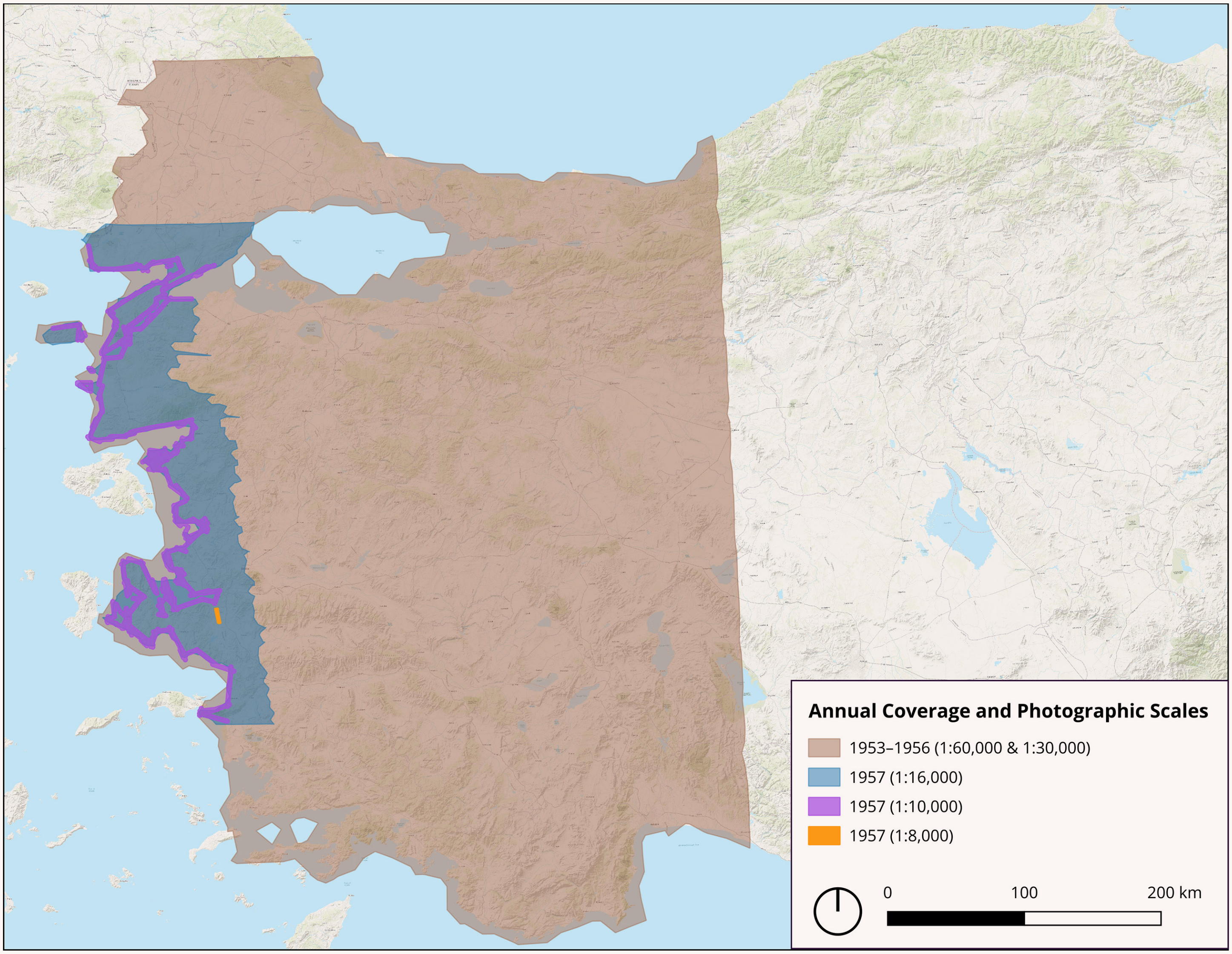

Figure 4. Map showing the geographic coverage of cartographic survey represented by the selection of data currently being processed.

useful for precision photogrammetric processing is known (e.g., camera calibration, lens distortion, principal point, or fiducial mark information). Nonetheless, from this information alone, a general sense of the cartographic missions that produced the archive was produced by reconstructing flight lines and overall coverage with the aid of GIS software.

Over the course of at least five years and involving at least VJ-62's Baker (B), Fox (F), Love (L), and Charlie (C) Detachments in 1953, '54, '55, and '56, respectively, and VAP-62's Easy (E) Detachment in 1957, at least 147 days of flying produced the nearly 60,000 images in the collection as of 2021 at a variety of photographic scales, apparently dependent on mission goals (Figure 3; Table 1). At present, it seems that only one plane from each detachment each year provided all the photographic output of the collection. Over 30 days in 1957, work focused on a large photographic-scale survey of Aegean coastal areas at 1:16,000 (12,837 images captured at 8,000 ft), with a small area covered by 1:8,000 (60 images captured at 4,000 ft) and the coastline itself by 1:10,000 scale imagery (2,301 images captured at 5,000 ft) (Figure 4). The larger body of work over 117 days between July 1953 and July 1956 was dedicated to broadscale mapping. Current holdings cover all parts of western Türkiye located west of a roughly north-south line running from near Karadeniz Ereğli, Zonguldak, to Manavgat, Antalya, represented by a total of 10,870 1:60,000 photographic-scale images and 33,054 1:30,000 photographic-scale images, all collected from 30,000 ft.

In each of the 1953–1956 flights, a combination of cameras with lens cones of different focal lengths were used to

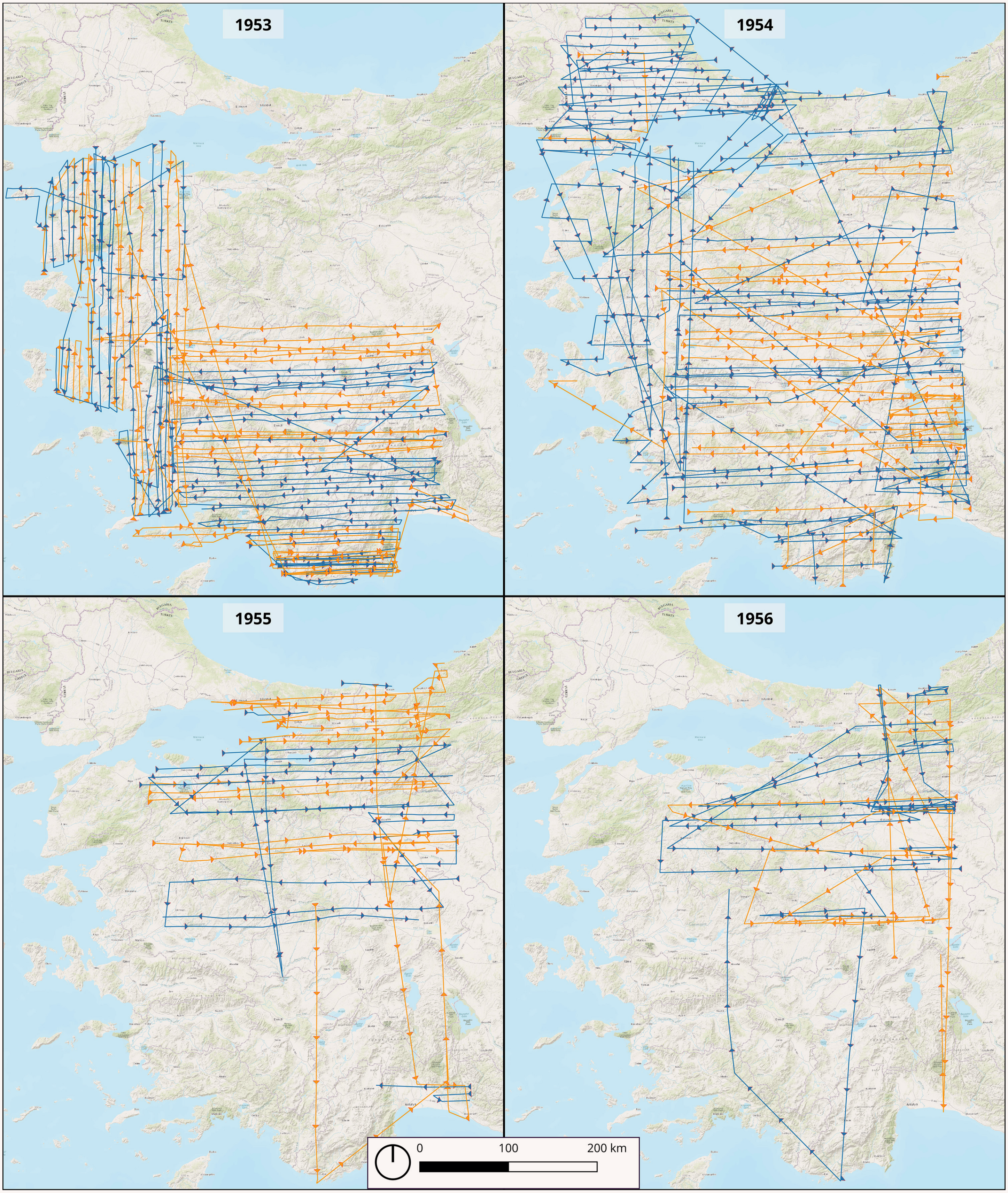

Figure 5. Maps showing the daily flight lines for 1953–1956 surveys and capture of 1:60,000 and 1:30,000 photographic scale images. Alternating line colors indicate different days.

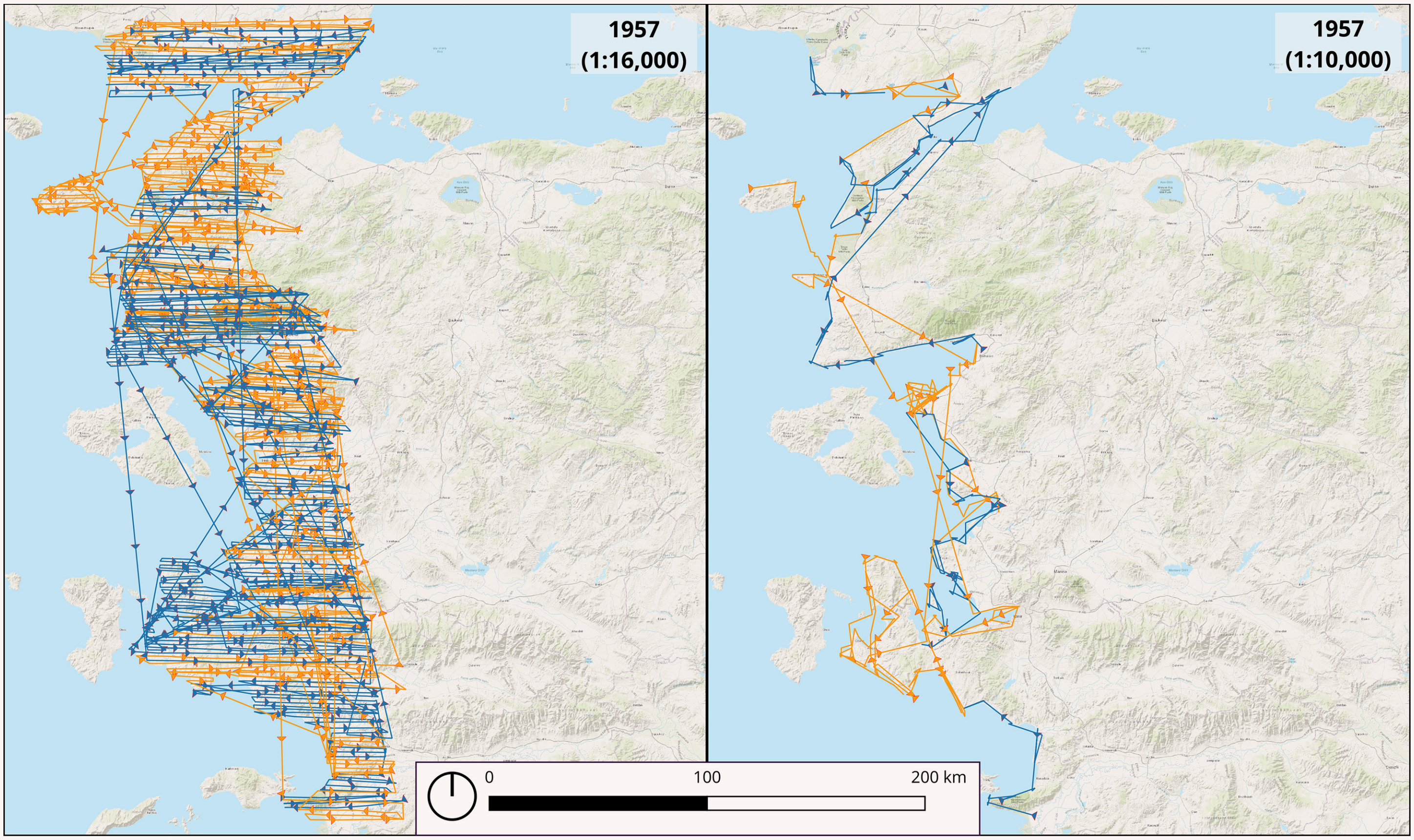

Figure 6. Map showing the daily flight lines for 1957 survey and capture of 1:16,000 and 1:10,000 photographic scale images. Alternating line colors indicate different days.

capture overlapping sets of images for stereoscopic and photogrammetric analysis (see below). A 6-inch focal-length prime vertical camera recorded a series of fore-lapping images at 1:60,000 photographic scale; these were likely used for flight-path monitoring, orientation, and subsequent larger-scale image localization. Simultaneously, a pair of 12-inch focal-length split vertical or slightly oblique cameras recorded sets of fore- and side-lapping exposures at a photographic scale of 1:30,000. Parallel runs or transects crisscrossed the landscape producing sets of contiguous images suitable for producing topographic maps at scales of around 1:25,000 (Figures 5–6).

As apparent in Table 1 and Figures 5–6, the intensity of work seems to have been highest in 1953 and 1954, judging by total distances covered and numbers of rolls and photos captured. The work of 1955 and 1956 appears to have aimed to fill gaps between the flight lines of previous years. Work in 1957 was intensive, also, as shown in the total distances covered, and the high numbers of rolls and photos derives from the lower altitude of the flights, which produced more detailed images at larger photographic scales. Average distances and rolls per day appear to fall within the ranges of other cartographic surveys of the time (see below), yet a few longer-distance outliers are evident. On 11 August 1953, for instance, Baker (B) Detachment of VJ-62 logged at least 3,267 km along survey runs alone—not including round-trip distances to landing strips, that is; the result was 3 rolls or 493 images at 1:60,000 photographic scale and 5 rolls or 1,672 photos at 1:30,000 scale. On 1 May 1957, Easy (E) Detachment of VAP-62 logged at least 4,205 km along survey runs and captured 9 rolls or 1,538 photos at 1:16,000 photographic scale.

Beyond this baseline-level of information reverse-engineered from the camera-printed labels, little more can be reconstructed about the collection images and the squadron that captured them. To learn more, one must zoom out and step slightly back in time to US Navy archives and aerial photography training manuals, as well as related magazines and newsletters, which illuminate the rich history of the US Navy's involvement in aerial photographic reconnaissance and cartography.

US NAVY AERIAL PHOTOGRAPHY SQUADRONS IN THE 1950s

The development of aerial photographic capacity in World War II (WWII) had significant impacts on the planning, implementation, and post facto assessment of wartime maneuvers in reconnaissance, tactical intelligence, and mapping (see Babington-Smith 1957; Heiman 1972; Goddard 1969; Brookes 1975). Wartime aerial photography missions of the US Navy were undertaken by mixed squadrons of fighter and bomber aircraft which were carrier- or land-based, designated Composite Squadron Sixty-One (VC-61) in the Pacific Fleet and Sixty-Two (VC-62) in the Atlantic Fleet (DeForge 1981, 3-10). Soon after WWII, these squadrons were reassigned and redesignated to suit administrative changes and narrowed functions. By 1951, it was decided that the fighter elements of VC-61 and VC-62 would focus on reconnaissance and tactical intelligence photography based primarily from carriers, while the bomber elements would be broken off to form Photographic Squadrons Sixty-One and Sixty-Two (again with Pacific [VJ-61] and Atlantic [VJ-62] designations), dedicated to long-range reconnaissance and cartographic surveys based typically from land, but also from carriers (Naval Aviation News 1953c; 1956a; 1958c, 8; DeForge 1981, 3-10; Campbell 2014, 361).

Accordingly, VJ-62 was commissioned in April 1952 with a home port at the US Naval Air Station (NAS) in Jacksonville, FL (Jax Air News 1952; Grossnick 1995, 314). Over the next five years, the home port of the squadron

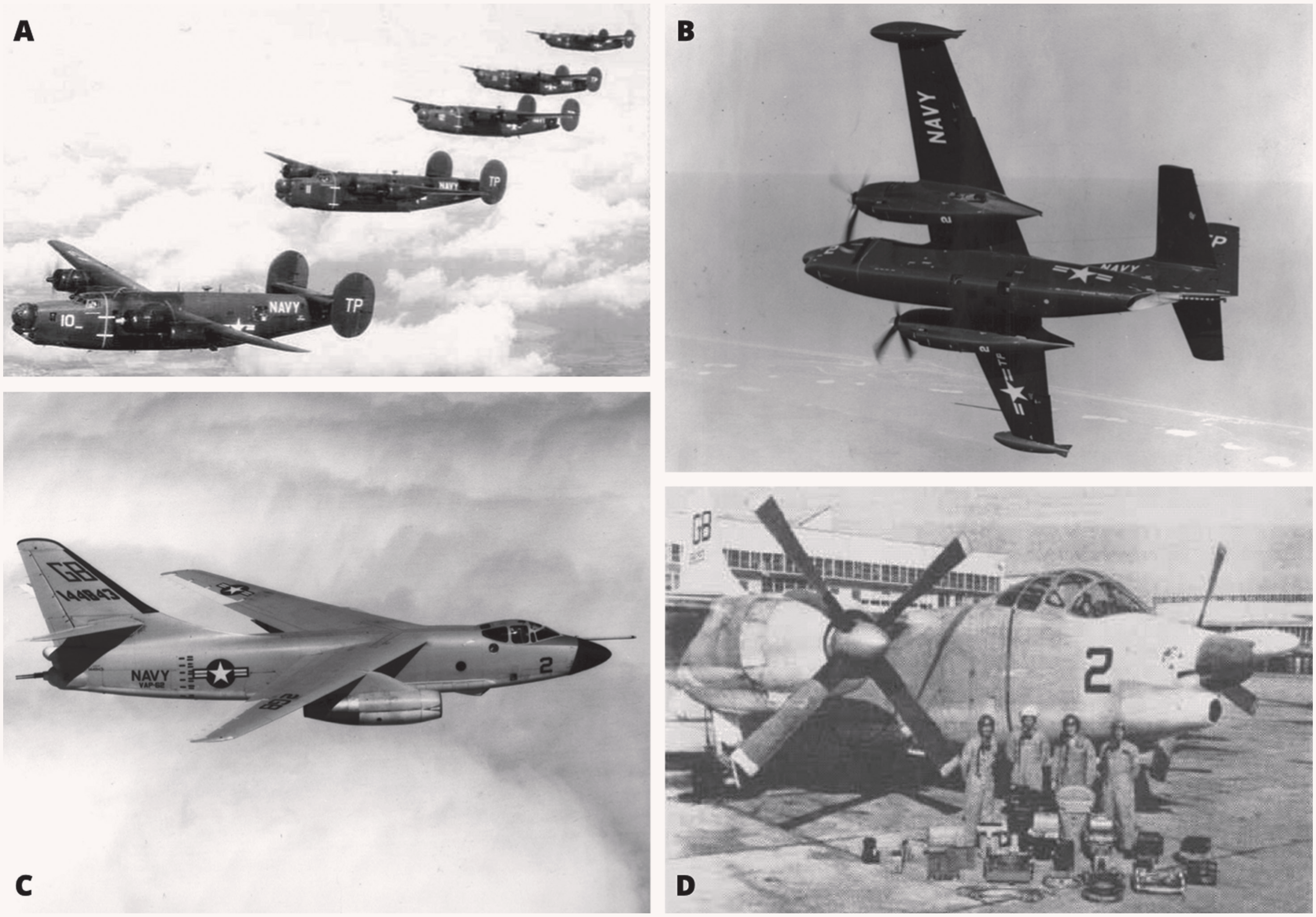

Figure 7. A selection of the aircraft employed in VJ/VAP-62 squadrons in the 1950s, showing tail codes "TP" (before July 1, 1957) and "GB" (after). A: Consolidated Aircraft's P4Y-1P "Liberators" from VJ-62. B: North American Aviation's AJ "Savage" from VJ-62 (note the underside camera windows). C: Douglas Aircraft's A3D-2P "Skywarrior" from VAP-62. D: North American Aviation's AJ-2P "Savage" from VAP-62, behind camera equipment and crew. All images from the US Navy, obtained via Wikimedia Commons, uploaded by contributor Cobatfor (Grossman 1995, 315).

changed several times—to Sanford, FL, Norfolk, VA, and back again to Jacksonville, FL (Grossnick 1995, 314)—while its missions remained relatively constant in supplying reconnaissance for the Atlantic Fleet and mapping and other photographic services for a variety of US and foreign entities, especially around the Mediterranean. In July 1956, the Navy's photographic squadrons were again redesignated according to new organizational and naming logic: the fighter-based reconnaissance and tactical VC squadrons were redesignated as Light Photographic Squadrons (VFP), and the long-range, bomber-based VJ squadrons were redesignated as Heavy Photographic Squadrons (VAP), again with Pacific (61) and Atlantic (62) designations (Naval Aviation News 1956b; DeForge 1981, 3-17; Grossnick 1995, 314). As is clear from the camera-printed labels in this collection, it was the bomber-based VJ/VAP-62 photographic squadron that focused its long-range and cartographic capabilities on Türkiye, the Mediterranean, and further afield (see below).

AIRCRAFT AND CAMERAS

In the first year following their commission in 1952, the VJ squadrons still used Consolidated Aircraft's WWII-era four-prop PB4Y "Liberator" bombers, modified for photoreconnaissance and designated P4Y-1P (Figure 7A; DeForge 1981, 3-7; Grossnick 1995, 315, 496). Already by the end of 1952, however, the squadrons began flying what would become their workhorse aircraft for much of the rest of the decade: North American Aviation's AJ "Savage" bomber, with turbojet and twin wing-mounted, reciprocating engines (Figures 7B and 7D; Doeppers 1972, 185; DeForge 1981, 3-10). Capable of both carrier and land deployment and modified as the AJ-2P for aerial photography, the Savage was more versatile than the Liberator and provided the best available long-range aerial photography solution at the time (Grossnick 1995, 315, 458). Owing to design and functional improvements, a version of Douglas Aircraft's A3D "Skywarrior" bomber, modified for photoreconnaissance and designated A3D-1P (and later A3D-2P), began to replace the Savage in VJ squadrons only five years later (Figure 7C), yet the Savage remained the aircraft of choice for most of the 1950s (Naval Aviation News 1958a; DeForge 1981, 325; Grossnick 1995, 315, 444, 551; US Navy Patrol Squadrons 2024a).

In addition to its long range, the Savage allowed for a versatility of carrier and land-based options, capacity for deploying flares (or "flash bombs") for night photography as well as in-flight changing of cameras and film magazines, and a spacious camera bay for accommodating diverse configurations of fixed vertical and oblique cameras (Figure 8; Doeppers 1972, 185; DeForge 1981, 3-7, 3-18). It is no wonder that the US Navy ordered 23 photoreconnaissance-readied AJ-2P Savages in 1950, even if VJ-62 operated only around 7–10 aircraft at any one time throughout the decade (Doeppers 1972, 185; Ginter 1992, 67).

The camera equipment typically used by these squadrons was similar to that used in WWII photoreconnaissance, yet with intermittent upgrades (DeForge 1981, 3-3). For fixed cartographic cameras, the US Navy used the WWII-era Fairchild Camera and Instrument Corporation's K-17 (CA-3-2) and its derivatives, as well as the newer T-11 (CA-14), specifically built for mapping (NTPC 1962,

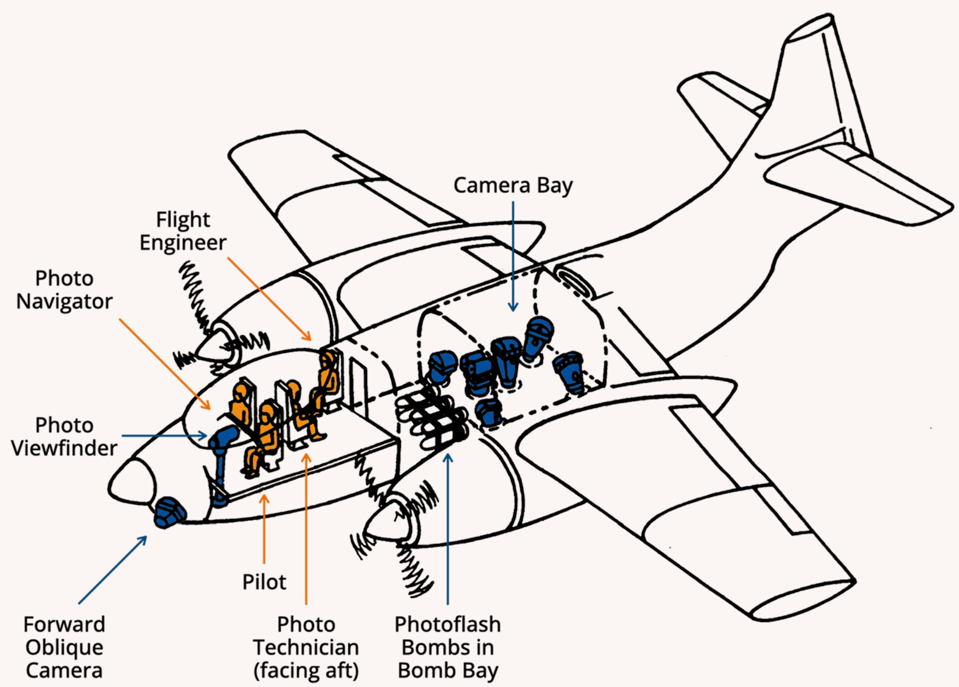

Figure 8. Schematic diagram of North American Aviation's's AJ-2P "Savage," refitted for cartographic photography, showing crew in orange and camera equipment in blue (after DeForge 1981, 3-25).

198–199; El Hassan 1978, 19). These cameras' large-format and adaptability to lens cones of varying focal lengths (6, 12, or 24 inches, most made by Bausch and Lomb) enabled large-area coverage while maintaining high-resolution at relatively high altitudes, making them some of the longest running and most versatile cameras long after WWII (Figure 9; NTPC 1962, 201–209; El Hassan 1978, 16, Figure 10, 21; Thomas 1999, 249, Figure 323). The different camera-printed label formats on the images in the current collection may suggest the updating of camera equipment over time.

