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Practical and Emblematic Roles of the American Polyconic Projection

Content

Summary

The polyconic projection was an emblem of nineteenth-century American federal cartography. Neither conformal nor equivalent, it minimizes distance distortion on large-scale sheet maps with a local central meridian. The Coast Survey, which published projection tables and a mathematical description in its 1853 annual report, adopted the polyconic projection for its nautical charts as well as for "smooth sheet" plots of raw survey data. The Survey began converting its nautical charts to a more suitable Mercator framework in 1910 but retained the polyconic projection for smooth sheets until digital technology obviated these plots in the 1990s. The U.S. Geological Survey, which adopted the projection in the early 1880s, incorrectly claimed a polyconic framework for its topographic quadrangle maps decades after switching to conformal projections around 1950. The polyconic projection's longevity reflects bureaucratic inertia as well as any map projection's potential significance as a graphic signature. As several small-scale world maps also demonstrate, a projection acquires emblematic value when an organization selects a single cartographic perspective from several plausible yet sub-optimal solutions.

Zusammenfassung

Die polykonische kartographische Abbildung war ein Symbol der amtlichen amerikanischen Kartographie des 19. Jhs. Sie ist weder konform noch flächentreu und minimiert Längenverzerrungen auf großmaßstäbigen Karten mit einem örtlichen Mittelmeridian. Das Coastal Survey publizierte Abbildungstabellen und eine mathematische Beschreibung im Jahresbericht 1853 und verwendete die polykonische Abbildung sowohl für seine Seekarten als auch für Arbeitskarten. Im Jahr 1910 begann das Coastal Survey seine Seekarten in eine dafür besser geeignete Mercatorabbildung überzuführen, behielt aber die polykonische Abbildung für Arbeitskarten bei, bis die digitale Technologie diese in den 1990er Jahren überflüssig machte. Das U.S. Geological Survey, welches die polykonische Abbildung in den frühen 1880er Jahren für topographische Karten übernommen hatte, wechselte um 1950 zu konformen Abbildungen, bezeichnete das räumliche Bezugssystem aber weiterhin fälschlich als ein polykonisches. Die Langlebigkeit der polykonischen Abbildung spiegelt sowohl administrative Trägheit als auch die potenzielle Signifikanz eines Kartnennetzentwurfes als grafische Signatur wider. Wie auch mehrere kleinmaßstäbige Erdkarten zeigen, gewinnt eine Netzabbildung symbolischen Wert, wenn eine Organisation eine einzelne kartographische Perspektive aus mehreren plausiblen, jedoch suboptimalen Lösungen, wählt.

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1 Introduction

This chapter explores the iconographic and practical roles of the polyconic projection, sometimes called the ordinary polyconic, the American polyconic, the Coast and Geodetic Survey polyconic, or HASSLER's polyconic. The latter name reflects the projection's vague mention at the end of a lengthy 1825 essay by Ferdinand Rudolph HASSLER, the Swiss geodesist who immigrated to the United States in 1805 and served as first superintendent of the Survey of the Coast (later known as the U.S. Coast and Geodetic Survey, and now part of the National Oceanic and Atmospheric Administration). Although textbooks (e.g., DEETZ & ADAMS 1945, p. 60; FISHER & MILLER 1944, p. 73) attribute the projection to HASSLER, its complete mathematical development was not available until the early 1850s, nearly a decade after HASSLER's death in 1843.

In this chapter I examine the various roles the polyconic projection played during the nineteenth and twentieth centuries at the Coast and Geodetic Survey, the U.S. Lake Survey, and the U.S. Geological Survey. In addition to chronicling the use of the polyconic projection many decades after more suitable map projections were readily apparent, I argue that its survival is partly a result of bureaucratic inertia and partly a reflection of its value to the Coast Survey as an emblem or graphic signature. Although the polyconic was used principally for survey plots and other large-scale maps, its emblematic role is at least vaguely akin to that of small-scale world maps adopted by organizations eager for a projection with a distinctive look or arguably advantageous cartographic properties.

2 The Polyconic Framework

As its name implies, the polyconic projection is developed from a multiplicity of cones (see figure 1). Because every parallel is a tangent line, east-west scale is constant. Unlike projections developed from a single cone, the parallels are not concentric. Their apexes align along the central meridian, which serves as the projection's backbone and is the only line free of distortion. Because the parallels diverge, north-south stretching increases with distance from the central meridian, as do distortions of angles and relative area. As the whole-world graticule in figure 2 shows, the projection is neither conformal nor equivalent.

An advantage of the polyconic projection is its ease of construction, especially for large-scale maps based on published projection tables (DEETZ & ADAMS 1945, pp. 63-64). Disadvantages arise when users require precise angular measurements for navigation or gunnery. For navigation the preferred framework was Mercator's projection, on which straight lines represent loxodromes. Until the advent of long-range artillery around the beginning of the twentieth century, gunnery officers typically relied on trial and error in aiming field cannons at visible targets. Longer-range field guns like the famous French 75, a rapid-fire 75-millimeter cannon that could hit targets five miles away, proved more reliable when direction and range were calculated using rectangular coordinates based on a conformal projection.