The shutter mechanism of these cameras was triggered either manually or electrically from a camera control panel near the cockpit; vacuum-sealed film magazines could hold enough 9½-inch film to capture around 225 or 465 9 × 9-inch exposures, depending on magazine size (NTPC 1962, 193; 194; 198). Kodak was the primary film supplier, with its reconnaissance or aerographic safety film the primary options (NTPC 1962, 211).

One common fixed-camera configuration for simultaneous cartographic image capture included what was referred to as a "trimetrogon fan," including an array of oblique and/or vertical side cameras with 12-inch lens cones and centrally located vertical cameras with 6- or 12-inch lens cones (Doeppers 1972, 185; DeForge 1981, 3-7; 3-18; US Navy Patrol Squadrons, 2024a quoting Harold L. Murphy; Redweik et al. 2010, 1009). This set up was apparently common in the AJ-2P Savage as well as in other WWII and Korean War-era aerial photographic squadrons using different aircraft and cameras (e.g., Mahan 2003, 34–35; Cahill 2012, 14; Schuster 2016). Most photographs, including those covering Türkiye, appear to have been captured using a configuration involving a 6-inch prime vertical and a pair of 12-inch split vertical or oblique cameras.

CREWS AND DEPLOYMENTS

To operate both the aircraft and camera systems successfully, the AJ-2P Savage accommodated a crew of four: a photo technician, photo navigator, pilot, and plane captain (Naval Aviation News 1958c, 8). The photo technician (officially designated a "Photographer's Mate") was intensively trained on full-scale mockups in Pensacola, FL at the Naval Aviation Technical Training Unit (DeForge 1981, 3-3; 3-18). In fact, all crew members had to be familiar with the operation of both aircraft and camera systems in order to work together seamlessly, as described in the Navy

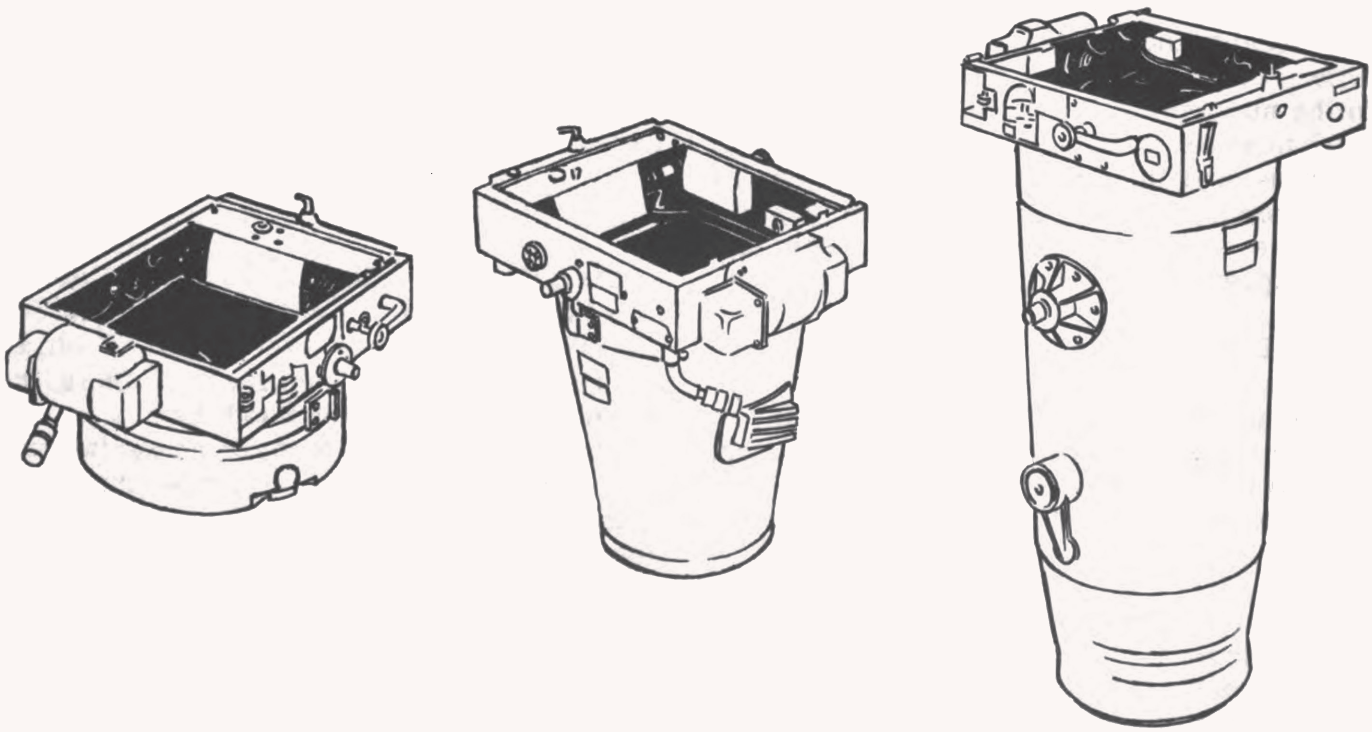

Figure 9. Schematic drawings of the Fairchild K-17 camera with 6, 12, and 24-inch lens cones, from left to right (after NTPC 1962, 188, Figure 11-1).

Photographer's Mate Training Series: Naval Photography (e.g., NTPC 1962; DeForge 1981). In order to capture high-quality imagery, care in piloting had to be matched by care in proper camera settings and operation.

As described in popular naval magazines and eyewitness accounts, pilots had to maintain steady headings for up to 400 km, regardless of altitude, while ensuring minimum lateral drift; photo navigators served as co-pilots, directing pilots to position aircraft directly over targets while computing ground speed, drift, and other flight data. Photo technicians translated flight data into camera settings, ensuring the capture of desired image parameters, while managing cameras and film before, during, and after flights (see Figure 8) (Naval Aviation News 1958c, 8). The skilled endurance of AJ-2P Savage crews and aircraft are shown in two flight-time records set in 1953 alone: 91 hours in March and 117.7 hours in July (Naval Aviation News 1954). Other records suggest that daily missions were planned with round-trip distances of around 1,100 km (ca. 600 nautical miles; Naval Aviation News 1953), even though at cruising speeds of around 370 kph (230 mph), the AJ-2P had a range of more than 2,500 km (ca. 1,600 miles) (Doeppers 1972, 185). As noted above, several flight days over Türkiye logged far greater distances than these, suggesting mid-day refueling or the use of extra fuel tanks, as described below.

Eyewitness accounts help give a sense of what participating in a VJ/VAP-62 mission in an AJ-2P Savage would have entailed. DeForge (1981, 3-25–26) quotes former Photographer's Mate J. D. Smyth directly:

> . . . In flight, the photographer would be found either at his seat at the camera control panel, on the flight deck behind the pilot, or in the camera bay.
>
> To get to the camera bay, you went down a ladder to the well deck, aft through a hatch, across the bomb bay, and through another hatch. There a photographer could change magazines in flight, change camera settings, even correct minor equipment problems.
>
> The photographer spent most of his time on the flight deck, monitoring the camera control indicators and the radar altimeter. He would only go down to the camera bay to change magazines or to check out a problem.
>
> . . . Photographers flying in the AJ often had to face difficulties their fellow crew mates weren't exposed to, like the bomb bay crawl. To make long distance flights, an extra fuel tank had to be hung in the bomb bay. This left only a narrow crawl space over the top of the tank for the photographer to reach the camera bay. It was too narrow to allow the photographer to wear a parachute or an oxygen bottle (needed on high altitude missions) when making the trip. So, when the tank was installed an extra chute and oxygen bottle were stored inside the camera bay.
>
> When a photographer needed to go into the camera bay, he would stow his chute outside the bomb bay hatch, check out with the pilot, take a few deep gulps of oxygen, and plunge through the hatch. Scrambling like mad, he would wriggle over to the camera bay hatch, hook up to the oxygen bottle and report in. If the pilot hadn't received a report after a couple of minutes had passed, it meant the [photo technician] was hung up in the bomb bay, so the plane captain was sent down to haul him out and revive him with oxygen.

Smyth also described a typical day on assignment, including a mission briefing as well as aircraft and equipment checks and maintenance (DeForge 1981, 3-25–26). Each squadron usually deployed in detachments of one to three aircraft to suit the assignment, yet detachments of many planes sometimes collaborated for faster survey of larger areas, at least within the US. The missions over Türkiye appear to have included detachments of only one aircraft. In the early 1950s, when the Pacific Fleet squadron was dedicated fully to Korean War reconnaissance (DeForge 1981, 3-8–10; Grossnick 1995, 314; 458), the Atlantic Fleet squadron flew a variety of missions in the US and elsewhere around the Atlantic basin. In these, they not only flew photographic missions for the Navy, but they also collaborated with many US and foreign entities with specific priorities developing out of US-led, postwar realignments of global power.

US NAVY AERIAL PHOTOGRAPHY IN THE LIGHT OF POSTWAR REALIGNMENTS OF GLOBAL POWER

The postwar activities of VC/VJ/VAP photographic squadrons were dictated by increasingly widespread US and NATO interests in Cold War security, just as they furthered US resource exploration and infrastructure development, as well as academic research. The US Navy's postwar photographic expertise in these areas grew not just from WWII activities, but from its interwar experiences as well. Beginning in 1923, photographic activities close to home had been associated with energy exploration in Alaska, California, and Colorado; dam and irrigation infrastructure in Florida; and slightly later infrastructure projects associated with the Tennessee Valley Authority (Campbell 2014; Brugioni 2010). Further abroad, and between 1924 and WWII, resource exploration (especially for rubber) and imperializing interests led to work in Cuba, the Dominican Republic, Nicaragua, Puerto Rico, Panama, Colombia, and Venezuela, as well as the Manua Islands, Philippines, and China (Campbell 2014, 71–121; Immerwahr 2019). State and federal cartographic data requesters and collaborators in this work included the Alaskan Coal Commission, the US Coast and Geodetic Survey, the Department of the Interior (Geological Survey), and, notably, the Department of Commerce (Campbell 2014). The US Navy's aerial photographic surveys, then, were part and parcel of American territorializing tendencies in many of these areas, well before the outbreak of WWII (Immerwahr 2019).

After WWII, the US Navy's photographic squadrons returned to prior patterns of work, providing cartographic surveys for and associated with a variety of federal departments and agencies (e.g., Geological Survey; Forest Service; Campbell 2014, 311), and these remained tied to resource exploration and infrastructural projects, as well as to research initiatives (Naval Aviation News 1958c; Ginter 1992, 70). Between 1946–1948, for instance, the US Navy provided mapping services to the Ronne Antarctic Research Expedition (Brugioni 2010, 43). Research projects to which cartographic aid was given included studies of the directional spectra of ocean waves (Chase et al. 1957) and the creation (and dissolution) of cloud formations (Naval Aviation News 1958b). Between April and November of 1953 and also in 1954, VJ-62's How (H) Detachment mapped ice flows in the Arctic Ocean between Alaska, Baffin Island, and Greenland over four seasons, based out of Argentia, Newfoundland (with VJ-61 doing the same from Fairbanks, Alaska), in aid to the US Hydrographic Office and Army Corps of Engineers (Naval Aviation News 1955; 1956c, 2; Weidick 1958). For the US Department of the Interior's Fish and Wildlife Commission, the Army Map Service, and the Coast and Geodetic Survey, VJ-62 imaged Florida's Okefenokee Swamp and both North and South Carolina (Naval Aviation News 1958c, 8–9; Ginter 1992, 70).

In addition to domestic research and development, US Navy aerial photography also continued to support the advancement of American interests abroad in collaboration with a broad set of US military, commercial, and scientific institutions. In assisting the planning of major construction jobs abroad, VJ-62 often aided the US Army Corps of Engineers and similar institutions, increasingly towards the eastern range of the Atlantic Fleet in the Mediterranean (Naval Aviation News 1958c, 8–9; DeForge 1981, 3-1–3; Grossnick 1995, 314). The intensity of US Navy aerial mapping activities in this area, in fact, resulted not just from such needs, but from a constellation of seemingly complementary interests that first came together in the early 1950s. These included robust NATO security planning and US military and construction business interests, all of which were dependent on up-to-date, large-scale, and regional knowledge of situations on the ground, situations that required the production of standardized, accurate, and appropriately scaled maps.

US-LED NATO SECURITY CONCERNS AND THE COLD WAR AMERICANIZATION OF GLOBAL GEOGRAPHY

A flurry of conceptual and technological changes related to mapmaking in the late 1940s and 1950s reflected a new globalizing turn and had significant impacts on aerial photography, photogrammetry, and their combination in mapmaking (Brugioni 2010, 34; Rankin 2016). As Cloud and Clarke (Cloud and Clarke 1999; Cloud 2001), Timothy Barney (2014), and William Rankin (2016) have explored in detail, needs for accurate and precise coordinates and map representations arose from WWII and postwar power realignments and the development of weapons with increasingly global ranges. While the eventually aborted International Map of the World initiative and contemporary World Aeronautical Chart sheets served navigational and other purposes at smaller scales, US and NATO military interests determined that larger-scale basemaps required standardization and improvement across NATO-unified territories.

Already in the late 1940s, from his post in the Office of Geographer in the US Department of State, Samuel Whittemore Boggs had commissioned a secret evaluation of the national map holdings of Türkiye, Greece, and other European countries concerning their specifications and reliability (Barney 2014, 91–92; Rankin 2016, 86). To be of transnational use, such maps needed to share representational language and also—crucially—unified reference and coordinate systems (Lieber 1954). While the international significance of the establishment of the ISO in the 1940s has been recognized previously (e.g., Immerwahr 2019), the relatively new Universal Transverse Mercator coordinate reference system—along with eventual shifts to the World Geodetic System reference frame and Global Positioning System navigation systems (both of which were soon to be primary developmental aims)—represented particularly American standards and solutions for transnational cartographic and tactical practices (Rankin 2016). While Cloud and Clarke (Clarke and Cloud 2000; Cloud 2002) see such globalizing technologies as a result of a reconvergence (vis-à-vis Anne Godlewska's [1989] divergence) of the disciplines of geodesy, cartography, and geography in the context of WWII and Cold War military-industrial-academic collaborations, Rankin (2016, 4) underlines the US military's co-development, implementation, and infrastructural installation of the same technologies as representative of the "Americanization of geography," with US power implicit in increasingly universal modes of cartographic knowledge production.

As part of this process of standardization, NATO adopted the Universal Transverse Mercator system in 1951, and existing western European maps began their transformation to this standard in March 1952 (Rankin 2016, 188). For most NATO countries, however, partial or complete remapping was necessary. This was often carried out by the US based on individual "special arrangements" (Rankin 2016, 189, n. 58), involving data, material, and operational exchanges aiming "to weld into one coordinated effort the over-all mapping needs of . . . [NATO] member nations" (Lieber 1954). So it was that the US's best-equipped mapping teams—the Navy's photographic squadrons—undertook the task at hand: to conduct aerial surveys that would enable the production of standardized, updated, and accurate maps for NATO members. As Barney (2014, 70) argues, "This impressive campaign to expand the map was part of an ideological impulse to advance a set of values that separated America from the Soviet Union and affirmed the nation's need to bring such values to the rest of the world."

It wasn't until the late 1940s and increased anxieties over Soviet designs on both eastern Turkish provinces and the Turkish Straits that Türkiye openly sought US influxes in military expertise and equipment (Üstün 1997; Atmaca, 2014; Adalet 2018), even if the US secretly provided these things already during WWII (Cossaboom and Leiser 1998; Guvenc and Uyar 2022). In 1947 the US Air Force was contracted to help modernize the Turkish military (Livingston 1994; Guvenc and Uyar 2022), when all official cartographic work still fell under the Ministry of National Defense. Turkish terrestrial cartographic work had begun much earlier in Ottoman times, expanded to aerial photography during World War I, and accelerated with terrestrial photogrammetric capabilities in the first decades of the Republic in the early twentieth century (Kanbay 1938; Evinay 1956; Ertung 1970; Önder 2002). In 1931, aerial stereophotographs were taken over Bursa and Istanbul for cartographic purposes using German equipment, and after 1938, most if not all mapping was conducted via aerial photogrammetry (Önder 2002). Nonetheless, no systematic aerial survey had been conducted for full coverage of the country as of the early 1950s, according to correspondence with the Turkish General Directorate of Mapping.

So it was that by the early 1950s the US's globalizing cartographic aims converged with pro-Western sentiments in Türkiye, driven by economic and military modernizing needs—as well as a newly elected government's desire for increased regional importance (Kumral 2020, 122)—to produce a symbiotic relationship with mutual benefits. After an initial rejection, and only following its contributions to the Korean War (Atmaca 2014, 24), Türkiye joined NATO in February 1952, together with Greece, and the two countries formed NATO's Southern Flank. The area fell under the control of the Commander in Chief Allied Forces Southern Europe, whose job included preparing the Aegean and eastern Mediterranean, as well as the Black Sea and the Turkish Straits, in case of Soviet advances (NATO 1976, 22–23; Chourchoulis 2015, 14; 38). The primary naval force of this group in the early 1950s was the same US Sixth Fleet to which the VJ squadrons were tied, and at the time it consisted of at least two aircraft carriers, which provided some of NATO's only air defense capability (Sokolsky 1991, 25; Rose 2007, 64–66; Chourchoulis 2009, 436). By September 1952, NATO's Headquarters Allied Land Forces Southeastern Europe was founded in Izmir, Türkiye, "with the mission of exercising operational command of the field armies of Greece and Türkiye in the event of war" (Chourchoulis 2012, 639; see also NATO 1976, 289). From mid-1952 to early 1953, NATO powers were continuously engaged in determining the best defensive stances for protecting the Southern Flank from anticipated Soviet aggression and "the occupation of Greek and Turkish Thrace on the one hand, and Anatolia, Iraq and Iran on the other" (Chourchoulis 2015, 133–140). Several planned phases of force retrenchment were developed in case of territorial loss, proceeding southward from the Turkish Straits, for example, with the aim of holding northwestern Anatolia (NATO 1976, 146; Livingston 1994, 780). Chourchoulis (2012, 642), highlights how the Istanbul, Bursa, and Izmir provinces of western Türkiye were particularly important because of their military facilities, ports, and airfields, and because they formed some of the most developed industrial and economic centers of the country at the time.

Elsewhere throughout the Mediterranean and Middle East, the "special arrangements" with individual countries mentioned above are suggested by sparse records of US Navy squadron activities and the film negatives of the US National Archives (Table 2). VJ-62 squadron's Easy (E) Detachment was stationed in Italy between October 1953 and April 1954 (U.S. Navy Patrol Squadrons 2004b), and VAP-62's Baker (B) Detachment returned there in 1956 (NAO 1956). Similarly, detachments were stationed in Spain in 1955 and 1959, presumably conducting special mapping projects (NAO 1958). Separately, these same squadrons were present to photograph such events as the 1956 Suez Crisis in Egypt and the landing of several thousand US Marines on the beaches of Beirut during the 1958 crisis in Lebanon, marked by some as the first US military ground incursion in the Middle East (DeForge 1981, 3-19; Brugioni 2010, 267–269; Campbell 2014, 412). Although not yet well documented publicly, the value of the photographic services of early VJ-62 detachments and the need for timely processing and study of their photographs may have contributed to the May 1953 establishment of the Fleet Intelligence Center for film processing and image interpretation at the nearby Port Lyautey Naval Air Facility in Morocco (DeForge 1981, 3-12; Campbell 2014, 379). VJ-62 aircraft were capable of longer than 4,200 km one-way trips (see above), making this facility

<table>
<tr><th>Year</th><th>Squadron Commander</th><th>Country</th><th>Squadron</th><th>Detachment</th></tr>
<tr><td>1952</td><td>J. Kennedy, Jr.</td><td>Saudi Arabia</td><td rowspan="10">VJ-62</td><td>Able (A)</td></tr>
<tr><td rowspan="2">1953</td><td rowspan="2">H. S. Klenk</td><td>Italy</td><td>Easy (E)</td></tr>
<tr><td>Türkiye</td><td>Baker (B)</td></tr>
<tr><td rowspan="4">1954</td><td rowspan="4">J. A. Goodwin</td><td>Iran</td><td>Jig (J)</td></tr>
<tr><td>Italy</td><td>Easy (E)</td></tr>
<tr><td>Arabian Peninsula</td><td>Jig (J)</td></tr>
<tr><td>Türkiye</td><td>Fox (F)</td></tr>
<tr><td rowspan="2">1955</td><td rowspan="2">J. A. Goodwin</td><td>Spain</td><td>King (K)</td></tr>
<tr><td>Türkiye</td><td>Love (L)</td></tr>
<tr><td rowspan="3">1956</td><td rowspan="3">E. B. Johnson, Jr.</td><td>Egypt</td><td>—</td></tr>
<tr><td>Italy</td><td rowspan="6">VAP-62</td><td>Baker (B)</td></tr>
<tr><td>Türkiye</td><td>Charlie (C)</td></tr>
<tr><td>1957</td><td>Henry W. Drum</td><td>Türkiye</td><td>Easy (E)</td></tr>
<tr><td>1958</td><td>Henry W. Drum</td><td>Lebanon</td><td>—</td></tr>
<tr><td>1959</td><td>Charles W. Hollinshead</td><td>Spain</td><td>—</td></tr>
</table>

Table 2. A partial reconstruction of 1950s VJ/VAP-62 deployments and detachments (where available) in the Mediterranean, Middle East, and Türkiye. (Squadron Commander information after Grossnick 1995, 316; other information from US National Archives).

reachable from anywhere in the Mediterranean with a single flight. The assembly-line processing capabilities (Sekula 1984) of such a facility would have been essential for the quick creation of metrically corrected photomosaics and for the provision of the same to both military planners and commercial groups engaged in infrastructural development.

THE CONVERGENCE OF CARTOGRAPHIC AND COMMERCIAL IMPERIALISM IN US-LED EXPLORATION AND INFRASTRUCTURE DEVELOPMENT

The US Navy's mapping missions abroad clearly supported regional objectives concerning NATO security commitments, and in Türkiye and elsewhere they also introduced US commercial interests (Kuniholm 2001, 346; Grathwol and Moorhus 2009, 27). Rankin (2016, 5) explored the general trends of the time and how "American programs of dollar diplomacy, cultural universalism, and Cold War containment . . . [shared] space with the ambitions of multinational oil companies, collaborations among European scientists, and regional surveying projects." While Daniel Immerwahr (2019) saw similar phenomena as leading to the establishment of a "pointillist" American empire, evoking also ideas of commercial imperialism, Barney (2014, 158–159) more explicitly makes the connection to mapping, whereby ". . . cartography was posited as a facilitating force for global development that could aid security and economic ideologies." Such linkages between security, resource exploration, infrastructure development, and US imperializing mapping initiatives are hardly surprising, as they date back to the US Navy's earliest attainment of aerial photographic capabilities (Campbell 2014). In the context of postwar realignment, however, the intensity and widespread nature of these associations are notable.

The US Navy's mapping projects and US commercial beneficiaries in late 1940s and early 1950s Saudi Arabia are a good example. There, in connection to airfield construction by the US Army Corps of Engineers at and around what was then the US-built and leased Dhahran Air Field (present-day King Abdulaziz Air Base) (Grathwol and Moorhus 2009) and in connection to the nearby oil explorations of majority-US-owned Aramco (Immerwahr 2019), VJ-62's Able (A) Detachment of five officers, 24 enlisted men, and one Liberator aircraft flew numerous cartographic missions in late 1952 (Grossnick 1995, 314). Between September and December of that year alone, the squadron logged 600 nautical-mile (1,111 km) round trips each day, totaling more than 16,000 km and 584 hours of flight (Naval Aviation News 1953). The oil-reserve potential of Dhahran, along with its strategic location for Soviet containment, was clearly worth this effort.

For Türkiye, the Truman Doctrine (1947), US Marshall Plan (1948), Point Four program (1949), and membership in NATO (1952), had already infused significant funds, in addition to the equipment and expertise described above; these policies of economic support extended to development of agriculture, industry, and infrastructure based on Türkiye's perceived "vitally strategic" nature in containing Soviet advances (U.S. Department of State 1949, 1; Hall 1999–2000, 67; Kuniholm 2001, 341–347; Atmaca 2014; Adalet 2018, 5; Luke 2019, 82–99). Türkiye's hope that its openness to reforms and contributions to defensive alliances would be matched by increased international support bore fruit (Simpson 1965, 142; Guvenc and Uyar 2022, 71). Significant US appropriations arrived through the Joint American Military Mission for Aid to Turkey (JAMMAT), and later the Joint US Military Mission for Aid to Turkey, and went directly to the Turkish Armed Forces; yet US companies increasingly won contracts to work on Turkish development projects. Contracts awarded by the US Department of State on generous terms and administered by the US Army Corps of Engineers funded, among other things, construction-equipment training for use in numerous projects (Grathwol and Moorhus 2009, 10–17). The detrimental effect of poor communication networks on defense was eventually acknowledged in Türkiye (Guvenc and Uyar 2022, 67; 72), leading to a cooperation between the Turkish Ministry of Public Works and the US Public Roads Administration (Kerwin 1950, 196–198; Karpat 1972; Livingston 1994; Adalet 2018). Improved roads would serve not just military but agricultural and industrial economic needs, too (Üstün 1997, 45).

Between 1950–1953 additional US support was allocated to the maintenance and construction of airfields, including existing facilities—at Bandırma, Erzincan, Balıkesir, Afyon, Kayseri, and Merzifon—as well as new ones in Diyarbakır, Eskişehir, and most importantly at İncirlik, Adana, all undertaken by Metcalf-Hamilton-Grove (an American joint venture) under the supervision of The United States Engineer Group, then based in Ankara, and part of the JAMMAT structure (Livingston 1994, 805; Grathwol and Moorhus 2009, 19–24). All told, this work resulted in the construction of two new bases and the rehabilitation of five existing ones, as well as work on fuel storage and distribution systems (Grathwol and Moorhus 2009, 26, 86).

Eisenhower's inauguration and Stalin's death in early 1953 brought new uncertainties for regional security, and a "New Approach" was developed for the Supreme Headquarters Allied Powers Europe (NATO 1976, vii–viii). One major component of the new plans, circulated in November 1953 and eventually approved in December 1954, concerned logistics and required the improvement or new development and safeguarding of lines of communication, port and storage facilities, and airfields that were deemed insufficient to the task of stopping a Soviet advance (NATO 1976, 23–24; 36–42; 69; 82). These projects included airfields in Bursa (Yenişehir), Adana, Manisa, and Erzurum; petrol, oil, and lubricant facilities to serve such airfields (e.g., storage and pipelines); VHF communication systems where topography allowed; and naval stations at Iskenderun in the northeastern Mediterranean, Marmaris and Izmir along the Aegean, and in the Black Sea (NATO 1953).

Development projects similar to these, as well as related cartographic missions of the US Navy, undoubtedly continued into the later 1950s, as suggested by VAP-62's large-scale imaging objective of 1957, focusing on the Cumaovası airfield in Izmir (Figures 3–4). Eventually, the US gave more than $5 billion in loans and grants to Türkiye between 1947 and 1968 for projects relating to industry and infrastructure, especially water-related infrastructure for hydropower, domestic water supply, and agricultural irrigation (Taylor 1976, 99–100; Luke 2019, 99–106). With Iran's (short-lived) nationalization of Anglo-Iranian Oil Company oil refineries at Abadan in 1953 and Egypt's nationalization of the Suez Canal in 1956 etched in recent memory (e.g., Luke and Leeson 2022), Türkiye's significance in preserving US military and commercial accesses to the Middle East and points further afield was likely never overlooked (Atmaca 2014, 21–25).

CONCLUSIONS

The US Navy's VAP-62 squadron continued working around the Atlantic for more than a decade following the last 1957 flights over Türkiye recorded in the current collection. By 1969, other priorities and squadron classifications had arisen, and VAP-62 was disestablished (Jax Air News 1969; Grossnick 1995, 314), its aircraft and crew reassigned or repurposed elsewhere. Already by the mid-1950s, US aerial photographic aims in and around Türkiye began to shift away from broad cartographic survey to tactical and intelligence-oriented imaging, a flexibility enabled by the establishment of the Türkiye-US Military Facilities Agreement signed in 1954 (Atmaca 2014, 27). As Dino Brugioni carefully outlines, it was from Türkiye, among other countries, that the US Central Intelligence Agency ordered the launch of Genetrix spy balloons in 1956, the same year it established the Incirlik Airfield in Adana as a base for U-2 operations, with its own Overseas Photo Interpretation Center (2010, 34–47; 140–147; 176–178; 270). In 1959 it was decided to place Jupiter missiles at Incirlik; in 1960 Gary Powers' made his ill-fated U-2 flight; and the ensuing history of events is well known by now.

Still comparatively poorly known are the US Navy's aerial surveys described above, and the imagery archive they left behind. The images in this archival collection, curated in the General Directorate of Mapping (and before that, the General Command of Mapping) of the Republic of Türkiye's Ministry of National Defense, as well as at least partially in the US National Archives, demonstrate the mutual interests that were served by the "special agreements" made between the US and peer NATO members. For Türkiye, "an agreement relating to mutual security" (UN 1954, 6 no. 2361) had already been established with the US on January 7, 1952, just before it joined NATO, tacitly paving the way for continuingly close collaborations (e.g., Budek 1956, 398–399; 440–441).

Following Türkiye's accession to NATO on 18 February 1952, it collaborated with the US Navy on this cartographic project over at least five years, and perhaps longer. Improved maps meant improved security planning and related infrastructure development. US dollars supported US agencies and contractors which not only participated in the work but also trained Turkish personnel to do the same. The intertwined NATO security and development projects, thus, were convincingly promulgated, with both Turkish and American benefits. That new American standards of cartographic practice and the power relationships they underlay were accepted in Türkiye in return for security guarantees, accurate documentation of Anatolian topography, understandings of economic geography, and improved regional communications is unsurprising. Similar symbiotic arrangements clearly pertained in other NATO-member circum-Mediterranean countries situated with strategic value for Soviet containment. What other seemingly mutual benefits may have been included in the arrangements that governed this work will have to await elucidation in future research.

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REFERENCES

Adalet, Begüm. 2018. *Hotels and Highways: The Construction of Modernization Theory in Cold War Turkey*. Stanford Studies in Middle Eastern and Islamic Societies and Cultures. Stanford, CA: Stanford University Press.

Atmaca, Ayşe Ömür. 2014. "The Geopolitical Origins of Turkish-American Relations: Revisiting the Cold War Years." *All Azimuth: A Journal of Foreign Policy and Peace* 3 (1): 19–34. **https://doi.org/10.20991/allazimuth.167319**.

Babington-Smith, Constance. 1957. *Air Spy: The Story of Photo Intelligence in World War II*. New York: Harper.

Barney, Timothy. 2014. *Mapping the Cold War: Cartography and the Framing of America's International Power*. Chapel Hill, NC: University of North Carolina Press.

Brookes, Andrew J. 1975. *Photo Reconnaissance*. London: Ian Allen.

Brugioni, Dino A. 2010. *Eyes in the Sky: Eisenhower, the CIA, and Cold War Aerial Espionage*. Annapolis, MD: Naval Institute Press.

Budek, Mieczyslaw. 1956. "Turkish Commercial Aviation." *Journal of Air Law and Commerce* 23 (4): 379–478.

Campbell, Douglas E. 2014. *Flight, Camera, Action! The History of U.S. Naval Aviation Photography and Photo-Reconnaissance*. Washington, DC: Syneca Research Group, Inc.

Cahill, William M. 2012. "Imaging the Empire: the 3rd Photographic Reconnaissance Squadron in World War II." *Air Power History* 59 (1): 12–19.

Chase, Joseph, Louis J. Cote, Wilbur Marks, Emanuel Mehr, Willard J. Pierson, Jr., F. Claude Rönne, George Stephenson, Richard C. Vetter, and Robert G. Walden. 1957. *The Directional Spectrum of a Wind Generated Sea as Determined from Data Obtained by the Stereo Wave Observation Project*. Technical report prepared for the Office of Naval Research under Contract NONR 285(03). New York: New York University. **https://doi.org/10.5962/bhl.title.39092**.

Chourchoulis, Dionysios. 2009. "High Hopes, Bold Aims, Limited Results: Britain and the Establishment of the NATO Mediterranean Command, 1950–1953." *Diplomacy & Statecraft* 20 (3): 434–452. **https://doi.org/10.1080/09592290903293779**.

———. 2012. "A nominal defence? NATO threat perception and responses in the Balkan area, 1951–1967" *Cold War History* 12 (4): 637–657. **https://doi.org/10.1080/14682745.2012.671297**.

———. 2015. *The Southern Flank of NATO, 1951–1959: Military Strategy or Political Stabilization*. Lanham, MD: Lexington Books.

Clarke, Keith C., and John G. Cloud. 2000. "On the Origins of Analytical Cartography." *Cartography and Geographic Information Science* 27 (3): 195–204. **https://www.doi.org/10.1559/152304000783547821**.

Cloud, John. 2001. "Imaging the World in a Barrel: CORONA and the Clandestine Convergence of the Earth Sciences." *Social Studies of Science* 31 (2): 231–251. **https://doi.org/10.1177/0306312701031002005**.

———. 2002. "American Cartographic Transformations during the Cold War." *Cartography and Geographic Information Science* 29 (3): 261–282. **https://doi.org/10.1559/152304002782008422**.

Cloud, John G., and Keith C. Clark. 1999. "Through a Shutter Darkly: The Tangled Relationships Between Civilian, Military and Intelligence Remote Sensing in the Early U.S. Space Program." In *Secrecy and Knowledge Production*, edited by Judith Reppy, 36–56. Cornell University Peace Studies Program, Occasional Paper 23. Ithaca, NY: Cornell University Peace Studies Program.

Cosgrove, Denis. 2001. *Apollo's Eye: A Cartographic Genealogy of the Earth in the Western Imagination*. Baltimore: Johns Hopkins University Press.

———. 2008. *Geography and Vision: Seeing, Imagining, and Representing the World*. London: I. B. Tauris & Co. Ltd.

Cosgrove, Denis, and William L. Fox. 2010. *Photography and Flight*. London: Reaktion Books.

Cossaboom, Robert, and Gary Leiser. 1998. "Adana Station 1943–45: Prelude to the Post-war American Military Presence in Turkey." *Middle Eastern Studies* 34 (1): 73–86. **https://doi.org/10.1080/00263209808701210**.

van Creveld, Martin. 1991. *Technology and War: From 2000 B.C. to the Present*. New York: Free Press.

———. 2011. *The Age of Airpower*. New York: Public Affairs.

Daston, Lorraine, and Peter Galison. 2007. *Objectivity*. New York: Zone Books.

De Landa, Manuel. 1991. *War in the Age of Intelligent Machines*. Cambridge, MA: MIT Press.

DeForge, Gerald T. 1981. *Navy Photographer's Mate Training Series: Naval Photography. Module 1. Naval Photography*. Pensacola, FL: Naval Education and Training Command; Naval Education and Training Program Development Center.

Doeppers, Daniel F. 1972. "An Incident in the PRRI/Permesta Rebellion of 1958." *Indonesia* 14: 182–195. **https://doi.org/10.2307/3350738**.

Dyce, Matt. 2013. "Canada between the photograph and the map: Aerial photography, geographical vision and the state." *Journal of Historical Geography* 39: 69–84. **https://doi.org/10.1016/j.jhg.2012.07.002**.

Edney, Matthew H. 2014. "Academic Cartography, Internal Map History, and the Critical Study of Mapping Processes." *Imago Mundi* 66 (1): 83–106. **https://doi.org/10.1080/03085694.2014.947853**.

El Hassan, Ismat Mohamed. 1978. "Metric Aspects of Reconnaissance Frame Photography." Ph.D. diss., University of Glasgow.

Erbaş, Mehmet. 2013. "Hava Fotoğrafı Arşivi Bilgi Sistemi [Aerial Photograph Archive Information System]." *Harita Dergisi* 150: 28–34.

Ertung, Özcan. 1970. "Hava Fotoğrafçılığının Öncüleri." *Harita Dergisi* 74: 81–90.

Evinay, Kerim. 1956 "Havadan Fotoğraf Alımı." *Harita Dergisi* 53: 13–68.

Ginter, Steve. 1992. *North American AJ-1 Savage (Naval Fighters Number 22).* Simi Valley, CA: Steve Ginter.

Goddard, George W., with Dewitt S. Copp. 1969. *Overview: A Life-Long Adventure in Aerial Photography*. Garden City, NY: Doubleday and Co.

Godlewska, Anne. 1989. "Traditions, Crises, and the New Paradigms in the Rise of the Modern French Discipline of Geography 1760–1850." *Annals of the Association of American Geographers* 27 (2): 192–213.

Grathwol, Robert P., and Donita M. Moorhus. 2009. *Bricks, Sand, and Marble. U.S. Army Corps of Engineers Construction in the Mediterranean and Middle East, 1947–1991*. Washington, DC: US Army Center of Military History and Corps of Engineers.

Grossnick, Roy A. 1995. *Dictionary of American Naval Aviation Squadrons, Volume I: The History of VA, VAH, VAK, VAL, VAP and VFA Squadrons*. Washington, DC: Naval Historical Center.

Guvenc, Serhat, and Mesut Uyar. 2022. "Lost in Translation or Transformation? The Impact of American Aid on the Turkish Military, 1947–60." *Cold War History* 22 (1): 59–77. **https://doi.org/10.1080/14682745.2020.1866551**.

Haffner, Jeanne. 2013. *The View from Above: The Science of Social Space*. Cambridge, MA: MIT Press. **https://doi.org/10.7551/mitpress/7878.001.0001**.

Hall, R. Cargill. 1999–2000. "From Concept to National Policy: Strategic Reconnaissance in the Cold War." *American Intelligence Journal* 19 (3/4): 63–75.

Harley, J. B. 2001a. "Maps, Knowledge, and Power." In *The New Nature of Maps: Essays in the History of Cartography*, edited by Paul Laxton, 51–81. Baltimore: Johns Hopkins University Press.

———. 2001b. "Silences and secrecy." In *The New Nature of Maps: Essays in the History of Cartography*, edited by Paul Laxton, 83–107. Baltimore: Johns Hopkins University Press.

Heiman, Grover. 1972. *Aerial Photography: The Story of Aerial Mapping and Reconnaissance*. New York: The Macmillan Co.

HGM Hava Fotoğrafı. 2023. "Analog Kamerayla Çekilmiş Hava Fotoğrafı." *Harita Genel Müdürlüğü*. Accessed March 3, 2023. **https://www.harita.gov.tr/urun/analog-kamerayla-cekilmis-hava-fotografi/161**.

Hong, Xin, and Christopher H. Roosevelt. 2023. "Orthorectification of Large Datasets of Multi-scale Archival Aerial Imagery: A Case Study from Türkiye." *Journal of Geovisualization and Spatial Analysis* 7: 23. **https://doi.org/10.1007/s41651-023-00153-1**.

Immerwahr, Daniel. 2019. *How to Hide an Empire: A History of the Greater United States*. New York: Farra, Straus and Giroux.

Jax Air News. 1952. "Photo Squadron 62 Commissioned Here." *Jax Air News* 10 (2). April 10, 1952.

———. 1969. "VAP-62 and VP-7 Slated for Decommissioning." *Jax Air News* 27 (27). September 25, 1969.

Kanbay, C. 1938. "Fotoğrametri ve Havadan Alınımış Fotoğraflardan Topoğrafların İstifadesi." *Harita Dergisi* 20: 30–33.

Kaplan, Caren. 2018. *Aerial Aftermaths: Wartime from Above*. Durham, NC: Duke University Press. **https://doi.org/10.1215/9780822372219**.

Karpat, Kemal H. 1972. "Political Developments in Turkey, 1950-70." *Middle Eastern Studies* 8 (3): 349–375.

Kerwin, Robert W. 1950. "The Turkish Roads Program." *Middle East Journal* 4 (2): 196–208. **http://www.jstor.org/stable/4322166**.

Kumral, Mehmet Akif. 2020. "The Affective Atmosphere of Ankara-Tehran Alignment in Cold War (1946–1979)." In *Exploring Emotions in Turkey-Iran Relations*, by Mehmet Akif Kumral, 119–182. Cham, CH: Springer International Publishing. **https://doi.org/10.1007/978-3-030-39029-7_3**.

Kuniholm, Bruce. 2001. "The Evolving Strategic Significance of Turkey's Relationship with NATO." In *A History of NATO: The First Fifty Years*, edited by Gustav Schmidt, 339–357. London: Palgrave Macmillan. **https://doi.org/10.1007/978-1-349-65573-1_20**.

Lieber, Albert C. 1954. "International Cooperation in Mapping." *Surveying and Mapping* 14: 71–74.

Livingston, Craig. 1994. "'One Thousand Wings': The United States Air Force Group and the American Mission for Aid to Turkey, 1947–50." *Middle Eastern Studies* 30 (4): 778–825. **http://www.jstor.org/stable/4283676**.

Luke, Christina. 2019. *A Pearl in Peril: Heritage and Diplomacy in Turkey*. Oxford: Oxford University Press. **https://doi.org/10.1093/oso/9780190498870.001.0001**.

Luke, Christina, and Madison Leeson. 2022. "UNESCO-UNDP Tourism and Security in Cold War Turkey and Iran. *Journal of Heritage Tourism*. 17 (6): 669–684. **https://doi.org/10.1080/1743873X.2022.2096457**.

Mahan, John H. 2003. "'EVERY MAN A TIGER': The RF-86A Sabre in Tactical Reconnaissance Operations during the Korean War, 1952–1953." *Air Power History* 50 (4): 30–37.

NAO. 1956. Naval Aeronautical Organization OPNAV NOTICE 05400 for Fiscal Year 1957 dated 20 November 1956.

———. 1958. Naval Aeronautical Organization OPNAV NOTICE 05400 for Fiscal Year 1959 dated 8 October 1958.

NATO. 1953. *Report by the Logistic and Materiel Planners to the Standing Group on the 1954 Common Infrastructure Program*. NATO Unclassified Archives. 1953-SG_173_32.

———. 1976. *History. Supreme Headquarters Allied Powers Europe. The New Approach, 1953–1956*. NATO Unclassified Archives. 3340/11-3/S/11/76.

Naval Aviation News. 1953. "Med Photo Plane Keeps Active." *Naval Aviation News* July 1953, 26.

———. 1953c. "'Glass Eyes' Map Secrets Of Enemy." *Naval Aviation News* December 1953, 9–11.

———. 1954. "AJ-2P Sets A New Record: VJ-62 Plane Piles Up Flight Time." *Naval Aviation News* January 1954, 14.

———. 1955. "Army Praises VJ-62 Work: Maps Greenland Ice for Engineers." *Naval Aviation News* April 1955, 18.

———. 1956a. "The World is their Camera Beat." *Naval Aviation News* January 1956, 31.

———. 1956b. "Photo Squadrons Re-Named: VCs and VJ's are Re-designated." *Naval Aviation News* August 1956, 14.

———. 1956c. "Ice Floes Ahead! Ships and Supplies Get through to Arctic Outposts Guided by Ice Forecasts Put Out by U.S. Navy Hydrographic Office." *Naval Aviation News* October 1956, 1–5.

———. 1958a. "VAP-62 Gets New Plane: Photo Skywarrior Arrives at JAX." *Naval Aviation News* January 1958, 36.

———. 1958b. "Clouds, Carbon and Change." *Naval Aviation News* October 1958, 20–23.

———. 1958c. "Cameras Are Their Weapons." *Naval Aviation News* November 1958, 7–12.

NTPC. 1962. *Photographer's Mate 2*. Navy Training Course. NavPers 10374-A. Instructional Standards of Materials Division of the Bureau of Naval Personnel. Memphis, TN: US Navy Training Publications Center.

Önder, Mustafa. 2002. *Geçmişten Günümüze Resimlerle Türk Haritacılığı / From Past to Present: The Illustrated History of Turkish Cartography*. Ankara: Harita Genel Komutanlığı.

Rankin, William. 2016. *After the Map: Cartography, Navigation, and the Transformation of Territory in the Twentieth Century*. Chicago, IL: University of Chicago Press. **https://doi.org/10.7208/chicago/9780226339535.001.0001**.

Redweik, Paula, D. Roque, A. Marques, R. Matildes, and F. Marques. 2010. "Triangulating the Past – Recovering Portugal's Aerial Images Repository." *Photogrammetric Engineering & Remote Sensing* 76 (9): 1007–1018. https://doi.org/10.14358/PERS.76.9.1007.

Rose, Leslie. 2007. *Power at Sea. Volume 3: A Violent Peace, 1945–2000*. Columbia, MO: Missouri University Press.

Saint-Amour, Paul K. 2011. "Applied Modernism: Military and Civilian Uses of the Aerial Photomosaic." *Theory, Culture and Society* 28 (7–8): 241–269. https://doi.org/10.1177/0263276411423938.

Schuster, Carl O. 2016. "Capturing Enemy Territory on Film." *Vietnam* 29 (1): 22.

Sekula, Allan. 1984. *Photography against the Grain: Essays and Photo Works, 1973–1983*. Halifax: Press of the Nova Scotia College of Art and Design.

Sichel, Kim. 2007. *To Fly: Contemporary Aerial Photography*. Seattle: University of Washington Press.

Simpson, Dwight J. 1965. "Development as a Process: The Menderes Phase in Turkey." *The Middle East Journal* 19 (2): 141–52. http://www.jstor.org/stable/4323847.

Sokolsky, Joel. 1991. *Seapower in the Nuclear Age. The United States Navy and NATO 1949–80*. London: Routledge.

Taylor, George, C., Jr. 1976. *Historical Review of the International Water-Resources Program of the U.S. Geological Survey 1940–70*. Geological Survey Professional Paper 911. Washington, DC: United States Government Printing Office. https://doi.org/10.3133/pp911.

Thomas, Geoffrey J. 1999. *Eyes for the Phoenix: Allied Aerial Photo-Reconnaissance Operations in South-East Asia 1942–1945*. Hants, UK: Hikoki Publications.

Truesdell, P. E. 1953. "Report of unclassified military terrain studies section." *Photogrammetric Engineering* 19 (3): 468–472.

UN. 1954. "International Agreement No. 2361." *Statement of Treaties and International Agreements Registered or Filed and Recorded with the Secretariat during November 1953*. ST/LEG/SER.A/Sl, 6.

Üstün, Senem. 1997. "Turkey and the Marshall Plan: Strive for Aid." *Turkish Year Book of International Relations* 27: 31–52. https://doi.org/10.1501/Intrel_0000000254.

U.S. Department of State. 1949. *Policy Statement*. Washington DC, May 5, 1949.

U.S. Navy Patrol Squadrons. 2024a. "VAP-62 History." Accessed May 16, 2024. https://www.vpnavy.org/vap62_history.html.

———. 2024b. "VJ-62 History." Accessed May 16, 2024. https://www.vpnavy.org/vj62_history.html.

Virilio, Paul. 1989. *War and Cinema: The Logistics of Perception*. London: Verso.

Weidick, Anker. 1958. "Frontal Variations at Upernaviks Isstrøm in the Last 100 Years." *Meddelelser fra Dansk Geologisk Forening* 14 (1): 52–60.

Wood, Denis, and John Fels. 1992. *The Power of Maps*. New York: Guilford Press.

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Ambient Occlusion for Terrain Shading

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Ambient occlusion is widely used in computer graphics to accentuate areas in a three-dimensional scene that are hidden from bright lighting. On maps, ambient occlusion adds spatial depth and nuanced texture to shaded relief images. Ambient occlusion images for maps can be calculated from digital elevation models using the Eduard relief shading application. This paper illustrates the use of ambient occlusion for cartographic terrain shading and introduces two extensions: (1) oriented ambient occlusion for modulation with a direction of illumination, and (2) reduced ambient occlusion for valley bottoms with consistent brightness.

INTRODUCTION

Ambient occlusion is widely used in video games and other graphics applications to add depth to computer-generated three-dimensional scenes. This article describes the application of ambient occlusion for terrain shading to enhance subtle details of a terrain surface. The best results are produced by combining ambient occlusion with traditional shaded relief images; the occlusion layer adds a nuanced texture that accentuates narrow drainages and other terrain features that are occluded from lighting (Figure 1). Ambient occlusion works best with detailed high-resolution elevation models for shaded relief at large and medium scales.

Ambient occlusion is added at the end of the rendering procedure. After a two-dimensional shaded image is computed, ambient occlusion calculates an occlusion value for each pixel that locally darkens the image.

In the time since Bavoil, Sainz, and Dimitrov (2008) introduced a computationally efficient method for ambient occlusion, many extensions to their algorithm have been proposed, but all extensions are variations of the following concept: for each pixel in an image, a search is conducted for occluding objects within a hemisphere centered on the corresponding location in the three-dimensional scene. If there are occluding objects around this location, the brightness of the pixel is reduced; if there are no occluding objects, the brightness of the pixel is unaltered.

Applying this concept to cartographic terrain shading, imagine a pixel in the bottom of a narrow valley. This pixel is surrounded by many occluding terrain elements like valley slopes and mountain ridges, resulting in a high ambient occlusion value. In contrast, a pixel on an exposed mountain ridge has neighboring terrain elements that are either located at elevations lower than the pixel's elevation or at distances exceeding the radius of the hemisphere. No other terrain elements occlude the pixel on the mountain ridge, so its brightness is not reduced.

All terrain visualizations in this article were created with Eduard (**eduard.earth**), a software application for producing shaded relief, ambient occlusion shading, and other types of cartographic terrain visualizations. Once these have been generated, Eduard can combine them with a variety of blending modes, masks, and adjustment curves. Eduard has a convenient, user-friendly interface for adjusting ambient occlusion parameters (Figure 2).

This article is structured as follows: The following section discusses the concept of ambient occlusion calculation. The article then introduces oriented ambient occlusion modulated with a direction of illumination and discusses a method for reducing ambient occlusion in flat areas. Appendix A provides details about the algorithm of the latter method.

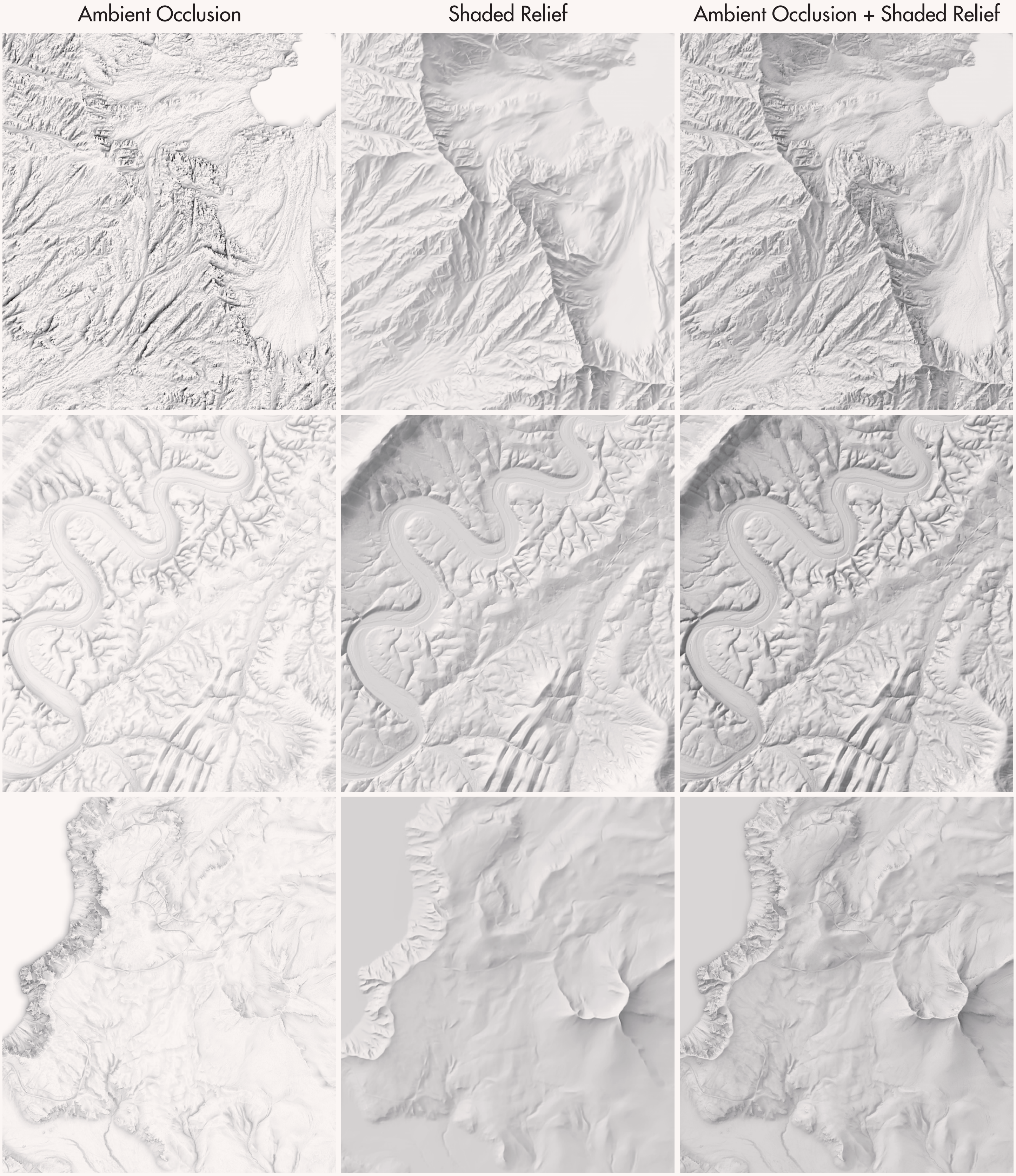

Figure 1. Ambient occlusion combined with shaded relief images. From top to bottom: Gore Range, Colorado (1 meter resolution); Massanutten, Virginia (10 meter); and Crater Lake, Oregon (3.3 meter). Elevation models from Kennelly et al. (2021).

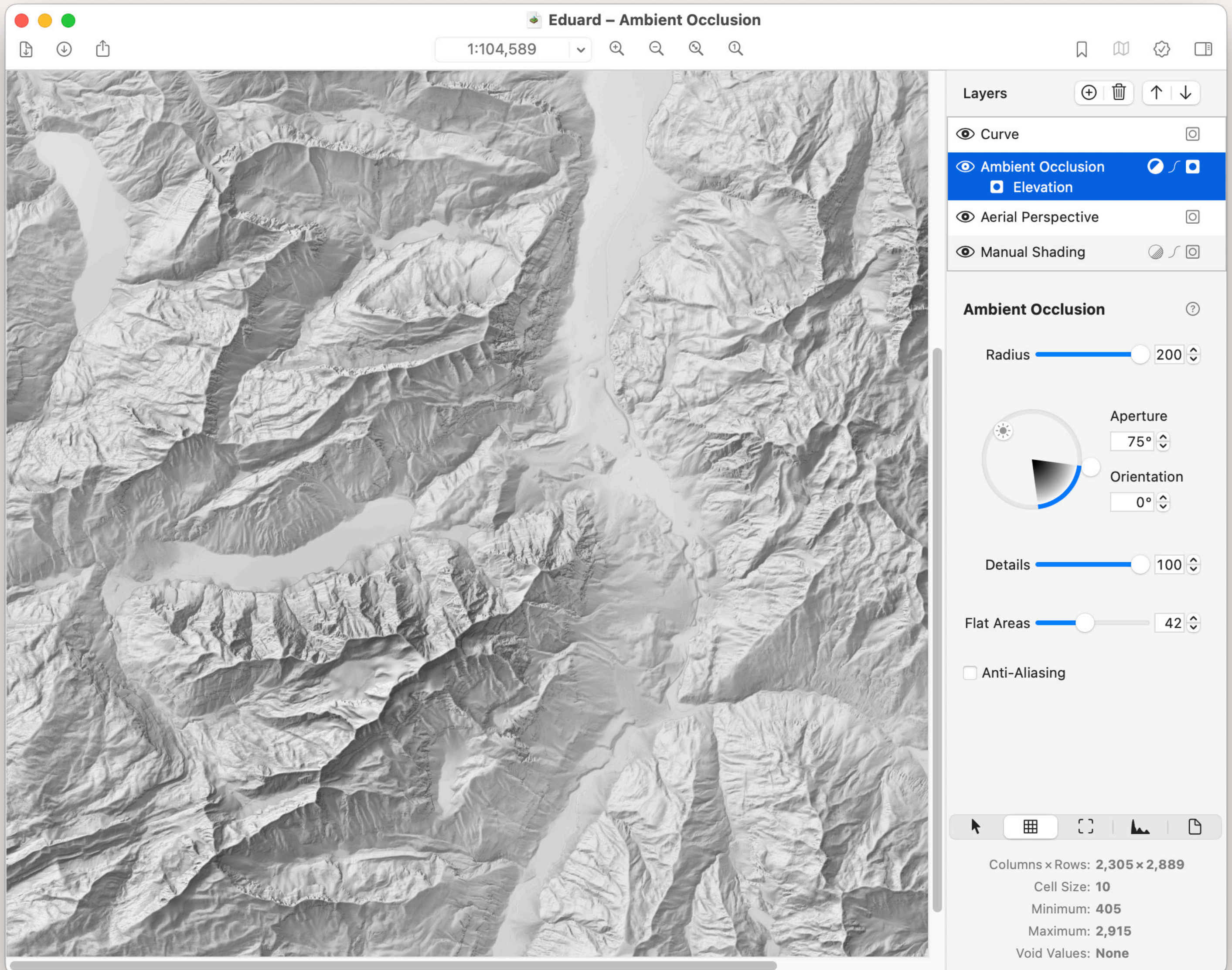

Figure 2. Rendering and combining ambient occlusion and shaded relief layers with Eduard. Adjustable ambient occlusion parameters include (in the sidebar on the right side) scan radius, aperture angle and direction for oriented ambient occlusion, amount of terrain details, reduction of ambient occlusion in flat areas to prevent dark valley bottoms, and anti-aliasing. swissALTI3D elevation model of Glarus by swisstopo downsampled to 10-meter resolution.

COMPUTING AMBIENT OCCLUSION

When rendering ambient occlusion for an orthographic shaded relief, the algorithm starts with a white image that is to receive ambient occlusion. The algorithm visits each pixel and repeatedly decreases the brightness of the pixel when an occluding object is found. To search for occluding objects, elevation values are sampled along radially arranged rays (Figure 3, left). Along each ray, elevation is extracted from the elevation model at a series of sampling points to determine whether that elevation is occluding the central pixel.

Various heuristics for choosing a sampling distance along the rays are possible. A constant sampling distance equal to the cell size of the elevation model results in visually pleasing images. Elevation values are sampled with bilinear interpolation.

Experiments with various numbers of radial rays found that for terrain shading, 20 rays with an angular spacing of 360° ÷ 20 = 18° produce smooth visual results. Fewer sampling rays can result in visual noise.

The scan radius *r* is the primary parameter when computing an ambient occlusion image. As illustrated in Figure 4, a short scan radius accentuates narrow valleys and escarpments, whereas a long scan radius darkens the slopes of larger valleys and adds a grayscale gradient to valley bottoms.

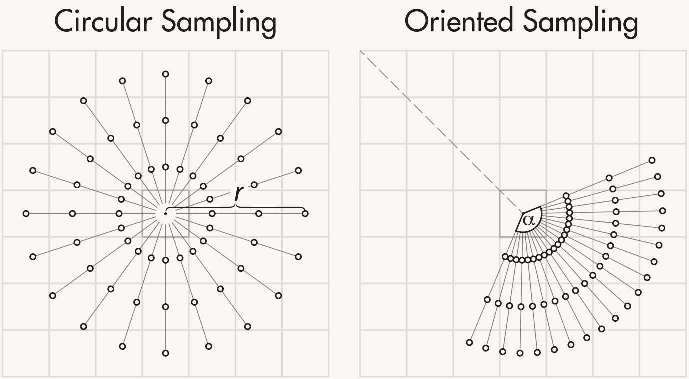

Figure 3. Orthographic top-down view of an elevation model. The small circles are the sampling points for computing ambient occlusion for the central pixel. This example has 20 sampling rays and a scan radius *r* equal to three grid cells. Left: circular sampling. Right: oriented sampling with an aperture angle α of 135° oriented along a top-left illumination direction indicated by the dashed line.

To determine whether a sampled elevation is occluding the central pixel, the vertical gradient of the line connecting the elevation at the central pixel with the elevation of the sample point is compared to the vertical gradient of the line to the previously sampled position. If the new gradient is greater than the previous gradient, then the new position is occluding the central pixel and its brightness value is reduced. The amount of brightness reduction is proportional to the vertical elevation distance between the new and previous elevation, multiplied by an attenuation factor that decreases the occlusion effect of distant elevations. Additional details about the algorithm can be found in the presentation and conference abstract by Bavoil, Sainz, and Dimitrov (2008).

ORIENTED AMBIENT OCCLUSION

Conventional ambient occlusion scans the area around each pixel in a circular pattern to detect occluding objects (Figure 3, left). This results in ambient occlusion images that are invariant to the direction of illumination (Figure 5, top left).

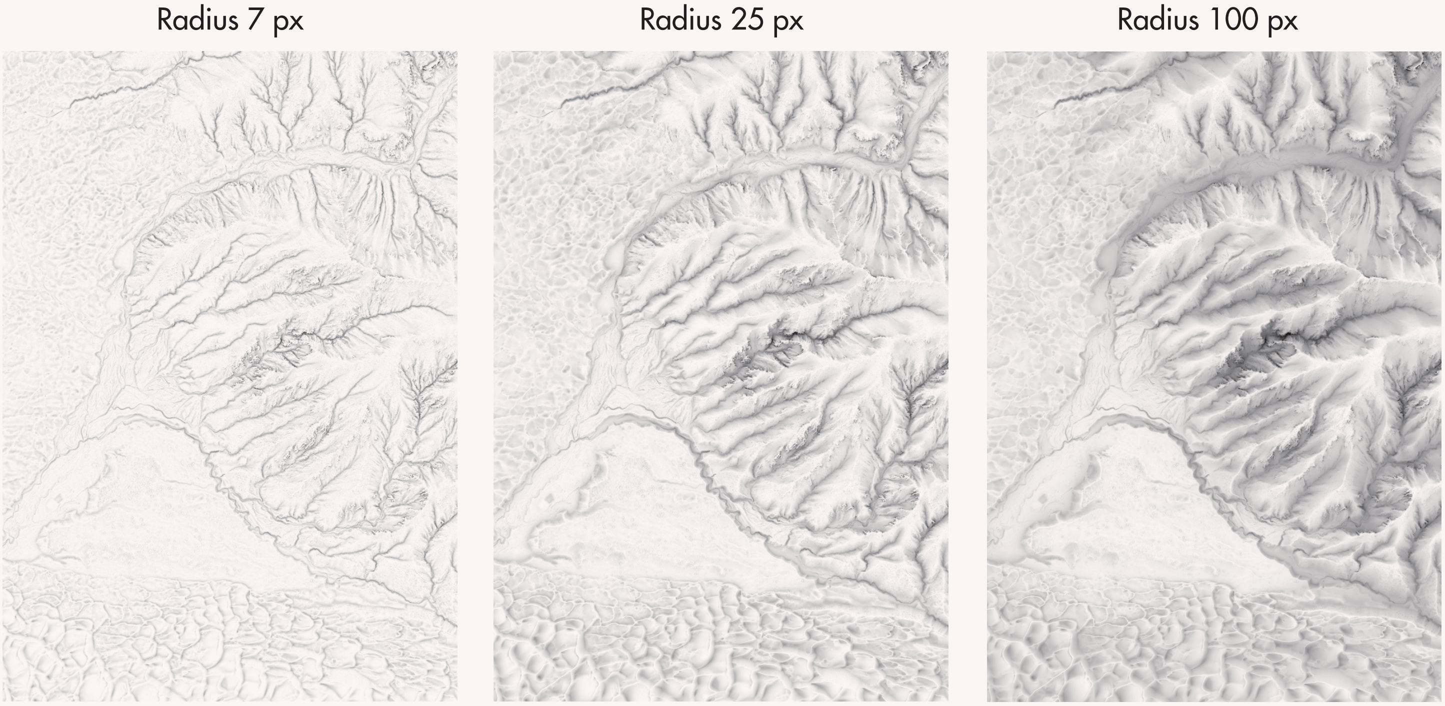

Figure 4. Ambient occlusion with a scan radius of 7 (left), 25 (middle), and 100 pixels (right). Great Sand Dunes, Colorado, 3.3-meter elevation model from Kennelly et al. (2021).

Alternatively, ambient occlusion can be modulated with a direction of illumination, in which the sampling rays are laid out in a fan-like arrangement (Figure 3, right). The example in Figure 3 applies a standard illumination direction for shaded relief from the top left, indicated by the dashed line. The rays radiate accordingly around the opposing direction towards the bottom right. The aperture angle α in this example is 135°. The aperture angle and the orientation of the radiating rays can be adjusted to any direction of illumination.

The resulting ambient occlusion image is shown in the bottom left of Figure 5. Compared to the ambient occlusion image with a circular 360° arrangement (Figure 5, top left), the brightness contrast with oriented ambient occlusion is stronger. Narrow valleys, gullies, and rock structures are more strongly accentuated. With oriented ambient occlusion, shades on valleys slopes are lopsided; slopes with a northwest exposure remain bright, whereas slopes with a southeast exposure are darkened.

In the right column of Figure 5, the two ambient occlusion images are combined with a shaded relief generated by a neural network imitating manual relief shading (Jenny et al., 2020). A moderate amount of aerial perspective is also applied (Jenny and Patterson, 2021). Both blended images contain informative texture details, but the image with the 360° arrangement lost some of the original shading's clearly structured illuminated and shaded slopes because illuminated slopes of main landforms are darker (Figure 5, top right). The combination of shaded relief with oriented ambient occlusion (Figure 5, bottom right) shows a stronger contrast between illuminated and shaded slopes of large landforms and more clearly accentuates narrow drainages and other terrain details.

REDUCED AMBIENT OCCLUSION FOR FLAT AREAS

Standard ambient occlusion can result in flat plains and lakes with varying brightness, which can be visually pleasing for waterbodies or wide valley bottoms. However, it can also be distracting when bright flat plains transition into narrow valleys, which are rendered considerably darker. Additionally, dark valley bottoms are likely to reduce the visual contrast with overlaying map features and result in a map that is difficult to read. An example of a dark valley bottom can be seen in Figure 4 (right). Figure 6 (top) is an example of an alpine lake that is excessively dark.

Dark valley bottoms can be brightened by applying an adjustment curve with a mask for flat areas, but reliably identifying coherent flat valley bottoms with an algorithmic method is surprisingly difficult. Adjusting the ambient occlusion algorithm can reduce the darkening of valley bottoms. The dark flat surfaces result from occluding sampling points that are both high relative to the valley bottom and close to the flat valley. Appendix A introduces a computational method that decreases the occluding effect of elevations that are (a) particularly high when compared to the elevation of a flat plain, and (b) particularly close to a flat plain. Figure 6 (bottom) illustrates the effect of this adjustment. Figure 2 shows a larger geographic extent of the same region at a slightly different scale rendered with a combination of shaded relief and an ambient occlusion image with reduced occlusion in flat areas.

CONCLUSION

Computation time for calculating ambient occlusion is fast with a graphics card because it can be calculated simultaneously for multiple pixels. For example, calculating ambient occlusion for an elevation model of 5,000 × 5,000 pixels with a radius of 30 cells and 20 scanning rays takes less than one second on an Apple Mac computer with an M1 chip.

As illustrated by the figures in this article, combining ambient occlusion with shaded relief enhances subtle and nuanced terrain details, which is most effective at large and medium scales. A detailed high-resolution elevation model is required to accentuate small details, such as narrow drainages and rock escarpments, which especially benefit from ambient occlusion. Oriented ambient occlusion is useful to preserve contrast between illuminated and

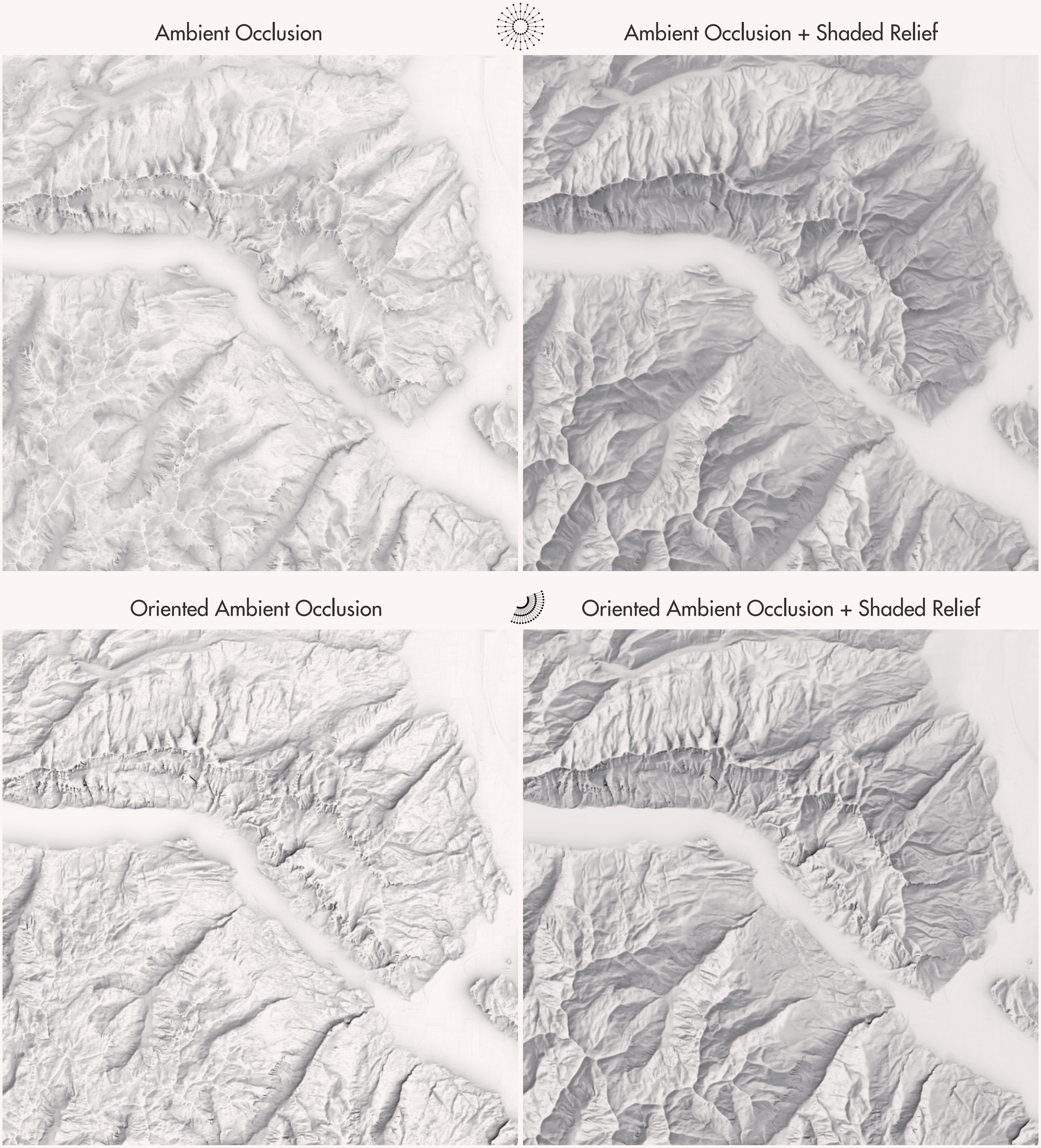

Figure 5. Ambient occlusion with a 360° scan angle (top row) and oriented ambient occlusion with a 135° scan angle with a northwest illumination orientation (bottom row). Ambient occlusion images are combined with a shaded relief (right column) with the multiply blending mode. A curves adjustment compensates for the darkening of the multiply blending mode. Churfirsten, Switzerland, 30-meter elevation model from Kennelly et al. (2021).

shaded slopes of large landforms and accentuate valleys, while adjusting the ambient occlusion for flat areas avoids dark valley bottoms with irregular brightness. Eduard is a tool that can efficiently produce ambient occlusion and shaded relief images that are visually pleasing and effective.

ACKNOWLEDGEMENTS

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DISCLOSURE STATEMENT

The author is one of the developers of the Eduard app. He does not receive any financial benefit from the sales of Eduard.

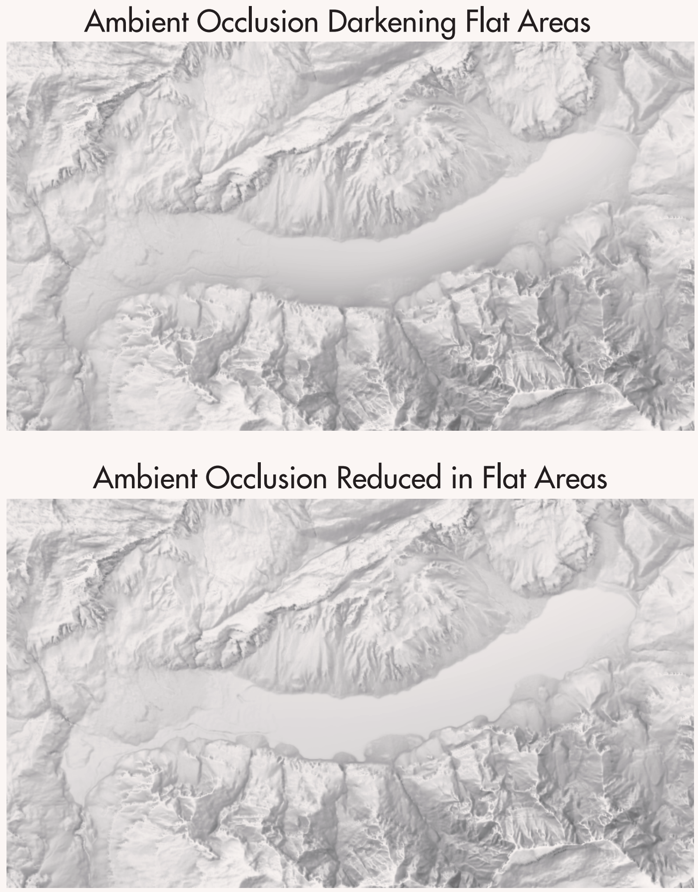

Figure 6. Ambient occlusion darkening a lake and a valley bottom (top); ambient occlusion reduced in flat areas (bottom). Scan radius r = 200 pixels, aperture angle α = 200°. Klöntalersee, Switzerland, swissALTI3D elevation model by swisstopo downsampled to a 10-meter resolution.

REFERENCES

Bavoil, Louis, Miguel Sainz, and Rouslan Dimitrov. 2008. "Image-space Horizon-based Ambient Occlusion." SIGGRAPH 2008, Los Angeles, California, August 11–15, 2008. New York: Association for Computing Machinery. **https://doi.org/10.1145/1401032.1401061.**

Jenny, Bernhard, Magnus Heitzler, Dilpreet Singh, Marianna Farmakis-Serebryakova, Jeffery Chieh Liu, and Lorenz Hurni. 2020. "Cartographic Relief Shading with Neural Networks." *IEEE Transactions on Visualization and Computer Graphics* 27 (2): 1225–1235. **https://doi.org/10.1109/TVCG.2020.3030456.**

Jenny, Bernhard, and Tom Patterson. 2021. "Aerial Perspective for Shaded Relief." *Cartography and Geographic Information Science* 48 (1): 21–28. **https://doi.org/10.1080/15230406.2020.1813052.**

Kennelly, Patrick J., Tom Patterson, Bernhard Jenny, Daniel P. Huffman, Brooke E. Marston, Sarah Bell, and Alexander M. Tait. 2021. "Elevation Models for Reproducible Evaluation of Terrain Representation." *Cartography and Geographic Information Science* 48 (1): 63–77. **https://doi.org/10.1080/15230406.2020.1830856.**

Shary, Peter A., Larisa S. Sharaya, and Andrew V. Mitusov. 2002. "Fundamental Quantitative Methods of Land Surface Analysis." *Geoderma* 107 (1–2): 1–32. **https://doi.org/10.1016/S0016-7061(01)00136-7.**

APPENDIX A: ALGORITHM FOR REDUCED AMBIENT OCCLUSION IN FLAT AREAS

This appendix provides details about the algorithm for reducing ambient occlusion in flat areas to prevent valley bottoms from becoming excessively dark. Ambient occlusion by Bavoil, Sainz, and Dimitrov (2008) is attenuated for pixels in flat areas and pixels occluded by close elevations.

The notation follows the presentation by Bavoil, Sainz, and Dimitrov (2008), slide 24, "Per-Sample Attenuation." The recording of their SIGGRAPH 2008 presentation, available as supplementary material to their paper, is recommended for an introduction to the ambient occlusion algorithm. The presentation contains diagrams that illustrate the various components of ambient occlusion computation.

The amount of per-pixel darkening for regular ambient occlusion *WAO* is initialized with *WAO* = 0, and *WAO* is increased each time an occluding surface point is found when stepping along a scan line (Equation 1).

$$WAO \mathrel{+}= W(S_2) \cdot (AO(S_2) - AO(S_1)) \quad (1)$$

Equation 1 was proposed by Bavoil, Sainz, and Dimitrov (2008). S_1 is the last sample point that was found to occlude the pixel, and S_2 is the current sample point that is occluding the pixel. $AO(S_1)$ and $AO(S_2)$ are the ambient occlusions contributed by S_1 and S_2. $W(S_2)$ is the attenuating weight applied to the difference between $AO(S_1)$ and $AO(S_2)$. Equations for $AO(S_1)$, $AO(S_2)$, and $W(S_2)$ can be found in the presentation by Bavoil, Sainz, and Dimitrov.

Equation 1 is extended with an additional dimensionless attenuation factor *f*, which incorporates a measure of flatness nearby the pixel under consideration (Equation 2).

$$WAO \mathrel{+}= (W(S_2) \cdot (AO(S_2) - AO(S_1))) \div \mathrm{f}, \text{ and } \mathrm{f} \geq 1 \quad (2)$$

The attenuation factor *f* equals 1 when the slope at the central pixel is steeper than a user-definable gradient threshold G_{max}, or when the occluding sample point S_2 is farther away than a user-definable distance threshold D_{max}.

What follows is a description of the calculation of the attenuation factor *f*. One can first apply a Gaussian blur filter with σ = 1 to the elevation model. The gradient *G* at the central pixel is then computed from the blurred elevation model (Shary, Sharaya, and Mitusov 2002) and normalized with the gradient threshold parameter G_{max} to obtain a normalized gradient *g* between 0 and 1 (Equation 3). Note that the normalized gradient *g* is computed for the central pixel and does not vary along the sampling ray.

$$g = G \div G_{max}, \text{ and } g \leq 1 \quad (3)$$

A normalized distance value *d* between 0 and 1 is computed from the distance *D* between the central pixel and the occluding sample point S_2. D_{max} is the threshold parameter for the distance (Equation 4).

$$d = D \div D_{max}, \text{ and } d \leq 1 \quad (4)$$

The normalized gradient and the normalized distance are combined (Equation 5).

$$w = \sqrt{g^2 + d^2}, \text{ and } w \leq 1 \quad (5)$$

In Equation 5, *w* is a dimensionless weight that is limited to a maximum value of 1. If *w* is close to 0, the occluding elevation is close to the central pixel and the central pixel is flat; if *w* is close to 1, the occluding elevation is far away and/or the slope at the central pixel is far from being flat. The attenuation factor *f* is finally computed with a linear mapping and a user-definable attenuation parameter *a* using Equation 6. The attenuation factor *f* reduces normal ambient occlusion if the pixel is in a flat area or if there are occluding elevations close to the pixel.

$$f = a - (a - 1) \cdot w, \text{ and } f \geq 1 \quad (6)$$

There are three user-definable parameters (G_{max}, D_{max}, *a*) for this calculation. G_{max} is the gradient threshold; for pixels with a slope flatter than G_{max}, the ambient occlusion is reduced. D_{max} is the distance threshold; occluding elevations closer than D_{max} result in a reduced ambient occlusion. The attenuation parameter *a* controls how much the brightness of flat areas is adjusted. To simplify the graphical user interface for controlling the adjustment of flat areas, G_{max} and D_{max} can be derived from *a* with: $G_{max} = \tan^{-1}(2a)$ and $D_{max} = r/2$, where is *r* the scan radius. These heuristics simplify the user interface to a single adjustable value and produce satisfactory results.

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A Synesthete's Atlas: Real Time Cartography in Performance

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It's coming up on the one-year anniversary of the premiere performance of my *A Synesthete's Atlas* project, so *Cartographic Perspectives*'s invitation to reflect on how it came to be, and how it's playing out, is timely, apt, and welcome. As I draft this article I've finished touring it up and down Colorado's Front Range and am headed to the Midwest, where I'll give my **first museum performance**, among others.

A Synesthete's Atlas gestated through two artist residencies:[1] at Signal Culture, in the isolated, Rust Belt town of Owego, New York,[2] and at Hangar, in the vibrant, multicultural Graça district of Lisbon, Portugal. Hangar, a "center for artistic investigation," skews toward post-colonial and Global South artists, hosting eight international artists at a time, offering modest live/work spaces, a painting and sound studio, a wet darkroom, and a general-purpose performance space. Two top-floor studios offer always-inspiring views.

I arrived with three map-related projects I planned to work on. This article focuses on the one that evolved into *A Synesthete's Atlas*, but touches on all three.

An unfiltered view from Hangar's Studio 6. Sandstorms in Northern Africa caused the Lisbon sky to take on this color for a few days. Photograph by the author.

1. Res Artis provides a searchable database of member artist residency programs worldwide at **resartis.org**.

2. **Signal Culture** has relocated to Loveland, CO, and is in the process of rebooting its studios and residency programs as I write this.

LESSONS LEARNED FROM EXPERIMENTAL FILM

The art form I've most closely identified with over the decades is experimental film. I'd loved cartoons since childhood, had, as an undergraduate, stumbled into *Trickfilm*, a multi-week festival of sophisticated international animation at the Art Institute of Chicago's Film Center, and yearned to find a venue for seeing similar work going forward. Chicago Filmmakers answered that call, and in so doing provided me with an informal introduction to contemporary and historical experimental film. My only formal education was taking a pair of animation courses at the School of the Art Institute as electives at the end of my undergraduate business school education at Loyola University Chicago.[3] Over the years I've made a handful of 16mm films and curated cinema programs for a variety of institutions, while also serving on boards of directors, and on grant-giving juries.

Frames from *Serene Velocity* (1970). © Ernie Gehr. Image courtesy the filmmaker.

16mm filmmaking is expensive and error-prone, as were the other antiquarian media I chose for my own artmaking (copperplate photogravure anyone?[4]). Fast forward to the mid-2010s, by which time I'd taught multiple incarnations of *Mapping as a Creative Strategy* at colleges and art centers, and had been doing freelance development using open geographic data and open source software: the realization hit me that the tools I was using for web mapping were tools that could be used to create a peculiarly constrained form[5] of experimental animation.

I gave a presentation in Washington, DC, at State of the Map-US 2014 called "**Lessons Learned from Experimental Film**." After reviewing the notion of *structural film* (Sitney 1969), I talked about how one film (*Serene Velocity*, by Ernie Gehr) and three filmmakers' strategies (Paul Sharits, Robert Breer, and Paul Glabicki) might be interpreted using digital cartography.

Ernie Gehr's *Serene Velocity* (1970) is set in a long institutional corridor having a green-gray tint. The camera alternates between fixed zoom positions, four frames taken per position, gradually stepping from subtle differentials to what feels like being slammed from one end to the other of the long hallway. One of the interesting things about the film is that even with the strong depth cues the screen space can flatten completely as the objects along the hallway (illuminated hot spots and shadows, ash trays, doorways) realign and confuse the visual perception system. For my presentation I used TileMill to create a tileset centered on Washington DC's Scott Circle. The radiating avenues of L'Enfant's city design produced similar illusions to *Serene Velocity*'s when subjected to a progression of rapidly alternating zooms, increasing in range.

3. To shed light on my abilities to write software, work with probability distributions, and analyze data, I'll note that I went on to get M.S. and Ph.D degrees in Operations Research from the Industrial Engineering and Management Sciences Department at Northwestern University.

4. Copperplate photogravure is an intaglio printmaking method used to produce high quality, continuous-tone photographic editions; its heyday was the late nineteenth and early twentieth centuries, but it continues to be practiced by artisans: **photogravure.com**.

5. My celebration of constraints derives from the Ouvroir de littérature potentielle (**Oulipo**); co-founder Raymond Queneau described Oulipians as "rats who construct the labyrinth from which they plan to escape."

Paul Sharits was a leader in the development of the color flicker film. Film frames of solid, saturated color might occupy the screen for 1/12th of a second before changing to a contrasting color. These optics, combined with repetitive soundtracks in many of Sharits's films, conspire to fatigue the eyes and ears, producing illusory colors and syllables.

Robert Breer's deceptively simple hand-drawn animations do many things well. One strategy used across his films was to create separate sequences of believable motions—a train conductor walking the aisle, validating tickets; a conical coffee cup rolling across a flat surface; hexagonal beams rotating on to and off of the screen—that carved out specific spatial expectations and behaviors. He then would interleave these sequences to create hybrid spaces with conflicting perspective cues.

Paul Glabicki, a generation younger than Breer, also created hand-drawn animation, but his were composed of dense diagrams, done in a technical drafting style, sometimes

Sequence from *Fuji*, 1974. 15 cartons de 10 × 15 cm. Crayons couleur, peinture à la bombe. 79 × 79 cm.
Courtesy: Kate Flax, gb agency, Paris

incorporating templates and Letraset rub-on type into scenarios of his own creation. Works such as *Film-Wipe-Film* benefit from repeated, analytical viewings. One strategy I'll highlight is his rendering of a recognizable object—the appearance of a simple chair, drawn in severe perspective—that then disintegrates into constituent lines that explode or slide down the screen, diminishing into smaller segments and points, vanishing completely, before cyclically reconstituting itself.

Unlike the *Serene Velocity* touchstone, I had no implementation to show for Sharits, Breer, or Glabicki. I proposed that Sharits' rapid color shifts could be applied to geographic layers, that Breer's interleaving could superimpose different locations/rotations, and that Glabicki's polygonal deconstructions could dematerialize OSM's *relations* and *ways*.

At the time of SotMUS 2014 I was weathering the fallout from being encouraged to "quit my job and come work for" a certain studio. I delivered on the former; the studio did not come through on the latter. I'd been given a tentative start date and signed an NDA, but foolishly relied on a handshake agreement, not a contract. Devastating. I set aside my lessons learned from experimental film and lost a few years picking apart the lessons of what can charitably be called "pranking."

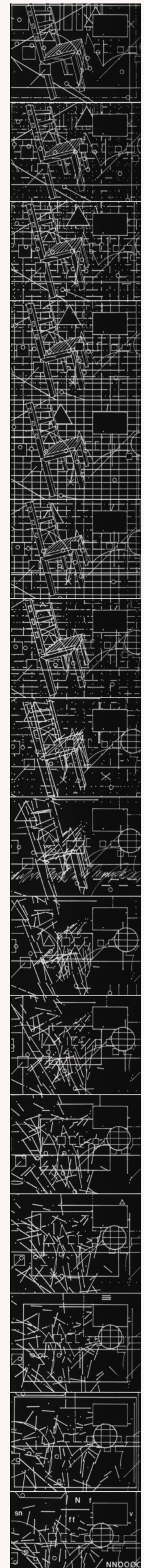
A FIRST IMPLEMENTATION

I'D HELD A FEW ARTIST RESIDENCIES, AND was familiar with researcher residencies, but it was a revelation to learn about the Toolmaker-in-Residence (TiR) program at Signal Culture. A unique opportunity, it seemed a perfect fit when I was ready to return to this project. I was awarded this residency in 2018 and 2019, each a two week stint.

As I've never had an organizational affiliation that gave me access to Esri products, my digital mapmaking stack has always been built on open source tools. In the timeframe discussed here, my preference for Leaflet coupled with TileMill/Mapnik (raster tiles) yielded to Mapbox GL JS coupled with hand-coded stylesheets occasionally supplemented by sessions with Mapbox Studio and Maputnik (vector tiles). At present I use MapLibre, a fork of Mapbox GL JS from when its licensing was at its most permissive. These toolchains were satisfactory for my freelance work but for my personal work I began to crave new ways to manipulate map styles and parameters: to quickly shuffle and surprise myself with color, zoom, bearing, pitch, labels, and movement. I wanted rapid prototyping with options to **give up** control.

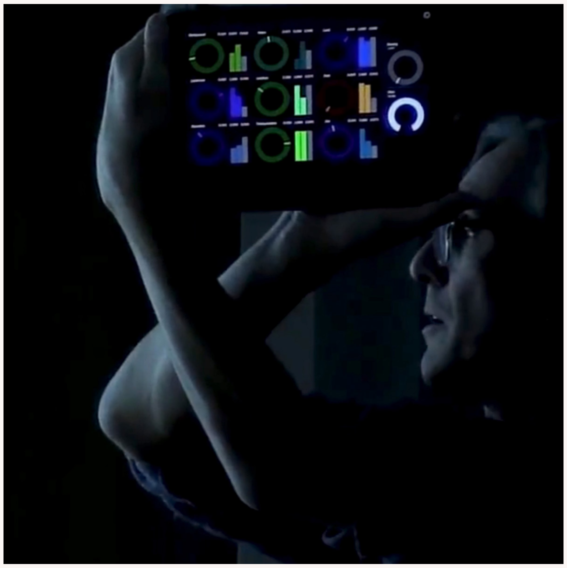
During my first Signal Culture TiR stint, I began working with Lemur. In the early 2000s, the Lemur was a high-end, multi-touch device for controlling musical instruments. The hardware was discontinued in 2010 but the software evolved into iOS and macOS apps that could be used to construct touch interfaces running on tablets or phones. Although the software company Liine gladly accepted my money via the Apple Store, it soon became apparent that I'd purchased abandonware. For example, the built-in editor was rendered inoperable simply by connecting an external monitor to my laptop.[6]

Still, I was able to cobble together hardware (iPad, MacBook Pro), software (Lemur, Mapbox GL JS, TinyColor, a few hundred lines of JavaScript), and data (metro extracts from OpenStreetMap converted to MBTiles format, *ad hoc* GeoJSON fragments) in order to develop proofs-of-concept for creating single channel, map-based experimental videos



Sequences from *Film-Wipe-Film* (1983). © Paul Glabicki. Images courtesy iotaCenter and the filmmaker.

6. **MIDI Kinetics** acquired Lemur in early 2023 and has plans to revive it.



The author presenting the Lemur implementation of Carto-OSC at Cornell University's Kroch Library.

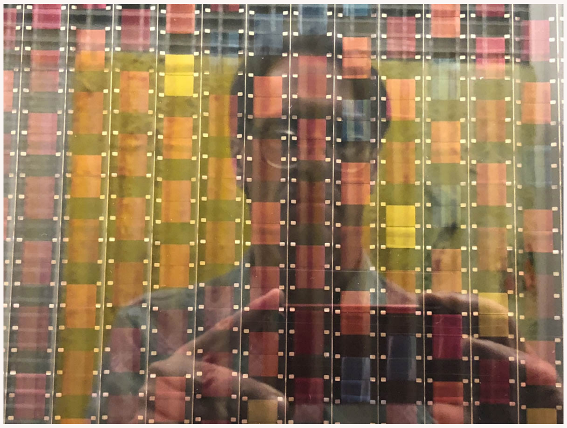
and the rapid prototyping tool outlined earlier. I presented these implementations at Cornell University's Kroch Library[7] shortly after my residency concluded. That audience—a mix of people coming from geospatial, filmmaking, arts and architecture, data science, and web technology backgrounds was supportive, inquisitive, and enthusiastic, and asked questions that I still refer to today as a reality check. I believe that the Cornell talk was where I first publicly referred to my platform as *Carto-OSC*, and first proposed using it for "map jockeying."

I had a handful of significant experimental film experiences during my first sojourn in Owego. Prior to my TiR I visited the Paul Sharits Collection at the Burchfield Penney Art Center Archives[8] in Buffalo. Videos I presented at Cornell were structured around maps whose rapidly changing layer colors were taken, via a Python script, from TIFF files of Sharits's *Frozen Film Frame Series* provided by the Archives. I began my trip by flying into Boston in order to attend the opening of *Introducing Tony Conrad: A Retrospective* held at both MIT's List Visual Arts Center and Harvard's Carpenter Center for the Visual Arts; Conrad being another flicker film pioneer as well as a minimalist composer/performer. And like any good experimental filmmaker I made a pilgrimage to the hallway at Binghamton University where *Serene Velocity* was filmed.

OSC THREE WAYS: SOUND, STAGE, AND CARTO-

I've not yet talked about how parameters set on the iPad touch surface are translated into actions that affect the appearance and behavior of the maps. You may have heard of the MIDI (Musical Instrument Digital Interface) protocol. It dates from the early 1980s and is used to exchange parameters between instruments, computers, and digital audio workstations. Your computer or mobile device likely "speaks" it natively, and if you own a digital keyboard instrument it almost certainly does. While Lemur could output MIDI, I found the protocol intimidating, and the note-focused (pitch, loudness, instrument, duration, modifiers) messaging not suitable for my purposes.

The author reflected in Paul Sharits's *Frozen Film Frame Series*, c. 1971–76, Burchfield Penney Art Center, Buffalo, New York, October 22, 2018.



Sequences from *Film-Wipe-Film* (1983). © Paul Glabicki. Images courtesy iotaCenter and the filmmaker.

7. Eternal gratitude to Keith Jenkins, Marsha Taichman, & Tre Berney for arranging my Cornell talk, which can be seen here: youtu.be/PXijK_q13do.

8. Eternal gratitude to Heather Gring and Tullis Johnson for facilitating my visit to the Archives. burchfieldpenney.org/public/documents/R2019.0806.001.pdf.

The OSC (Open Sound Control) protocol is of a more recent vintage and is more flexible in the types of messages it can send and receive, such that I could use it to send information that was not specifically musical. That it uses a URL-like namespace for its addressing was especially appealing to me as a RESTful API developer. What I mean by this is that a message such as

```
{
 address: '/label/country',
 args: [
  {
   type: 's',
    value: '[ Stoke-Regular,108.37, 0 ]'
  },
  { type: 'f', value: 108.37 },
 ]
}
```

followed by

```
{
 address: '/label/country/color',
 args: [
  { type: 'f', value: 313.3916 },
  { type: 'f', value: 0 },
  { type: 'f', value: 50 },
  { type: ‘f’, value: 0.5 },
  { type: ‘f’, value: 313.3916 }
 ]
}
```

can be sent from virtual controls on a touch surface via OSC and interpreted by software running on my laptop as a set of parameters for setting the font and font-size (in pixels) used for labeling entities in a country layer, and then altering its color using a tuple for HSVα (hue, saturation, value, alpha channel). Observant readers may be curious about the redundancy in these messages. The final line of the `args` array is the value provided by the virtual control. Carto-OSC acts upon the previous lines, implemented more naturally as a `preArg` where multiple controls provide input for multiple parameters.

By the time of my 2019 TiR I'd become aware of a JavaScript-based, open source alternative to Lemur called **Open Stage Control**, and much of my residency was spent reimplementing my 2018 work using that platform. Open Stage Control, developed by French percussionist Jean-Emmanuel Doucet, is remarkably capable,

The primary Carto-OSC panel with editor exposed. Screenshot by the author.

Sequences from *Film-Wipe-Film* (1983). © Paul Glabicki. Images courtesy iotaCenter and the filmmaker.

and is frequently updated in response to its active user base via a Discord forum.

The glue that holds Carto-OSC together has grown to a few thousand lines of JavaScript running in the web browser on my laptop. Incoming OSC messages are routed by address to individual modules that control the map style (e.g., `setPaintProperty`), the map movement (e.g., `flyTo`, `setZoom`), or the style of the HTML page into which the map is embedded using CSS margins, backgrounds, gradients, border-radiuses, et al. Some modules do very little and are only a few lines of code; others are rather complex and run to hundreds of lines. The router pattern makes it relatively straightforward to insert a new address and add complexity to the corresponding new behavior without adversely affecting existing, understood behaviors.

Carto-OSC served its purpose as a rapid prototyping tool for two short videos I released during the COVID lockdown: ***If Map #7***, a tribute to the late media scholar, Gene Youngblood, that screened in the **Experiments in Cinema** festival, and ***If Map #4***, an animated "poster" promoting an episode of the ***Remains to be Streamed*** Instagram Live program on the subject of film preservation.

FIRST PERFORMANCES

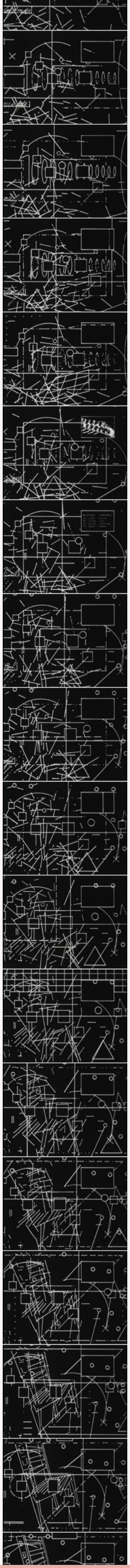
I'd wanted to return to Lisbon ever since my first visit in 1997, so when I learned about Hangar's International Residency program, I prioritized applying. I went with three map-related projects in mind: a series of sixteen short monochrome animations based on place names found within anagrams of the phrase "nonfungible tokens" (*If Map #9* and *9.1–9.16*), an experimental film in which older and younger versions of myself converse using Morse Code (*If Map #6*), and bringing Carto-OSC to fruition by giving a public performance.

The premiere performance of *A Synesthete's Atlas* was a collaboration with Helena Espvall, performing on cello and electronics, hosted in Hangar's performance space on April 21, 2022. About thirty people were in attendance: my co-residents, other local artists and gallerists, curious people from the neighborhood, and a few intrepid travelers who'd read about it on social media.

Three takeaways from that performance:

1. I learned more about the interaction of color in that fifty minutes than—with all due respect—hours spent with the Bauhaus-derived color-theoretic exercises of Josef Albers, Johannes Itten, Hans Hofmann, et al.
2. I was surprised by how my attention was allocated. I'd expected the majority of my energy would be spent manipulating map controls but my subjective impression was that 70–80% of my energy was devoted to listening to Helena's improvisations.
3. To my great satisfaction, the audience's attention, questions, and applause convinced me that there was, indeed, a "*there* there," that manipulating projected maps in dialogue with an improvising musician could produce a meaningful, non-narrative, pre-verbal experience for an audience.

Upon my return to the US at the end of June 2022, I gave three performances along the East Coast (Cambridge, Brooklyn, and Washington, DC) and another handful in California and Minneapolis in the autumn. Now, a year later, I'm touring Colorado and the Midwest, and beginning to line up another East Coast tour for the autumn, closing out 2023 with over two dozen performances in total. In post-performance Q & As, film curators have argued over whether my project is anti-cinema, post-cinema, or pre-cinema, and one geospatial colleague opined that "*A Synesthete's Atlas* sets a new bar for the notion of *radical cartography*."



Sequences from *Film-Wipe-Film* (1983). © Paul Glabicki. Images courtesy iotaCenter and the filmmaker.

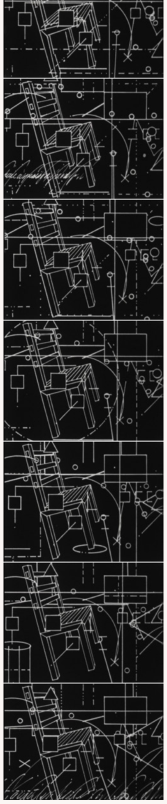
MORE ON THE *THERE* THERE

CONCERNS, INFLUENCES, AND THE FEEDBACK LOOP

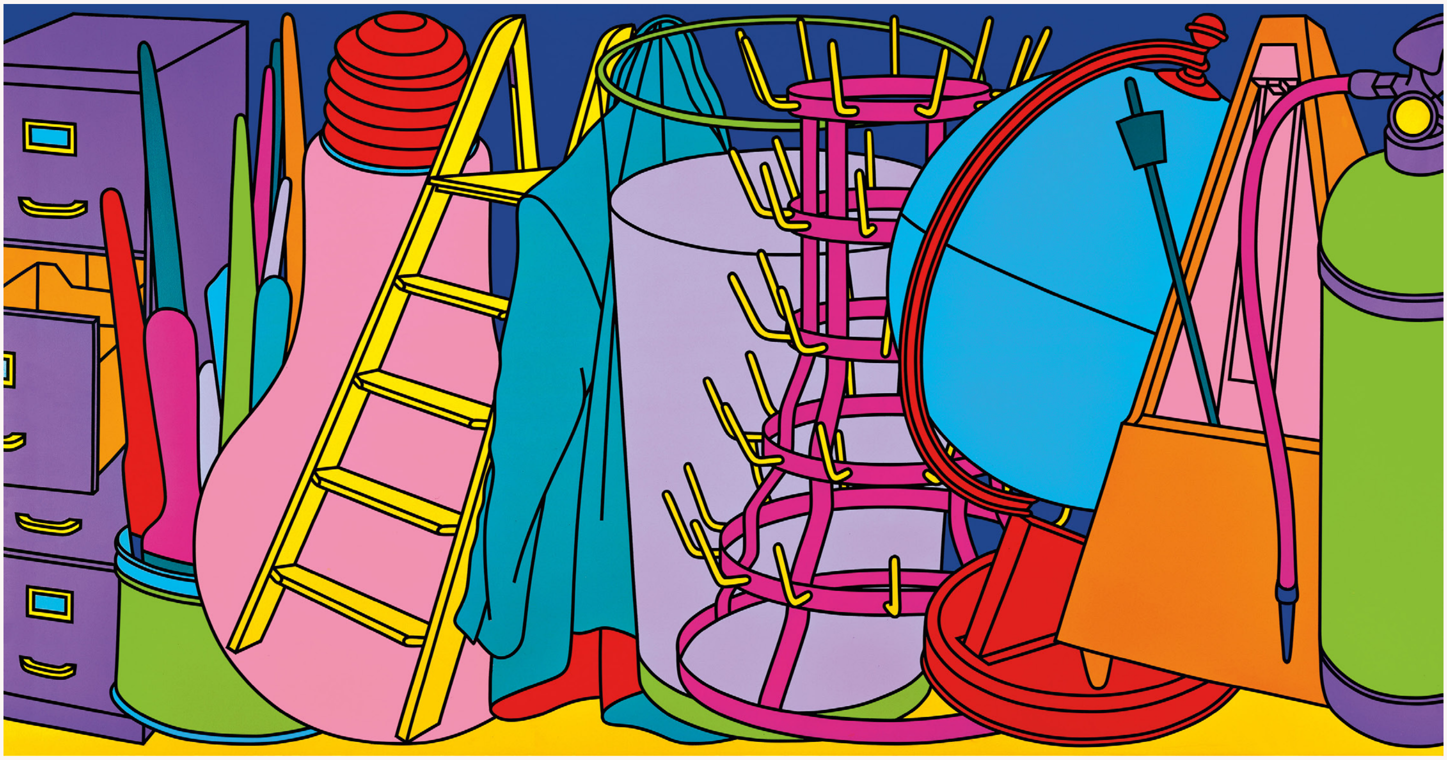
My overriding concern in these performances is color, particularly the subtleties of color perception and the freedom to apply unconventional palettes to geographic representations. Over the course of a performance I'll work with dramatic color differences—displaying saturated, "acid" colors in conflicting contrasts—and just-noticeable differences, where what might normally be thought of as foreground and background become indistinguishable or switch places.

There's a superficial similarity between the British painters Patrick Caulfield and Michael Craig-Martin. Both make use of constant-width black outlines and unmodulated expanses of solid color, leading unkind critics to call it "coloring book art." Caulfield's palette departs from the naturalistic in pursuit of atmospheric or emotional weight. In contrast, Craig-Martin's appears stridently arbitrary, yet harmonious. He often works on an architectural scale, creating room-sized drawings of common objects using black tape and painted walls. I study and take inspiration from both of their approaches to color, and my floor-to-ceiling projections allow the same impact as Craig-Martin's wall drawings.

But painters do not work in time-based media. The influence of Paul Sharits's color flicker films is especially visible when my projections are evolving quickly. I've come to see James Turrell's *Ganzfeld* installations as a referent when the pace slows. Turrell's installations, found at numerous museums worldwide, bathe viewers in slowly modulated colors and, due to their intensity and construction, the borders of the enclosing space—walls, floors, ceilings, even the portal for entry—vanish as the eyes try to make sense of the unfamiliar monochromatic, immersive, and unrelenting environment.



Sequences from *Film-Wipe-Film* (1983). © Paul Glabicki. Images courtesy iotaCenter and the filmmaker.



Full, 2000, Acrylic on canvas, 84 × 162 inches (213.4 × 411.5 cm). © Michael Craig-Martin. Courtesy the artist and Gagosian.

Like many artists, I lift inspiration from wherever I find it. I learned of François Morellet's grid paintings when one was installed several stories high on the wall of Dia Chelsea in 2017. Toying with this idea, I implemented simple, but effective controls that can alternate map rotation by dialed-in degrees at a slider-set pace.

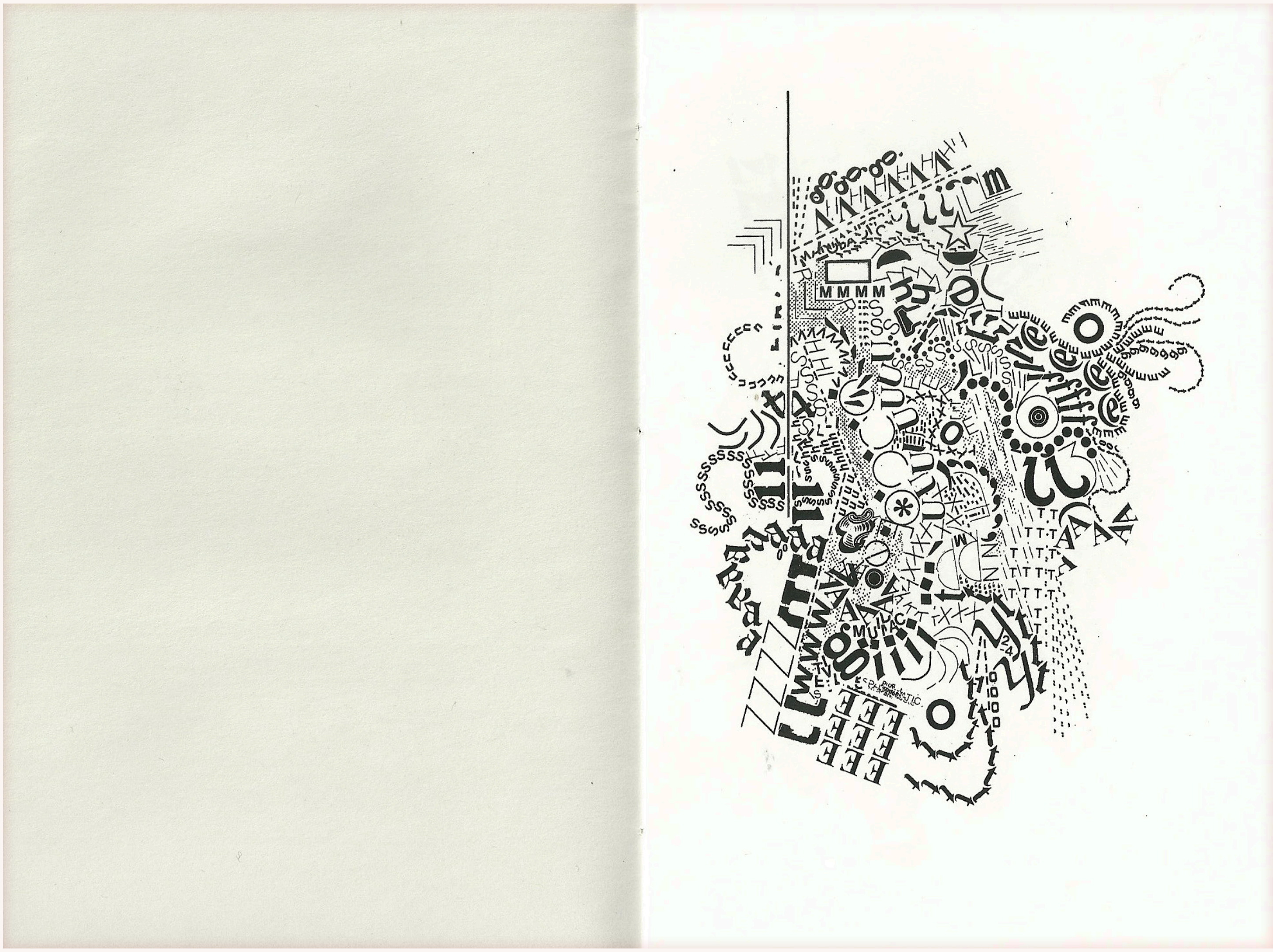
I was too young (and too square) to have witnessed light shows at the peak of their popularity, yet through popular culture (television, most likely) I was aware of them and was fascinated by the lively, abstract visuals. Eyedroppers squirting colored liquids into transparent, fluid-filled trays set atop overhead projectors while loud psychedelic rock music blared. Slide projectors, 16mm film projectors, shutter mechanisms, strobe lights. *Visual music*, a concept whose organizing principle is that fine art should attain the nonrepresentational aspects of music, has subsumed the light show (Brougher and Mattis 2005, 7 and 148–178); also, media theorist Gene Youngblood considered the light show a form of *expanded cinema* (Youngblood 1970, 387–398). I see my work as following in those traditions and am gratified whether someone calls a performance "trippy," or goes into great detail about the relationship between my colors and movement and their own psychedelic experiences.

"Trippy" may be a proxy for another of my chief concerns: dislocation. During a performance, north is only occasionally at the top of my maps, water only occasionally blue. Through orientation and motion I strive to make the familiar less familiar. By muting layers and labels, and by working with data that's devoid of elevation, it's possible to let features from the natural or built environment appear as a child's scribble, a ganglion, a printed circuit or schematic, or an abstract painting come to life.

I worry that legible labels of well-known geographies will too strongly anchor a performance. The question of how to treat them was partially answered by my admiration for the letterform experimentation of concrete poetry, pioneered by the Dadaists, and visual poetry as practiced by contemporary poets such as Derek Beaulieu. As with painting, my inspiration comes from primarily static works, but my performances are deliciously complicated by the label placement algorithms built into any mapping library. Most *Cartographic Perspectives* readers will be familiar with the phenomenon of a label placement algorithm prioritizing a small town over a large city due to available space; this adds a good dollop of unpredictability and humor to the proceedings.

The author performing with Kevin Corcoran, textural percussion & manipulated field recordings, at Other Cinema, San Francisco, California, November 5, 2022. Photograph by Mai Adachi.

François Morellet, *Trames 3°, 87°, 93°, 183° (Grids 3°, 87°, 93°, 183°)*, 1971/2017, which appeared on the western facade of Dia Chelsea, New York City, from October 28, 2017 through October 31,2019. Photograph by the author.



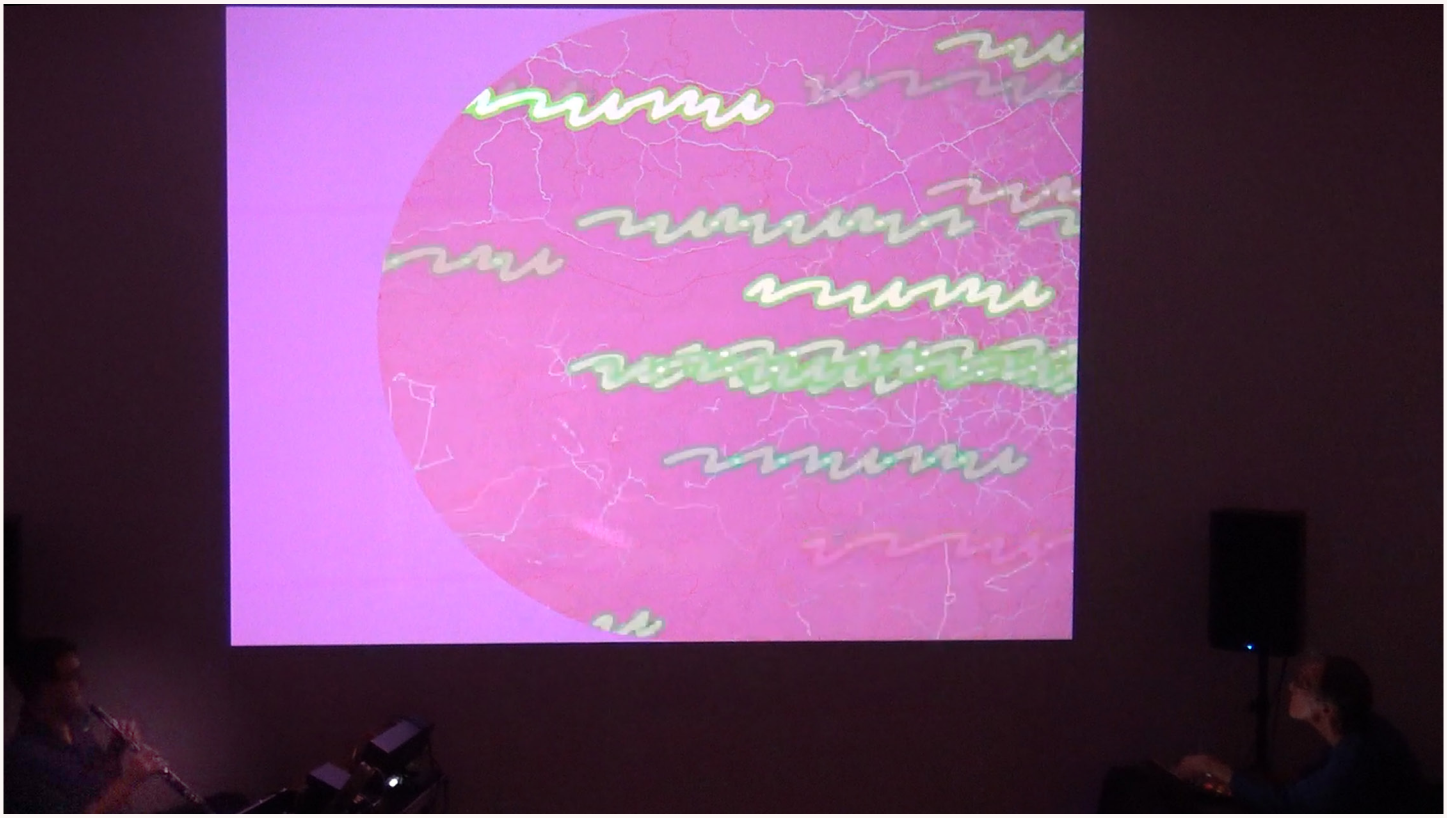
From *2 poems for Kristen,* by Derek Beaulieu (2009). ***derekbeaulieu.files.wordpress.com/2017/01/beaulieu-2-poems.pdf***.

Carto-OSC has a tab where I can control fonts, sizes, colors, halo characteristics, and whether to lock the label to the map or to the viewport during map rotation. A number of decidedly non-traditional fonts have been turned into glyphs using the `build-glyphs` script included with Mapbox's `node-fontnik` package. These include redaction and barcode fonts as well as fonts representative of various styles, e.g., Art Deco (PollerOne), the Arts and Crafts Movement (Strong Glasgow), script (Zapfino), etc. I'm simultaneously excited by dynamic font sets and saddened that they're far from being drop-in replacements for web mapping glyphs.

FINDING VENUES & COLLABORATORS

There's a kinship between experimental film and music, and I've been in the audience for what's variously called new music, contemporary classical, free jazz, punk, and noise for decades. I've been fortunate to live in cities with thriving scenes and to have made friends with exceptional musicians simply by being a member of their audience. Oakland is home to percussionist Jacob Felix Heule's long-running monthly workshop for improvisers, ***Doors That Only Open in Silence***, and Carto-OSC's early development was shaped by my sitting off to the side at sessions, imagining what I'd like maps to do in response to these spontaneous exercises in sound.

Naturally, it's different when traveling, especially with the gap in public performances caused by COVID-19. My typical approach, when faced with an unknown area, is to search the internet for venues that seem likely candidates (microcinemas, alternative art galleries, and performance spaces) for hosting a combination projection and sound collaboration, then begin making inquiries. I'm



The author performing with Kyle Bruckmann, oboe and electronics, at Shapeshifters Cinema, Oakland, California, September 25, 2022.

aided by a small number of experimental film databases ("**Experimental Cinema: News and Resources**," "**This week in avant garde cinema**") holding historical venue information. It's rare that I don't record my performances, and my **Vimeo showcase** and **Instagram feed** allow venues to understand what I'm proposing.

As a venue commitment begins to come into focus, my attention turns to collaborators. I may know of someone by reputation or recommendation, but often the same search I use for venues will yield a list of potential collaborators. Ideally they'll have a Bandcamp or Soundcloud presence, or a portfolio of YouTube or Vimeo performances, and I can ascertain whether there's a potential match.

And then I send an email.

No one has yet said "not interested" to the idea; artists' fees or prior commitments are the usual reasons a collaboration doesn't proceed.

The economics of experimental film dictate a cycle of production cost, application cost, and then poor or even non-existent exhibition fees; it remains surprising to be paid for performing, whether on an institutional budget or for a share of what's collected at the door.

Even with performances at home it's rare to have the opportunity to rehearse. My collaborators and I either meet over a beverage or via Zoom and go over the possibilities and desired ways of working together. The subtleties come across in the video/audio documentation but the coarse "contract" my collaborators and I arrive at are worth unraveling. Instrument builder Krys Bobrowski adopted the approach of composer John Cage and choreographer Merce Cunningham: music and dance being separately composed, simultaneously performed, and merged only through the audience's perception. The duo of Jim Ryan (winds) and Darien Baiza (drums) chose to interpret my projections strictly as an unfolding score. In most performances there's a creative give-and-take between the visuals and sounds.

I do query my collaborators about what I've taken to calling *trigger geographies*: either specific locations or types (rigid street grids, fractal river deltas, points of interest that memorialize a person or incident) that might somehow impact or redirect their playing. Keyboardist Derek Gadalecia (a.k.a. Headboggle) ran the furthest with this prompt; as he pre-records backing tracks in advance of a performance, he provided me with sixteen tracks, named after specific locations, a week ahead of ours. I investigated the geographies of each, added the visually evocative ones directly into Carto-OSC's *Destinations* tab, and used the others' names as springboards to other locations. I ask similar questions of my collaborators regarding the impact of screen energy: how might changes in palette or contrast, aggressiveness of flickering, speed of rotation or oscillation, or changes in standard map parameters such as zoom level, pitch, or speed of interlocational "flight" affect their playing?

THE FUTURE THERE

Truman Capote famously said of Jack Kerouac's *On the Road*, "That isn't writing; it's typing." I imagine there are people who feel the same about my performance cartography, although, thus far, they've kept mum. Cartographers in attendance have told me that my performances have made them excited to go back to work the next day.

After every performance, it's common to create a handful of self-assigned GitHub issues related to gestures I felt moved to make but had no interface with which to do so (I file bug reports, too). Small issues are addressed before the next show, medium ones might get a temporary hack with an eventual refactor. Epic issues—e.g., the ability to dematerialize polygons à la Glabicki—serve as fodder for future residency or grant proposals.

I love working with musicians who play acoustic instruments but I understand that contemporary electronic gear—loopers and other effects processors—has become standard equipment, requisite for a solo artist to perform for 40–50 minutes. Thus far I've worked with three exclusively electronic artists: sampling pioneer/laptopist Carl Stone, the aforementioned Headboggle, and modular synthesist Brett Darling. My imagery is, frankly, well-suited to electronic and dance music and I anticipate the day will come when I'll collaborate with a DJ over beat-driven music in a nightclub/rave setting. And while I presently use OSC only to exchange messages between my iPad and laptop, coding time is the only obstacle to extending this to a network of musicians and their instruments. The ability to simply sync tempo would have immediate advantages but allowing notes/sounds to drive map parameters or map gestures to trigger musical events opens interesting new possibilities. I enjoy the actual playing too much to let Carto-OSC devolve into a plug-and-play visualizer/screensaver and hope to one day have the luxury to write these extensions during a residency at an electronic music laboratory where the pool of talent and experience is deep.

While I'll always perform in scrappy, DIY, underground venues, booking more museum- and university-hosted performances will help keep this project sustainable through guaranteed honoraria instead of door splits and by committing experienced staff to publicity, outreach, and stage tech. With dozens of performances behind me I'm beginning to skim the cream of Carto-OSC improvisations to create animations to be displayed as public art at the scale of New York City's Times Square or London's W1 Curates, and to produce portfolios of works on paper. Other hopes for the future include working with spoken word artists—slam-style poets seem a natural match—and choreographers. Finally, once Carto-OSC is a little less feral, it's possible I'll open source some or all of it so that designers having more traditional narrative and/or data visualization requirements will be able to make productive use of it.

EPILOGUE

Although this article is appearing in the summer of 2024, it maintains a spring 2023 perspective. I take sole responsibility for the many delays and commend Daniel Huffman, Nick Bauch, and Jim Thatcher for having patience exceeding Job's. The only significant change to my stack has been a switch to Brandon Liu's Protomaps (**protomaps.com**) for serving tiles; it's been liberating. Performances continue, with northern European dates coming together for July–October 2024. In the be-mindful-what-you-wish-for department, I'll be creating an atlas of screenprinted maps based on performance highlights during September and October at Amsterdam's AGA Lab, and my 10 minute ***If Map #5*** looped atop San Francisco's Salesforce Tower throughout February of this year as part of their Midnight Artist Series.

ACKNOWLEDGEMENTS

In addition to everyone already mentioned in this article I'd like to thank every collaborator, curator, and audience member, past and future, who's taken a chance on this work; an up-to-date list of performances can always be found at **erictheise.com/a-synesthete-s-atlas**. Special thanks to Kate MacKay, Kevin Koy, Janine Firpo, and Gary O. Larson for words and deeds that led to the artist residencies where this work initially took form; this project's unimaginable without their early and ongoing support. Shout out to Emma Strebel as well for shepherding the Salesforce Tower Top project from inception to completion.

This article is dedicated to the late Jim Ryan, DC-based multi-instrumentalist, whose post-collaboration enthusiasm for my work is on the short list of memories I drum up when my confidence wavers.

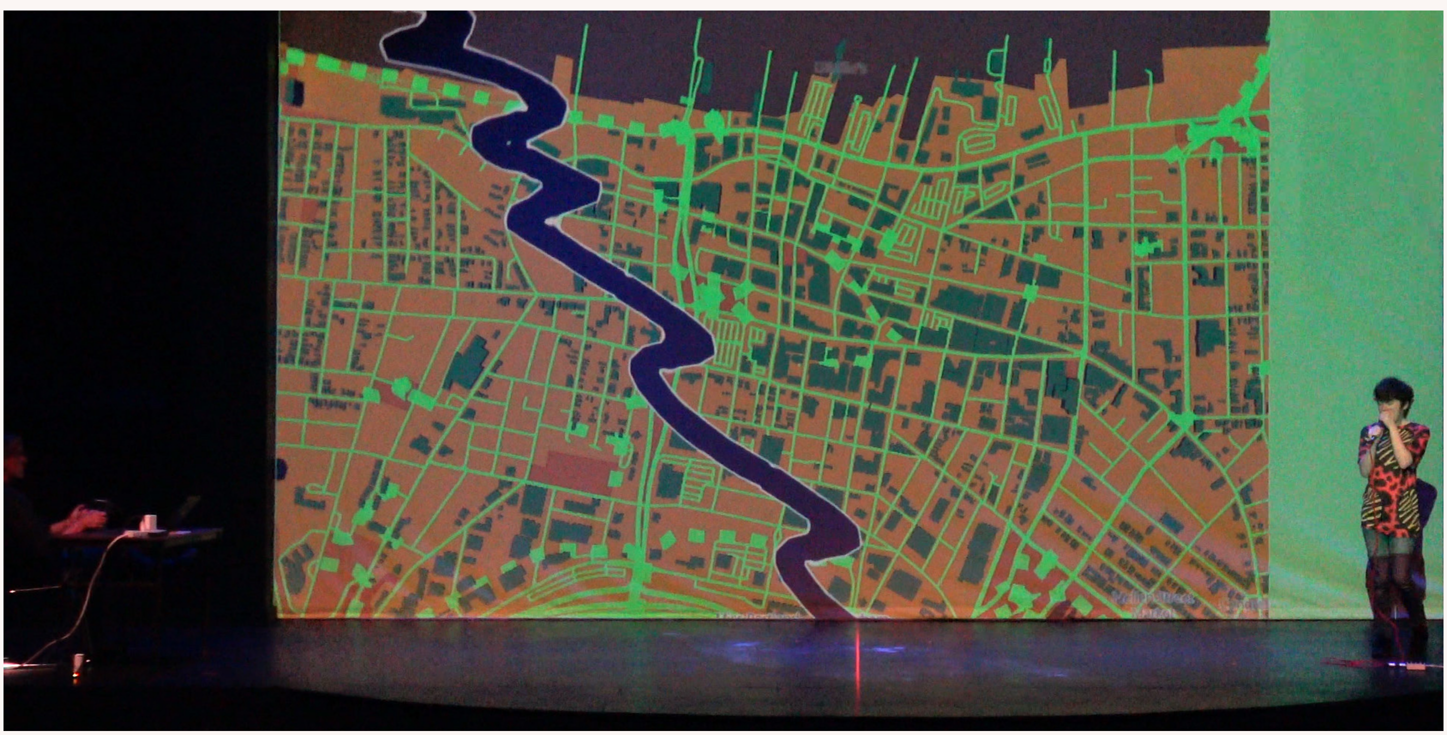
If, as it advanced, the countermap's counter twirled the map around and down, spiraling out from Salesforce Tower to Bolinas as unwaveringly as the boléro. (If Map #5) on the second tallest building west of the Mississippi River, San Francisco, California, February 2024. The Salesforce Tower Top art project is a partnership between Jim Campbell Studio and BXP/Boston Properties.

REFERENCES

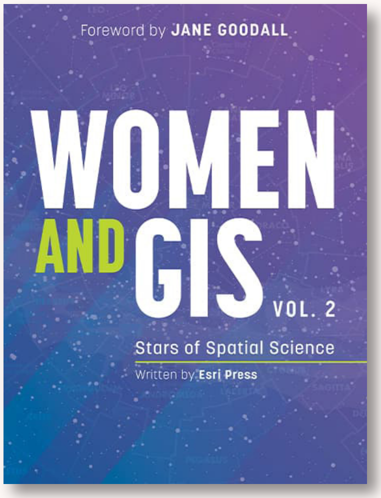
Brougher, Kerry, and Olivia Mattis. 2005. *Visual Music: Synaesthesia in Art and Music since 1900*. London: Thames & Hudson.

Sitney, P. Adams. 1969. "Structural Film." *Film Culture* 47: 326–349.

Youngblood, Gene. 1970. *Expanded Cinema*. New York: E. P. Dutton & Co., Inc.



The author performing with The Asthmatic (Sigrid Harmon), voice and electronics, at Russell Hall Theatre, University of Southern Maine, Gorham, Maine, October 2, 2023. Performance sponsored by the Osher Map Library and Smith Center for Cartographic Education, and the Department of Theatre at USM. Many thanks to Libby Bischof, SeifAllah Salotto-Cristobal, and Matthew Edney.



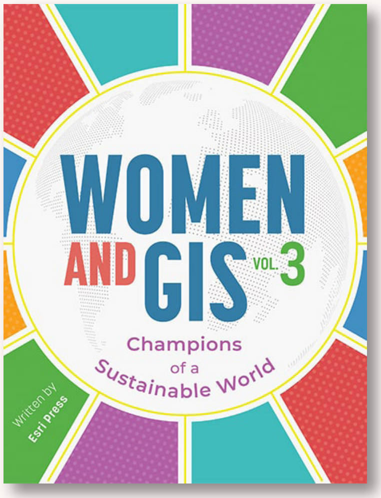
WOMEN AND GIS VOLUME 2: STARS OF SPATIAL SCIENCE

By Esri Press

Esri Press, 2020

274 pages

Paperback: $23.99, ISBN 978-1-58948-594-5



WOMEN AND GIS VOLUME 3: CHAMPIONS OF A SUSTAINABLE WORLD

By Esri Press

Esri Press, 2021

320 pages

Paperback: $23.99, ISBN 978-1-58948-637-9

Review by: Rebecca Ramsey

The unprecedented three volume series *Women and GIS* delves into the lives and journeys of women in the field of GIS. Volume 1: *Mapping Their Stories*, was published in 2019 and reviewed in **issue 100** of *Cartographic Perspectives* (2022), so this review will focus on Volume 2: *Stars of Spatial Science*, and Volume 3: *Champions of a Sustainable World*. Both of the newer volumes follow the lead of the first in celebrating the achievements and diverse experiences of women in GIS by introducing readers to a multitude of women from varying backgrounds, ages, and fields, at assorted moments in their careers.

The second and third books maintain the inaugural volume's familiar format, with individual chapters of about eight pages, each dedicated to a different woman and recounting her personal journey from early childhood to her entry into, and experiences in, the professional world of GIS. Each navigated her own way through the tangles of educational programs, jobs, career paths, and projects to find success for herself in the GIS field, and readers are provided an opportunity to hear from each why she undertook the journey and how she found her way. The books provide engaging and detailed stories while maintaining a concise format, making it ideal both for readers who prefer short reading sessions and for those who enjoy a long binge read. It's a win either way.

Again, as in Volume 1, each woman profiled has provided several color photographs of her childhood, family, educational milestones, professional presentations, and award ceremonies—making the narratives more personal, accessible, and effective. As the series has progressed, there has been an increasing number of photographs and a corresponding reduction in the number of maps: there are only about half as many maps in either Volumes 2 or 3 than appeared in Volume 1. This re-balance has shifted the focus away from career oriented projects and towards the personal narratives—potentially allowing readers more opportunity to recognize likeness to themselves and their own situations and ambitions among so many diverse faces, cultures, interests, and geographic locations.

Both volumes open with the same "Foreword" by the renowned Dr. Jane Goodall, Dame Commander of the Most Excellent Order of the British Empire (DBE). Jane mentions how often people have thanked her for "teaching them that because you did it, I realized that I could do it too" (xv). Her words bring home the fact that a major step towards gaining the confidence that one can achieve a goal in STEM is sometimes simply to see the face of someone else like oneself doing similar work. The importance of these stories, and of the photographs each woman thought it pertinent to share, cannot be stressed enough when it comes to influencing the next generation of women in GIS.

Among the volume-to-volume changes are the way pull quotes are presented. Volumes 1 and 2 employ a similar style, with quotations prominently positioned on the page fly and printed in large, bold text in eye-catching colors. In Volume 3, however, key passages are instead emphasized in place. This method draws the reader's attention to significant remarks in the context of the narrative instead of pulling them out and repeating them in isolation. In a practical sense, it also means that without the displays in the margins, more page space is available for each woman's story. To my thinking, Volume 3's integration of narrative and highlighting seems to strike the right balance by indicating powerful remarks without aggrandizing them.

The personality and experience of each woman profiled in Volume 3 is emphasized by the "Tips and Fun Facts" blocks placed throughout the book in the page margins. The "Tips" are words of wisdom from each woman regarding a career in GIS, such as recommendations on finding a community in the field or reminders to expand your horizons. The "Fun Facts" introduce us to the character of each woman, including their preferred hobbies such as athletic ventures like bike riding, yoga, tennis, and swimming, as well as other, creative arts hobbies like jewelry making, poetry, crocheting, and photography. Still other hobbies, such as traveling to distant countries, cooking new recipes, and even raising chickens, defy those two categories. Some "Fun Facts" detail items that occupy desk space—dinosaur figures, a copy of ***The Little Engine That Could*** for extra motivation on challenging projects, cat-chewed Post-It love notes from a spouse, copper wire to fidget with during virtual meetings, or pink pens with fluff on the end. These seemingly external-to-GIS topics are actually another brilliant opportunity for readers to see commonalities between these women's lives and interests and their own, allowing each reader to see their own personality traits reflected back from the page.

As the number of women, and therefore chapters, increased—the twenty-three in Volume 1 grew to thirty in Volume 2 and thirty-one in Volume 3—the publisher tried different ways of visually indicating similarities and commonalities between the various diverse paths trodden by these remarkable women. Volume 2 uses a complex and confusing multi-dimensional icon based on a four pointed star—in keeping with its "Stars of Spatial Science" theme, and harkening back to Volume 1's compass rose motif (Figure 1). These stars are embellished with various decorations indicating the profiled woman's career fields (Science & Research, Education, Government, Business, Humanitarianism, Environment & Conservation). This central element is printed in colors denoting the geographic regions (North America & the Caribbean; South America; Europe; Africa; Asia & the Middle East; Australia & Oceania) where they are active. More than

Figure 1. Part of the table of contents for Volume 2, showing the multidimensional icons that symbolize each woman's career fields, region of activity, and roles.

one career field symbol or geographic region color may be included. One or more smaller, yellow stars in the corners of the icon constellation identify the various roles (Leader, Pioneer, Entrepreneur, Fieldworker) each filled in their undertakings. Unfortunately, this whole scheme comes across as a bit too complicated. When I was in the thick of reading, I found myself frequently leaving one page to flip to the key and back to the chapter in an effort to determine what woman landed where.

Volume 3 improved upon this logic—dropping the "Role" and "Geographic" dimensions entirely—and instead presenting a simple infographic illustrating each woman's primary, secondary, and tertiary fields of focus by means of a colored, three element "sunburst icon" to the left of their name (Figure 2). The six field of focus options are similar to those in Volume 2, with some minor modifications. "Education" is combined with "the Arts," "Business" is merged with "Entrepreneurship," and the "Government" field is replaced outright by "Social Justice." I, myself, found this simplified organization scheme to be a vast improvement. In particular, this focus on primary, secondary, tertiary fields allows the reader to better grasp each woman's multi-faceted interests and activities—something that is a common and often reiterated theme in the text of both Volumes 2 and 3 of *Women and GIS*.

Another Volume 3 innovation is the way each woman's current job position and educational background is presented right up front in the margin text at the beginning of her chapter. Previously, it was buried in the body of text, and a reader learned about them gradually, as a part of following the narrative. Spoiler alert, no two current career positions or educational backgrounds were alike. Unlike Volume 1, Volumes 2 and 3 place significant emphasis on when each woman discovered GIS: showing that while some entered the field later in their careers, many others found their way there at a younger age. This possible trend may indicate a promising shift toward earlier exposure to GIS in education, or it may be due to more career fields leading more women to consider GIS sooner, or maybe both. And maybe, too, a series like *Women and GIS* is, or will be, doing its part, too.

Figure 2. "Sunburst icons" indicate the primary, secondary, and tertiary career fields of Volume 3's women.

The *Women and GIS* series goes beyond a corporate diversity puff piece, or a careers pamphlet, and instead brings the lives of actual women doing important work in GIS into the foreground: showcasing their passion, their determination, and the variety of steps that have led them, via various paths, to success. Soon after the publication of Volume 2, the series went one step further by leaping from the published page to a three part webinar series that can still be found on online. Each webinar, one in **May**, **June**, and the **Fall** of 2020, lasted around one and a half hours and was spent chatting with some of the women featured in the book. The webinar series was hosted in partnership with *WECAN*, Esri's *Women Enablement and Career Advancement Network*.

Volumes 2 and 3 stand as testament to the fact that there is no one-size-fits-all approach to entering the GIS field. Each woman profiled carved her own path, and this individuality is celebrated throughout the books. Volume 3, in particular, underscores the diverse educational backgrounds found among the participants. It is a smorgasbord of degree programs including: Geospatial, Engineering, Architecture, Biology, Urban Planning, World Politics, Geology, Agronomy, Business, Ecology, Physics and Astronomy, Music therapy, American Studies, Policy Studies, Religious Studies, Public Affairs, and the list goes on. Some pursued undergraduate and graduate studies steeped in geography or GIS right from the start, while others followed more peripatetic paths through alternative programs and degrees, and eventually found on the job that GIS could be a useful and critical tool to support their work. There are numerous avenues to enter GIS, giving hope to professionals of any field that a shift to GIS is not impossible and if anything is common. One of the most important takeaways from this series is that there is no one school that you must attend; no single program you must seek out; and no particular certificate you must obtain to be successful in this field. There is no such thing as starting too late or too early, and there are avenues open to neophytes, to established professionals, and to everyone in between. The possibility is in your own hands to find what fits you, and what works for you, based on your own needs and lifestyle.

In conclusion, Volumes 2 and 3 of *Women in GIS* represent a meaningful continuation of the series, marking a consistent effort to highlight the invaluable contributions and experiences of women in the GIS field. These books are a celebration of careers of inspiring women, and of the welcoming and supportive professional community those women have built. All three volumes provide essential insight into the lives, struggles, and achievements of women in GIS, and are a powerful resource for aspiring professionals in the field. Each book is a testament to the fact that the path to GIS is not rigidly set in stone, and each makes clear that diversity and individuality not only exist within the field, but are among the well-springs of its strength. A continuation of this series would only be natural, and we can surely anticipate more deep dives into the world of women in GIS in the future. It could be said, based on the examples in this series, that there are many faces to GIS, and that your face could be one.

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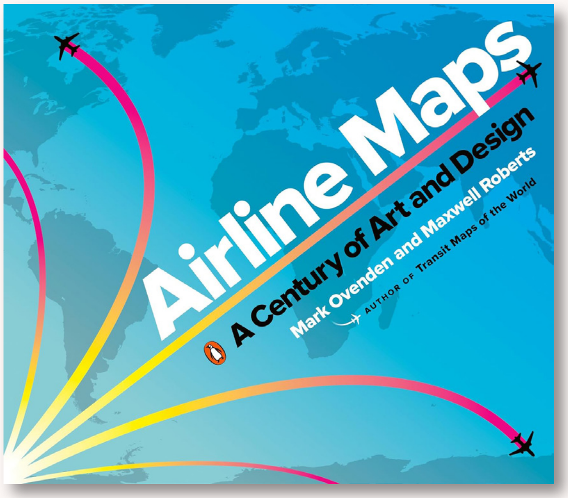


AIRLINE MAPS: A CENTURY OF ART AND DESIGN

By Mark Ovenden and Maxwell Roberts

Penguin Books, 2019

144 pages, 82 maps

Paperback: $30.00, ISBN 978-0143134077

Review by: Lily Houtman (they/them),
The Pennsylvania State University

Airline Maps: A Century of Art and Design by Mark Ovenden and Maxwell Roberts examines design trends of airline maps from 1919 to the present. The book is composed mostly of maps, with short bits of contextual information, to allow readers to comprehend how the look of airline maps has changed over time. As a whole, the book is visually striking and will be of interest to many cartographers and graphic designers. However, it is disappointing that the authors provide such a limited historical context to supplement the visuals, because art and design trends do not exist in isolation. The index and bibliography are also both very limited, and a reading list pointing to further information about air travel and the maps associated with it would be a great opportunity for further learning.

The book is divided into seven chapters, each representing a ten to twenty year period in the history of airline maps. The text provides a brief description of air travel in each era, highlighting the improved flight range of airplanes, the growing affordability of flights for average people, and the evolving interrelations between the airline industry and other forms of travel like boats and trains. These changing conditions are reflected in the maps; for example, the scale of early airline maps typically showed flights within a single country or region because flights could not yet travel worldwide distances.

Historically, airline maps have been meant not for navigation, but instead to encourage the public to use air

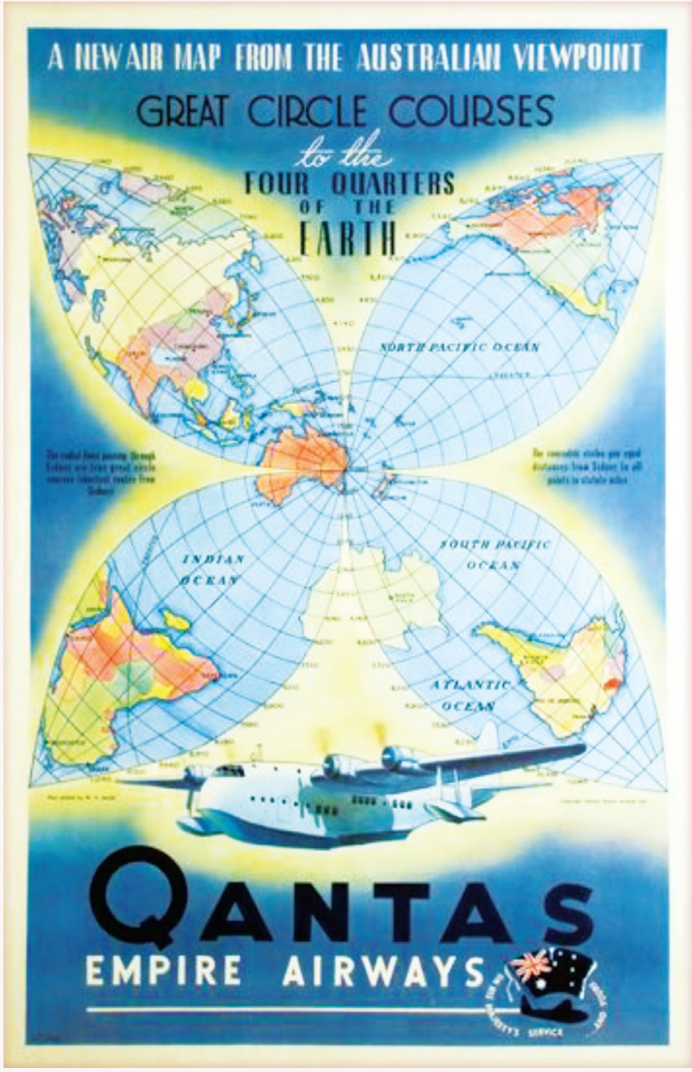


Figure 1. Qantas map from the 1940s (47).

travel by providing a sense of speed, security, and ease—and sometimes of foreign exoticism. In the early days of air travel, mapmakers were given freedom to experiment, and thus, both between and within airlines, map designs show little consistency. The approaches that were adopted were based in both science and artistry, with many creators drawing on well-established cartographic practices—using real projections, for example. Some designers chose to use novel projections (Figure 1) or unique orientations (Figure 2) that are rarer today, choices that might be confusing in other contexts, but are potentially enticing when the maps do not have to be practical navigation tools. Other creators adopted data visualizations, much like transit maps, prioritizing simplicity. For a few maps, especially some of the earliest ones, the maps are exercises in modernist graphic design, artistically highlighting a single destination. As a whole, visual appeal was prioritized over wayfinding.

Figure 2. Western Air Express Map from 1929.

The authors do not try to downplay the problematic history of many airlines, noting the imperialist nature of many early flight routes, a fact hidden by neither the airlines nor the maps. Air France, for example, flew to Africa, but only its own colonies. The British-based Imperial Airways colored Britain and its colonial possessions red, using another color for everywhere else (Figure 3). The earliest worldwide airline maps often included pictorial elements of foreign destinations, with figures engaged in activities or dressed in ways that promoted exoticizing, racist stereotypes. As the authors note, "By twenty-first-century standards, some [of these depictions] might be deemed inappropriate, but they are of their time and would not have been intended as offensive" (13). The majority of airlines, especially early on, were Western based, and the collection in *Airline Maps* reflects this. Some maps from non-Western airlines are included as well, though are not the focus of this book.

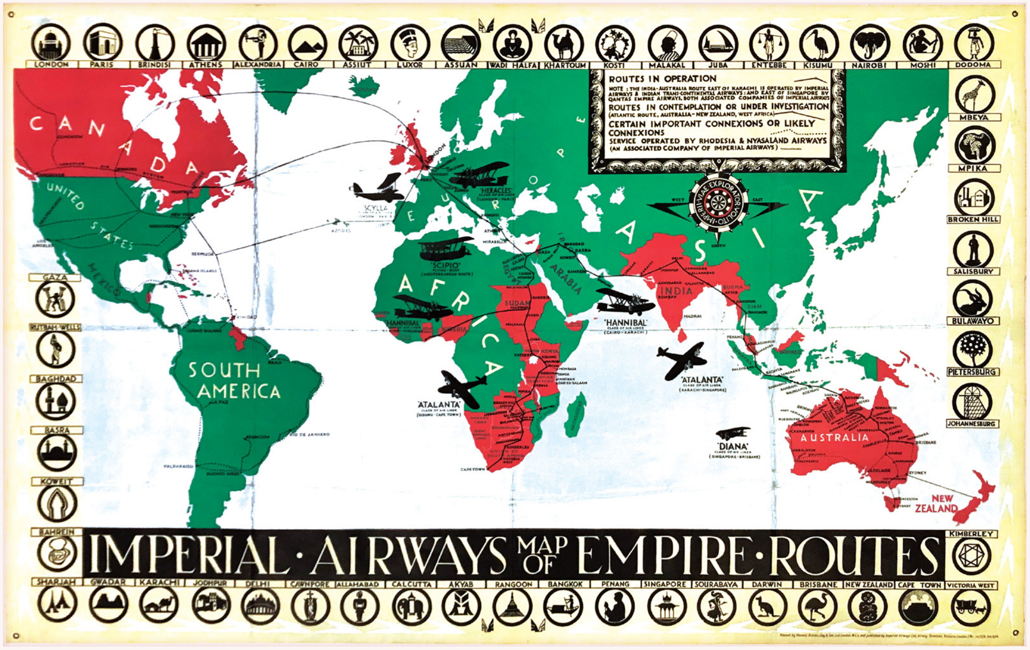


Figure 3. Imperial Airways map from 1935 (34).

"Women . . . played a major part in early aviation," (13) so it is unsurprising that they often featured in airline maps and other advertisements—for example, one 1923 postcard from the Belgian airline

Sabena features "an entirely female crew and passengers" (13, illustration 12 top left). Women also, as the authors note, made at least some airline maps. Ruth T. White, for example, authored the three Western Air Express maps shown on page 13—from 1925, 1928, and 1929—although only the 1928 map is directly credited to her. The inclusion of women in airline maps was not always positive, though, and often women were used as seductive marketing features, such as in Pan American maps from the 1930s. The Pan Am maps, targeted at a "rich vacation-minded clientele" (30, illustration 30 top left and bottom middle), exhibit similar problematic tropes to maps which exoticized non-Western individuals.

As the century progressed, airline maps began to have somewhat more consistent styles. World maps become much more common, many using curved lines to indicate flights between destination cities. However, many of these maps continued to employ both racist and sexist tropes. By the 1950s and 1960s, planes were faster and fares were cheaper, while middle class affluence was growing. With increased demand for flights, more airlines opened, resulting in greater competition. In response, airlines advertised to Western male consumers by highlighting both the "exotic" destination cultures and the friendly, attractive, female flight attendants staffing the planes.

A shift in consumption led to a shift in maps, beginning around the 1970s. Chapter 5 begins with the comment: "as planes got bigger and faster, maps seemed to get less attention" (102). While some maps remained beautiful and abstract, others became much more schematic and practical. This style change leads to a tone shift in the book: the authors have a clear preference for the older maps in this collection, and can be quite dismissive about ones for which they care less. They are especially snide about the 1968 and 1971 BOAC (British Overseas Airways Corporation) maps on page 104, noting that "neither of [them] work especially well," and that the earlier of the two "appears as if the designer may have swallowed some of the psychoactive substances in circulation in the late 1960s" (105). In a book meant to assess the changing styles of airline maps, these comments feel inappropriate, especially since the authors have sought to portray their book as a mostly visual product, with very little textual content. At the very least, the presence of opinions is inconsistent, since none of the previous chapters had such negative comments.

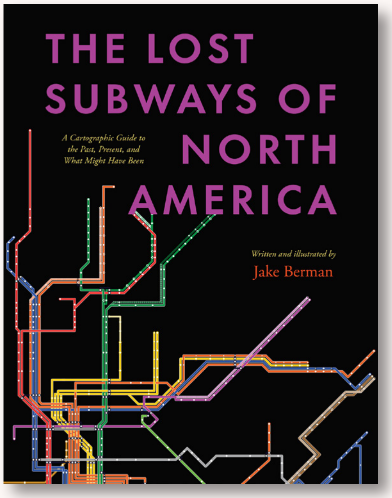
The authors' opinions on more recent airline maps are reflected in the reduced space dedicated to the final three chapters. The first four chapters, spanning 48 years of early aviation, are given 95 pages, while the last three chapters, spanning the most recent 51 years of aviation, are given only 41 pages. In a book with the subtitle *A Century of Art and Design*, it is disappointing that half the century receives reduced attention. During this later period, more airlines opened, existing airlines were expanding, jet engines made longer distance flights possible, and more types of maps could be produced (such as digital ones)—suggesting there are many interesting options to compile. One author opens the book by remarking, "there [was] no shortage of material to include" (5), so while it is possible that archives of earlier years were simply more complete, the authors do not provide an explanation for the difference in chapter sizes. The authors' passion clearly lies in these early eras, and the remaining chapters are both more vague and more opinionated, and fall disappointingly flat.

Another shortcoming of the text is that there is no discussion of, or even much indication of, the context in which each map originally appeared. They could have been for small or large audiences, printed at any size, or distributed at any number of locations. The extent to which the public saw any of the maps included in any of the chapters is difficult to discern, and that makes the comment about maps getting less attention in the 1960s and 1970s difficult to verify. Additionally, the authors did not provide an index of individual maps—only photo credits—and even the table of contents seems to be missing a few entries. The citations that *are* included name only the collection that the map comes from, with no useful information about the map itself, such as its title in the collection. Thus, re-finding any particular map one remembers seeing requires tedious page flipping.

Readers of *Airline Maps: A Century of Art and Design* must recall the title when picking up the book and understand that its contents are a venture into art and design, not history. The authors catalog a number of airline artifacts which may provide design inspiration, but offer limited historical context, which some readers might wish for to supplement and contextualize the maps. The review copy of this book was provided to me digitally (as a PDF), but, to my mind, a physical copy would have been preferable, given the focus on design. Some of the maps extend across two pages, and these would likely look better in print. Additionally, because the book is dominated by maps, some of the text is cut off mid-sentence and is not continued for up to ten pages. For example, the text at the bottom of page 83 ends with: ". . . the French-designed

Sud-Est Aviation Caravelle, introduced in 1959, showed that," and then picks up again on page 93 with, "jets for short-haul flights could also be economic." While a small silhouette of an airplane displays a number indicating which page the sentence continues on, navigating all over the book like this is much more difficult in a PDF than in a physical volume.

Overall, I am of two minds on recommending this book. Audiences broadly interested in the visual changes of airline maps over the past century or who are looking for unique cartographic inspiration may enjoy this book. However, for audiences who, like me, are deeply fascinated by the subject of airline maps, this book may leave them wanting more, as it did for me. While such a brief book could never comprehensively cover this vast subject, I find myself frustrated by its modesty: I want to know more about who was making these maps, where they were displayed, who was seeing them, and where I can go to see some of them myself. This book will spark your curiosity, and while the short trip may be plentiful for many readers, I find myself wishing I could take a longer look out this window into the past.



THE LOST SUBWAYS OF NORTH AMERICA: A CARTOGRAPHIC GUIDE TO THE PAST, PRESENT, AND WHAT MIGHT HAVE BEEN

Written and Illustrated by Jake Berman

The University of Chicago Press, 2023

272 pages, 107 maps

Hardcover: $35.00, ISBN 978-0-226-82979-1

Review by: Matthew Buchanan

The *Lost Subways of North America* is a well researched exploration of subway, light rail, and elevated metro systems in selected cities in North America. Delving into the evolution of urban rail transit on this continent, it offers the reader an engaging and succinct narrative of the mass transit related aspirations, challenges, successes, and lost opportunities that shaped the history and the present realities of the systems as we know them today.

The author showcases twenty cities in the United States, and three in Canada, to discuss some of the problems, and a few of the successes, of rail rapid transit. Each of the twenty-three chapters is devoted to a single city, and every chapter opens with a full-page index map showing the geographic extent of that city's rail transit system at different periods in its history. These maps, though, simply set the stage for the story of the birth and evolution of each city's transit system throughout the decades. Each chapter is supported by between one and six colour maps that chart the course of public transit in that place—from the earliest horse drawn tramways of the late 1800s to the present day, including various proposals that were never constructed, or were dramatically scaled back.

Without a doubt, it is these system maps that are the standout feature of this book. Composed by the author, Jake Berman, all are original and done in styles and colour schemes inspired, where possible, by the official maps. This variation makes them even more compelling and interesting to study. Making legible transit maps is a balancing act between simplicity and complexity, as well as between the desire for a clean diagram and geographical accuracy. Berman has done an excellent job finding the right balance.

The maps are mostly drawn in the diagrammatic style we have come to expect of transit maps, though some are quite geographically accurate and even include scale bars. Some include proposed and "under construction" lines, and others include the higher orders of bus lines like busways or bus rapid transit (BRT) when such modes are an integral part of the system.

Most of the profiled cities have faced some combination of challenges with their transit system, and each chapter highlights a different problem. For example, the first chapter is about the city of Atlanta. From the late 1890s until about World War Two, Atlanta—in common with many North American cities—had an extensive streetcar network. Streetcars, however—again, like in most North American cities—fell out of fashion after the war due to rise of affordable automobiles and of generous government subsidies for highway construction. It wasn't long, though, before those highways were clogged, and alternatives were needed. In the 1950s and 1960s Atlanta's ambitions of growth led civic leaders to propose a comprehensive, rail-based, rapid transit system much like the contemporary systems planned for Washington, DC and the San Francisco Bay area. Unfortunately, issues of race and funding, along with bouts of urban-suburban squabbling, meant that the system of today is not nearly as successful as it might have otherwise been.

Other chapters of the book highlight different issues that similarly led to less than optimal outcomes. *The Lost Subways of North America* meticulously outlines a series of critical missteps in the development of each urban transit system—missteps ranging from the shortsighted dismantling of thriving streetcar lines to enduring political stalemates hindering system expansions. The book scrutinizes the consequences of building stations in inconvenient locations, failing to construct comprehensive networks, and neglecting fare adjustments to match inflation rates. Moreover, it delves into the adverse effects of prohibiting urban density around transit hubs, and highlights the detrimental impact of prioritizing long suburban rail extensions over vital destination-dense corridors within cities, exacerbated by legal impediments like zoning laws and parking restrictions that obstruct the construction of high-density buildings near transit infrastructure. Additionally, the book critiques the flawed assumption that commuters will predominantly drive to stations, leading to the construction of sprawling parking lots or garages rather than promotion of walkability and accessibility.

Various impractical flash-in-the-pan transit trends are discussed, including monorail projects in Seattle, Los Angeles, Las Vegas, Montréal, and New Orleans. Berman also discusses the trend for automated "people movers," with proposals ranging from Pittsburgh's fully-automated, 19,800 passengers-per-hour Skybus to less-ambitious examples in Detroit and Jacksonville. Only Miami's can be considered a success. The more recent trend of building downtown streetcars is also discussed in the chapters about Detroit and New Orleans.

Using, among others, Los Angeles and Minneapolis–St. Paul as examples, the author briefly addresses, and largely debunks, the many conspiracy theories involving automobile manufacturers buying up streetcar lines just to shut them down and replace them with busses. The only instance of this he can find is in Minneapolis–St. Paul, and even in that place there is no shortage of other villains.

Chapters are also devoted to the smaller cities of Richmond, Virginia; Rochester, New York; and Cincinnati, Ohio—none of which have a rail transit system today but all of which have had extensive streetcar systems in the past. Cincinnati started building a subway in the 1920s but abandoned the construction due to high costs. Rochester has the distinction of being the only city in North America to first build a subway, and then to abandon it. Today, Richmond has only a busway.

Success stories are few and far between in this book, although a few cities can be considered successful in some regards. The city of Houston, despite its car dependency and vast sprawl, built a well functioning light rail system that focuses on its inner-city areas. The Houston system carries twice as many riders per mile of track as does the one in Dallas, a city with a similar metro population. The Montréal Metro system is a notable success story, too, unlike many other large municipal projects there. Pittsburgh's decision to focus on a good bus system in conjunction with its few light rail lines is shown to be a success. In British Colombia, Vancouver built an automated, mostly elevated, rail transit system that is well liked and is well used. In this, Vancouver contrasts with other cities that rejected elevated tracks in favour of more expensive underground systems, such as Washington, DC, which built a good system in its core city.

Despite the *North America* in the title, the book includes only United States and Canadian cities. The author acknowledges the absence of chapters about Mexican urban rail systems, explaining that the history of urban transit in Mexico follows a different trajectory. While this limitation may disappoint some readers expecting a continental scope, it allows for a more in-depth exploration of the unique challenges and successes experienced by American and Canadian cities in the realm of urban transportation.

While most of the maps that Berman created are excellent, there are instances where certain maps suffer from very small font sizes, especially the maps of historic streetcar and elevated lines in New York, Philadelphia, Detroit, and Montréal. Many of these maps appear to have been originally designed for use at a larger size: for example, on his **website** Berman sells prints of the Montréal map at 12×18 and 24×36 inches, but that map was reduced to approximately 9×11 in order to fit the page size constraints of the book, leading to cramped labeling and poor readability. A larger book format would have been preferable to accommodate these maps more comfortably and enhance their legibility, ensuring that readers can fully appreciate the wealth of information they convey.

Additionally, maps that feature black backgrounds pose readability challenges due to the small font size used for labels. Fortunately, such maps are relatively few within the book, mitigating the impact of this issue.

While the maps serve as a defining feature of the book, their relationship with the accompanying text could be strengthened. A more cohesive link between textual descriptions and visual representations would enrich the reader's understanding, allowing for seamless navigation between narrative explanations and map illustrations. This integration would enhance the overall reading experience, facilitating a deeper engagement with the complex evolution of urban transit systems across different cities.

The historical map of Vancouver is missing some crucial details. The interurban line to Richmond and the lines in the eastern suburbs are not shown. These omissions detract from the map's comprehensiveness and may leave readers with incomplete insights into the city's transit history. There are other missing pieces, too. While some of the maps show the most recent situation of the city, including under-construction lines (Los Angeles, New York, Seattle and Toronto), others do not (Minneapolis, Vancouver, and San Francisco). It would have been good to include these in all cases.

The author explains why North American cities ended up with car dependency, sprawl, and bad transit. Dysfunctional politics, auto-oriented development patterns, racial tensions, and the law of unintended consequences all contributed to the complex web of challenges faced by urban transit planners and policymakers. By elucidating these root causes, the reader is offered a deeper appreciation of the systemic issues underlying the development and management of urban transportation infrastructure.

The selection of cities featured in this book is purposeful, aiming to spotlight specific aspects—whether positive or negative—of their transit histories. While notable cities like Edmonton, Calgary, Denver, and others with mid-sized light rail systems are not included, this deliberate omission doesn't detract from the book's focus. Rather, it allows for a more in-depth examination of a diverse array of urban transit experiences, balancing large metropolises like New York and Chicago with smaller cities that may lack transit systems altogether. Indeed, the book wasn't intended to serve as a comprehensive atlas of every city but rather as a nuanced exploration of select case studies.

The *Lost Subways of North America* is a compelling read for transportation enthusiasts, urban planners, and cartographers. By offering both a critical analysis of past mistakes, and a hopeful outlook for the future, this book serves as a valuable resource for envisioning more sustainable and efficient urban transportation solutions. The conclusion has a hopeful tone, but it acknowledges that it will also be long and difficult job to make transit better.

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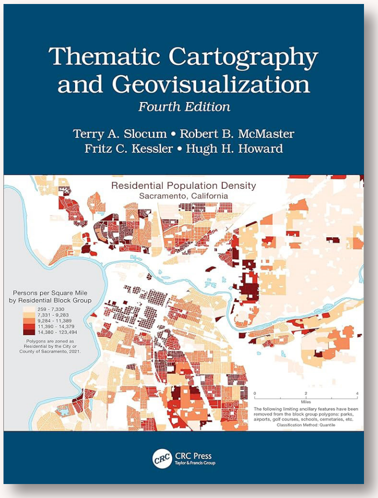

THEMATIC CARTOGRAPHY AND GEOVISUALIZATION, FOURTH EDITION

By Terry A. Slocum, Robert B. McMaster, Fritz C. Kessler, and Hugh H. Howard

CRC Press, 2023

612 pages, with more than 400 maps, artwork, and diagrams

Hardcover: $180.00, ISBN 978-0-367-71270-9

eBook: $180.00, ISBN 978-1-00-315052-7

Review by: Daniel G. Cole, Smithsonian Institution

While I have not read a cartography textbook in several decades, I welcomed the chance to do so here, given the important advances that have taken place in cartography and geovisualization since the last edition of this textbook was published in 2008. The book is divided into twenty-eight chapters, grouped in three parts after Chapter 1: "Principles of Cartography," "Mapping Techniques," and "Geovisualization." It is somewhat grandly stated, right at the beginning of the "Preface," that

> This comprehensive and well-established cartography textbook covers the theory and the practical applications of map design and the appropriate use of map elements. It explains the basic methods for visualizing and analyzing spatial data and introduces the latest cutting-edge data visualization techniques. (i)

The authors then go on to provide justifications for this new edition, including the rise of volunteered geographic information, big data, cloud cartography, story maps, and a variety of new hardware types. The "Preface" also notes the availability of both an e-book and a companion **website**, the latter with student and instructor resources, and answers to the chapters' study questions (available to registered and verified course instructors on a password-protected **Instructor Resources Download Hub**). Lastly, the authors give suggestions on how the book can be used for either one- or two-semester classes.

Beginning with the first, "Introduction," each chapter opens with an overview or introductory section, followed by a list of learning objectives, and then finishes with a summary section, study questions, and references. Unsurprisingly for a work entitled *Thematic Cartography*, thematic maps are addressed immediately in this first chapter, with a definition of what they are and how they are used. The authors illustrate their descriptions with both well and poorly designed examples of dot, proportional circle, choropleth, animated, and physiographic maps, and explanations of why, for example, using a rainbow color scheme on a choropleth map is generally considered bad practice (3, Fig 1.1). Other discussions in this chapter cover map communication, the consequences of recent technological changes in cartography, a definition of geovisualization, and a rundown of geoscience techniques, as well as an overview of some of the cognitive, social, and ethical issues in cartography.

Chapter 2, "A Historical Perspective on Thematic Cartography," opens the "Principles of Cartography" part with a brief, illustrated history of cartography in general, followed by a history of thematic cartography that includes the rise of social cartography. The authors next take up academic cartography, dividing their narrative of this post-1900 phenomenon into four Periods. The history of Period 1 focuses on four leading practitioners active in the mapmaking field before World War II, and Period 2 focuses on three pioneering university programs that emerged after 1945. The development of alternative training forums in the 1970s and 80s is recounted in Period 3, "The Growth of Secondary Programs," with specific mentions of ten such programs such as cartography at Syracuse University, to name just one. Finally, the integration of cartography with GIScience is identified as characterizing Period 4. The chapter finishes with discussions on European thematic cartography (specifically Swiss, British, and French), and what are termed the paradigms of American cartography, discussed under the headings of analytical cartography and of maps and society. The latter is broken down into the sub-paradigms of privacy, power and access, ethics, and public participation GIS/mapping.

The third chapter, "Statistical and Graphical Foundation," is the only one devoted to spatial statistics. It begins with an explanation of the importance of differentiating between populations and samples, and between descriptive and inferential statistics, before moving on to methods that can be used for analyzing the distribution of both individual and multiple attributes using tables, graphs, and numerical summaries. The chapter finishes with discussions of exploratory data analysis and of numerical summaries for geographic data.

Chapter 4, "Principles of Symbolization," succinctly covers the nature of a variety of geographic phenomena, including: spatial dimensions (points, lines, areas, and volumes); discrete and continuous models; levels of measurement (ordinal, interval, ratio, balanced, and unipolar); and visual variables for quantitative and qualitative phenomena. The authors continue with sections on comparing four common thematic mapping techniques (choropleth, proportional symbol, isopleth, and dot maps), on selecting from a variety of visual variables for choropleth maps, and on ways of using other senses (sound, touch, and smell) to interpret spatial patterns.

Chapter 5, "Data Classification," begins by discussing when and why one might employ classed versus unclassed data. It then dives into the many standard classification techniques available, such as equal intervals, quantiles, mean-standard deviation, natural breaks, optimal median (including the Jenks-Caspall and Fisher-Jenks algorithms), and head/tail breaks classing methods. The discussion points out the advantages and disadvantages of each method, and ultimately outlines criteria for selecting a classification method and what to consider regarding data distribution.

Chapter 6, "Scale and Generalization," lays out the differences between geographic and cartographic scales, and addresses the advantages and concerns encountered when using multi-scale databases. Generalization is discussed in its manual and digital domains, with the models of Robinson, Sale, and Morrison (1978) and McMaster and Shea (1992) analyzed. The need for clarity, and for relief from the congestion, coalescence, and conflict of map features, are why generalization is often required. Various operations of generalization are outlined with numerous examples and a few notes on relatively recent developments on how it might be approached.

The basic characteristics of the earth's graticule—latitude, longitude, distance, and directions—are covered in Chapter 7, "The Earth and Its Coordinate System," along with details of the earth's size and shape. It is here that oblate spheroids, reference ellipsoids, graticules, geoids, and geodetic datums, and their relationship to thematic cartography, are succinctly examined.

Chapter 8, "Elements of Map Projections," starts with the concept of projection, and touches upon related matters such as reference globes, developable surfaces, and the mathematics of projecting a globe to a map. The possible geometric classes (cylindrical, conic, and planar), cases (tangent and secant), and aspects (equatorial, oblique, and polar) of projections are covered. The general patterns of map distortion are discussed next, through visual appearance, scale factor, and Tissot's indicatrix; the projection software **Geocart** is suggested for visualizing projection distortions. The final portion of the chapter concerns projection properties (area, angles, distances, and direction), how they are, strictly speaking, mutually exclusive, and how compromise projections can be a potential solution to balancing the strengths and weaknesses inherent in using purely equivalent or conformal coordinate systems.

Chapter 9's advice for "Selecting an Appropriate Projection" is grounded in Snyder's (1994) map projection guidelines for producing maps of the world, a hemisphere, a continent, or an ocean, and for preserving special properties, such as straight rhumb lines, straight line great circle routes, or (in specific instances) correct distances, and is illustrated with numerous examples. The authors finish by writing about using the **Projection Wizard** app to assist in selecting projections for static and web-based interactive maps. I was pleased to see this chapter broken out as a distinct topic, rather than simply being tacked on to

Chapter 8. Given the range of projection-related problems I see in many maps from non-cartographer GIS users, it is clearly critical that projection selection have its own chapter in any "comprehensive and well-established cartography textbook" (i).

Chapter 10, "Principles of Color," begins with how color is processed by the human visual system, and proceeds to explain five commonly used color models (RGB, CMYK, HSV, Munsell, and CIE), the terminology associated with each, and their practical uses. Color wheels, tints, shades, and tones are also discussed, as are the cartographic conventions for qualitative and quantitative color schemes, with the latter including sequential and divergent color ramps.

Chapter 11, "Map Elements," is the first of three chapters concerned with the map as a composed graphic artifact. It starts with the graphic design principles of alignment, centering, balance, and the avoidance of visual noise; many of which are revisited in Chapter 13. Also covered are elements like the frame and neat lines, map area, inset, title and subtitle, legend, data citation, verbal and bar scales, map and page orientation, north arrow versus graticule use, and relative type sizes for various map elements. This last-mentioned topic leads directly to Chapter 12, "Typography," which deals with the characteristics of type (face, family, style, size, weight, case, spacing, and kerning) and with line issues such as alignment and leading. Some of the standard North American map type usage conventions (for example, labeling natural features with serifed faces, and cultural features with sans-serif) are laid out, alongside specific guidelines for how labels should be placed in relation to point, line, and area features, as well as a discussion of aligning labels horizontally versus along with the graticule. The chapter closes with a discussion of the special concerns encountered with automated type placement.

Chapter 13, "Cartographic Design," begins with discussions of the five step "map communication model" based on Shannon's (1948) mathematical theory of communication, the history of map design research, the eight Gestalt principles, the seven step engineering design process (define, ask, imagine, plan, prototype, test, and improve), and the graphic principles of visual hierarchy, contrast, figure-ground, and balance. The rest of the chapter deals with a case study of the steps and procedures involved in designing an attractive, readable, and understandable real estate suitability map.

Chapter 14, "Map Reproduction," appropriately starts with the advice to plan ahead. Among the points to consider are: your audience, budget, deadline, and printing material; if you will need to print in black & white or in color; the sheet size that will be required, if the final product will be folded or flat, whether you will print on only one or on both sides, and what print quality is achievable; and last, but not least, copyright. This is followed by sections on map editing, raster image processing, screening for print reproduction, aspects of color printing, and specialized matters connected with high-volume print reproduction that may or may not apply when delivering a map for publication by a third party.

The second part of the text, "Principles of Cartography," begins with Chapter 15, "Choropleth Mapping," and opens with advice on the selection of appropriate data for enumeration districts, and a recommendation to standardize raw data before use. There is also advice about selecting a color scheme, systems for specifying the colors in those schemes, and approaches appropriate for classed and unclassed choropleths. Completing the chapter are sections on legend design and illuminated choropleth mapping.

Some basic approaches to use for dasymetric mapping are discussed in Chapter 16, "Dasymetric Mapping," with particular attention on selecting appropriate data and ancillary information. The authors highlight the studies by Eicher and Brewer (2001) and Mennis and Hultgren (2006) on intelligent dasymetric mapping (IDM), plus details on two more possible approaches for producing dasymetric maps of population density: mapping landcover, and the use of zoning polygons, while limiting ancillary data sets for both. **SocScape: mapping residential segregation and racial diversity**, a web based data and geo-app site created by Dmowska, Stepinski, and Netzel (2017) is summarized as well, although the URL given in the text is no longer working. The chapter is completed with discussions on mapping global population distribution via **Gridded Population of the World** (GPW), **LandScan**, and **Global Human Settlement Layer** projects.

Chapter 17, "Isarithmic Mapping," deals with selecting appropriate data with the assumption that its output will be continuous and smooth. Further to that goal, there are sections on manual and automated interpolation, with the latter covering triangulation, inverse-distance weighting, kriging, thin-plate splines, and advice on choosing amongst the interpolation methods. The authors single out Tobler's (1979) pycnophylactic, or volume-preserving, interpolation as "a more sophisticated approach for handling conceptual point data" (321). They finish the chapter with an analysis of isarithmic symbolization schemes: contour lines, continuous-tone maps, fishnet maps, and the color-stereographic effect as discussed by Eyton (1990).

Chapter 18 on proportional symbols outlines how to match data with the appropriate type of proportional symbols (pictographic or 2D and 3D geometric), noting the advantages and disadvantages inherent in each. The scaling of proportional symbols (mathematical, perceptual, or range-graded scaling) is discussed, as is the question of whether proportional symbol legends should be nested or linearly orientated, and whether they should adhere to range-graded sizes as determined by Meihoefer's (1969) perceptual study or by Dent's (1999) practical experience. The handling of unclassed versus classed symbols and how to deal with overlapping symbols is addressed as well. The chapter finishes with an evaluation of the necklace maps developed by Speckmann and Verbeek (2010). These last are a type of proportional symbol map that displaces the symbols, sometimes called beads, along a curve surrounding the map's geographic area of interest.

Chapter 19 investigates the key issues in creating dot maps: determining dot size, value, distribution (uniform, geographically weighted, or geographically based to reflect realism), and manual versus digital placement. Should the legend equate a single dot with a single value, or should it display samples of significant densities? The text discusses both possibilities. Graduated dot maps are also presented, with an example employing three sizes of dots. Interactive dot maps are addressed through an evaluation of Walker's (2018) **Educational Attainment in America** online map. Readers should note that the URL in the book takes them to a map of Hawaii, while the example in the book is of San Francisco, and the urban examples given on the website are of five other urban areas, none of which are San Francisco or in Hawaii.

Chapter 20 addresses the most common forms of cartograms (distance, value-by-area, univariate, and bivariate). The authors analyze attempts to preserve shapes with contiguous, non-contiguous, gridded, and mosaic cartograms, as well as other methods that do not preserve shapes, such as rectangular, Dorling, and Demers cartograms. The accuracy of each of these disparate cartogram methods is discussed, supported by a user study of how accurately each type is read. The chapter ends with consideration of some alternatives to cartogram methods, including: combined choropleth/proportional symbol maps, value-by-area maps, and balanced cartograms. Arguably, this last alternative, introduced by Harris et al. in 2017, may be the easiest to read and interpret.

Chapter 21, "Flow Mapping," starts with the three main types of flow maps (origin-destination, trajectory-based, and continuous) and the six flow map design issues as identified by Dent, Torguson, and Hodler (2009):

> Flow lines have the highest intellectual importance and thus should be placed at the top of the visual hierarchy on the map. Smaller flow lines should appear on top of larger flow lines. Arrows should be used if the direction of flow is critical to the map meaning. Care should be taken in selecting a map projection appropriate for flow mapping… If data permits, flow lines should be placed such that the map appears balanced… Legends should be unambiguous and include units where necessary. (379)

The evolution of flow mapping is illustrated with two examples of flow maps created before automation, three examples of early digital efforts by Tobler, and several recent examples of digital flow mapping by Stephen and Jenny (2017), Koylu and Guo (2017), Koylu, Tian, and Windsor (2021), and Yang et al. (2019). Finishing this chapter is an evaluation of the geovisual analytics of flow maps via an integration of 2D maps with 3D space-time cubes.

Chapter 22, "Multivariate Mapping," begins with bivariate mapping; comparing choropleth maps, miscellaneous thematic maps, and maps showing data for two points in time. This leads into an exploration of the combination of two variables on the same choropleth map, and then to additional bivariate mapping techniques. Multivariate techniques elucidated include multiple map comparisons, multiple colored dot maps, and other multivariate point symbol maps, including ray-glyphs or stars, polygon glyphs or snowflakes, 3D bars, data jacks, Chernoff faces, and ring maps. The chapter ends with several pages on the basic steps for making multivariate maps and for adding a contiguity constraint in hierarchical cluster analysis.

The third part, "Geovisualization," begins with Chapter 23, "Visualizing Terrain." Here, the authors start off with techniques to represent data or elevation surfaces (hachures, contour-based methods, Raisz's physiographic method, shaded relief, and morphometric techniques). They follow up with analyses of oblique views (block diagrams, panoramas, and plan-oblique relief), physical models, and details involved in creating shaded relief: generalization, selecting azimuth and sun elevation, contrast, Swiss-style drawing, and colors for hypsometric tints.

Chapter 24, "Map Animation," quickly covers the early developments in map animation tools, followed by definitions of the pertinent motion/visual variables (duration, rate of change, order, display date, frequency and synchronization). Among the examples of temporal animation are: movement and flows, animated choropleth maps and the issues involved, proportional symbol maps, isarithmic maps, and bubble plots. Nontemporal animations are represented by some early works by Peterson (1993; 1999) and Gershon (1992), fly-overs, plus Viegas and Wattenberg's **Wind Map**. These examples lead into a discussion of ways to enhance interactivity in animations, with reference to the work of researchers such as Harrower, MacEachren, and Griffin (2000), Harrower (2002), and **CoronaViz** by Samet et al. (2020). After rhetorically asking if animations really work, the authors conclude that more research is necessary to make them effective. They wrap up the chapter by providing a set of eight guidelines for producing animations, and a closing section on using 3D space for displaying temporal data.

"Data Exploration" is the title of Chapter 25. It starts with a discussion of the goals and methods of data exploration, and proceeds to an analysis of how nine data exploration software applications (Moellering's 3D mapping software, ExploreMap, Project Argus, MapTime, CommonGIS, **GeoDa**, **Micromaps**, **ViewExposed**, and **Tableau**) measure up in applying the methods to achieve those goals.

In Chapter 26, "Geovisual Analytics," the authors take up the question on everyone's lips: *What is geovisual analytics*? They answer by diving into the characteristics and limitations of big data; the concept of the Self-Organizing Map (SOM) as developed by Skupin and Agarwal (2008); and a description of five examples of geovisual analytics: **TaxiVis**, **Mosaic Diagrams**, **CarSenToGram**, **Crowd Lens**, and **SOM**.

Chapter 27, "Visualizing Uncertainty," begins with the basic elements of uncertainty (MacEachren et al. 2005), and goes on to address the general methods and visual variables appropriate for the depiction of uncertainty, including the use of Tissot's indicatrix and MacEachren's dimensions of clarity (crispness versus fuzziness), resolution, and transparency. Appropriate situations for the employment of uncertainty visualization include: choropleth class breaks, the use of SAAR (*S*patial *A*nalysis using *A*rcGIS Engine and *R*) software, climate change, decision making for water balance and hurricanes, along with some examples of interactivity and animation. Sound can also be used to depict data uncertainty, and the authors cite thirteen sound dimensions as identified by Ballatore, Gordon, and Boone (2019), but note that the cited article did not involve a spatial component, and is thus only a first step towards cartographic use.

Chapter 28, "Visual Environments and Augmented Reality," completes the textbook, first by defining the terms visual environment (VE) and augmented reality (AR), describing the four "I" factors of VEs (immersion, interactivity, information intensity, and intelligence of objects), and surveying the many forms that hardware for such systems can currently take: personalized displays (head-mounted and desktop) and room-size, wall-size, and drafting table displays (**GeoWall**, **CAVE**, and **ImmersaDesk**). Having thus described the lay of the VE/AR land, the authors identify four key questions to be addressed: *Are specialized symbols necessary for thematic maps created in VE*? *Are stereoscopic maps more effective than non-stereoscopic maps*? *What are some examples of VEs that make use of CAVES and wall-size displays*? and *What progress has been made toward developing a digital earth*? They jump to some recent examples of AR use including: the AR Sandbox, using AR to enhance understanding of topographic maps, developing novel methods for interacting with AR environments, and holograms. A discussion of health, safety, and social issues (such as cybersickness) that can arise when using VEs and AR rounds out the chapter.

The tome is completed with a twenty-page glossary and a twelve-page index.

My quibbles with the fourth edition of *Thematic Cartography and Geovisualization* are few, and uniformly minor. An example of one, a typo that occurs in several other places as well, appears on page 26: a website URL with the "s" missing after "http." Another complaint concerns where the authors note, on page 30, that *Goode's World Atlas* is now available in its twenty-first edition. A quick web search reveals that the twenty-*third* edition had, in fact, appeared before this book was published. I also note the occasional dead or misdirected web link that crops up here and there throughout the text, but it could be argued that such issues are endemic when hardcopy books cite dynamic internet sources.

I recently heard from one of the authors (Kessler, in a personal communication, 2024) that *Thematic Cartography and Geovisualization* is more popular in Europe than it is in the United States; something I have a hard time understanding. Overall, to my mind, this impressive book stands far above any other cartographic textbook available. I recommend it as required reading for every GIS/cartographic program across academia. At a list price of $180 (though it can be found for less), this is not an inexpensive textbook; but considering that it can, or should, be used for two quarters or semesters of classwork and will remain a rich and relevant resource of cartographic and geovisualization knowledge for some years to come, it is a worthwhile investment. While the cost may be prohibitive for some, it is available in eBook format for 10% less at times; and, in both electronic and paper format, it gives students and instructors access to valuable online resources.

REFERENCES

Ballatore, Andrea, David Gordon, and Alexander P. Boone. 2019. "Sonifying Data Uncertainty with Sound Dimensions." *Cartography and Geographic Information Science* 46 (5): 385–400. **https://doi.org/10.1080/15230406.2018.1495103**.

Dent, Borden D. 1999. *Cartography Thematic Map Design, Fifth Edition*. Boston, MA: McGraw-Hill.

Dent, Borden D., Jeffrey S. Torguson, and Thomas W. Hodler. 2009. *Cartography: Thematic Map Design, Sixth Edition*. Boston, MA: McGraw-Hill.

Dmowska, Anna, Tomasz F. Stepinski, and Pawel Netzel. 2017. "Comprehensive Framework for Visualizing and Analyzing Spatio-Temporal Dynamics of Racial Diversity in the Entire United States." *PLoS ONE* 12 (3): e0174993. **https://doi.org/10.1371/journal.pone.0174993**.

Eicher, Cory L., and Cynthia A. Brewer. 2001. "Dasymetric Mapping and Areal Interpolation: Implementation and Evaluation." *Cartography and Geographic Information Science* 28 (2): 125–138. **https://doi.org/10.1559/152304001782173727**.

Eyton, J. Ronald. 1990. "Color Stereoscopic Effect Cartography." *Cartographica* 27 (1): 20–29. **https://doi.org/10.3138/K213-2288-7672-U72T**.

Gershon, Nahum. 1992. "Visualization of Fuzzy Data Using Generalized Animation." *Proceedings, Visualization '92,* Boston, MA, 268–273. **https://doi.org/10.1109/VISUAL.1992.235199**.

Harris, Richard, Martin Charlton, Chris Brunsdon, and David Manley. 2017. "Balancing Visibility and Distortion: Remapping the Results of the 2015 UK General Election." *Environment and Planning A* 49 (9): 1945–1947. **https://doi.org/10.1177/0308518X17708439**.

Harrower, Mark. 2002. "Visual benchmarks: Representing Geographic Change with Map Animation." Ph.D. diss., The Pennsylvania State University.

Harrower, Mark, Alan MacEachren, and Amy L. Griffin. 2000. "Developing a Geographic Visualization Tool to Support Earth Science Learning." *Cartography and Geographic Information Science* 27 (4): 279–293. **https://doi.org/10.1559/152304000783547759**.

Koylu, Caglar, and Diansheng Guo. 2017. "Design and Evaluation of Line Symbolizations for Origin-Destination Flow Maps." *Information Visualization* 16 (4): 309–331. **https://doi.org/10.1177/1473871616681375**.

Koylu, Caglar, Geng Tian, and Mary Windsor. 2021. "FlowMapper.org: A Web Based Framework for Designing Origin-Destination Flow Maps." *Journal of Maps* 19 (1): 1996479. **https://doi.org/10.1080/17445647.2021.1996479**.

MacEachren, Alan M., Anthony Robinson, Susan Hopper, Steven Gardner, Robert Murray, Mark Gahegan, and Elisabeth Hetzler. 2005. "Visualizing Geospatial Information Uncertainty: What We Know and What We Need to Know." *Cartography and Geographic Information Science* 32 (3): 139–160. **https://doi.org/10.1559/1523040054738936**.

McMaster, Robert G., and K. Stuart Shea. 1992. *Generalization in Digital Cartography*. Resource Publications in Geography. Washington, DC: Association of American Geographers.

Meihoefer, Hans-Joachim. 1969. "The Utility of the Circle as an Effective Cartographic Symbol." *The Canadian Cartographer* 6 (2): 105–117. **https://doi.org/10.3138/J04Q-1K34-26X1-7244**.

Mennis, Jeremy, and Torrin Hultgren. 2006. "Intelligent Dasymetric Mapping and its Application to Areal Interpolation." *Cartography and Geographic Information Science* 33 (3): 179–194. **https://doi.org/10.5194/essd-14-2833-2022**.

Peterson, Michael P. 1993. "Interactive Cartographic Animation." *Cartography and Geographic Information Systems* 20 (1): 40–44. **http://doi.org/10.1559/152304093782616724**.

———. 1999. "Active Legends for Interactive Cartographic Animation." *International Journal of Geographic Information Science* 13 (4): 375–383. **https://doi.org/10.1080/136588199241256**.

Robinson, Arthur H., Randall D. Sale, and Joel L. Morrison. 1978. *Elements of Cartography, Fourth Edition*. New York: Wiley.

Samet, Hanan, Yunheng Han, John Kastner, and Hong Wei. 2020. "Using Animation to Visualize Spatio-Temporal Varying COVID-19 Data." In *1st ACM SIGSPATIAL International Workshop on Modeling and Understanding the Spread of COVID-19*, Seattle, WA, 53–62. **https://doi.org/10.1145/3423459.3430761**.

Shannon, Claude Elwood. 1948. "A Mathematical Theory of Communication." *Bell System Technical Journal* 27 (3): 379–423. **https://doi.org/10.1002/j.1538-7305.1948.tb01338.x**.

Skupin, André , and Pragya Agarwal. 2008. "Introduction: What is a Self-Organizing Map?" in *Self-Organizing Maps: Applications in Geographic Information Science*, edited by P. Agarwal and A. Skupin, 1–20. Chichester, UK: John Wiley. **https://doi.org/10.1002/9780470021699.ch1**.

Snyder, John P. 1994. *Map Projections: A Working Manual.* Washington, DC: US Government Printing Office. **https://doi.org/10.3133/pp1395**.

Speckmann, Bettina, and Kevin Verbeek. 2010. "Necklace Maps." *IEEE Transactions on Visualization and Computer Graphics* 16 (6): 881–889. **https://doi.org/10.1109/TVCG.2010.180**.

Stephen, Daniel M., and Bernhard Jenny. 2017. "Automated Layout of Origin-Destination Flow Maps: U.S. County-to-County Migration 2009-2013." *Journal of Maps* 13 (1): 46–55. **https://doi.org/10.1080/17445647.2017.1313788**.

Tobler, Waldo R. (1979) "Smooth Pycnophylactic Interpolation for Geographical Regions." *Journal of the American Statistical Association* 74 (367): 519–536. **https://doi.org/ 10.1080/01621459.1979.10481647**.

Walker, Kyle .E. 2018. "Scaling the Interactive Dot Map." *Cartographica* 53 (3): 171–184. **https://doi.org/10.3138/cart.53.3.2017-0021**.

Yang, Yalong, Tim Dwyer, Bernhard Jenny, and Kim Marriott. 2019. "Origin-Destination Flow Maps in Immersive Environments." *IEEE Transactions on Visualization and Computer Graphics* 25 (1): 693–703. **https://doi.org/10.1109/TVCG.2018.2865192**.

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