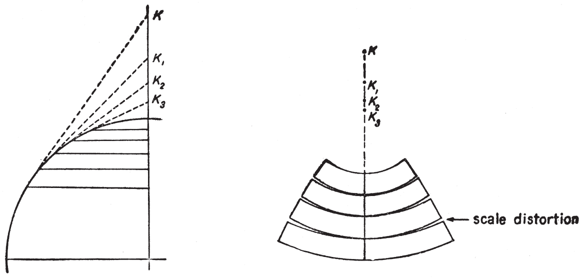

Fig. 1: Development of the polyconic projection, as exemplified by three or four cones covering narrow belts and sharing the same central meridian (from DEETZ & ADAMS 1945, p. 61, fig. 48)

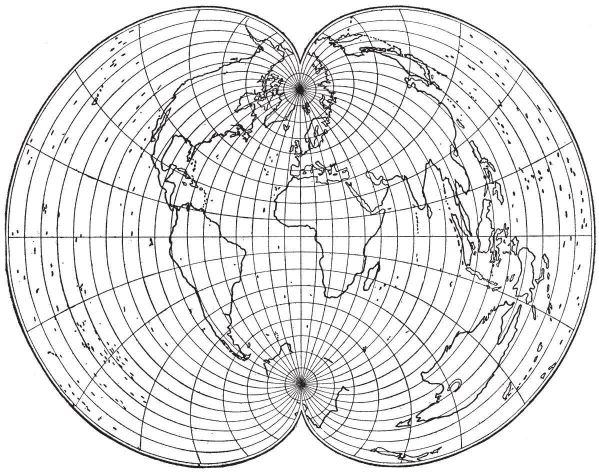

Fig. 2: Whole-world polyconic projection (from DEETZ & ADAMS 1945, p. 61, fig. 49)

HASSLER's was not the only polyconic projection. Variations noted by SNYDER (1993, pp. 119-122, 247-248) include the equal-area and equidistant polyconic projections, as well as the modified polyconic with two standard parallels once used for the 1:1 million-scale International Map of the World (DEETZ & ADAMS 1945, pp. 65-70). A related framework is the projection named for Rigobert Bonne, who used it for a 1752 atlas of coastal France (SNYDER 1993, pp. 60-61). A modification of Ptolemy's second projection, Bonne's projection (see figure 3) preserves relative area, maintains true scale along all parallels, and is free of distortion along both its central meridian and its central parallel. Because these properties reflect the modification of a simple conic projection with one standard parallel rather than the use of multiple cones, the Bonne projection is considered pseudoconic rather than polyconic. According to DEETZ and ADAMS (1945, p. 62),

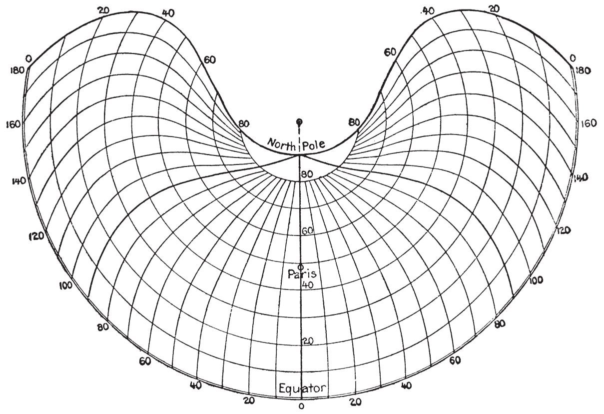

Fig. 3: Bonne projection of the northern hemisphere, as developed for a cone tangent at 45°N (from DEETZ & ADAMS 1945, p. 70, fig. 52)

the Bonne and polyconic projections are "practically identical" within 3° of a common center because errors attributable to the construction of the graticule and the distortion of the paper exceed discrepancies between the projections.

3 HASSLER's Role

Historians attribute much of the Coast Survey's success to Ferdinand HASSLER, the Swiss mathematician-geodesist hired in 1811 to develop procedures and buy equipment for the new agency, authorized by Congress in 1807 (WEBER 1923, pp. 1-5). Appointed superintendent in June 1816, HASSLER took over an underfunded agency vulnerable to impatient politicians with little interest in scientific principles and accurate measurement. Congress forced him out in April 1818 by assigning the fledgling agency and its executive positions to the Navy. Between 1818 and 1832, when he was rehired as superintendent, HASSLER supported his family by farming, surveying, teaching, writing textbooks, and selling off family heirlooms. Under Navy management the poorly funded Coast Survey made little progress. In 1832 Congress transferred the agency to the Treasury Department, which had hired HASSLER in 1830 to direct its Office of Weights and Measures. Reappointed superintendent of the Coast Survey, HASSLER continued to serve as the country's chief metrologist.

HASSLER's reappointment is hardly surprising. In 1820 he had sent the American Philosophical Society an insightful treatise, which was published in the Society's Transactions in 1825 under the title "Papers on Various Subjects connected with the Survey of the Coast of the United States." Deterred by neither his dismissal nor a less than fluid command of English, HASSLER presented a workable strategy for measuring and delineating the nation's coastline, harbors, and coastal waterways. Various sections describe scientific instruments and systematic techniques for measuring baselines and conducting fieldwork.

HASSLER's "Papers" includes ten plates and runs to nearly two hundred pages. He raised the issue of map projection at the end of his final section, which addresses the pragmatics of a triangulation survey and the transfer of measurements to paper maps. In his words, "the accuracy of the projection is therefore the basis upon which the accuracy of the whole work depends, and to this great attention is to be paid" (HASSLER 1825, p. 406). HASSLER introduced his concept of a polyconic framework with a short description of a simple conic projection:

"The projection which I intended to use was the development of a part of the earth's surface upon a cone, either a tangent to a certain latitude, or cutting two given parallels and two meridians, equidistant from the middle meridian, and extended on both sides of the meridian, and in latitude, only so far, as to admit no deviation from the real magnitudes, sensible in the detail surveys. . . ." (HASSLER 1825, p. 406).

I call your attention to his use of the past tense, "intended," and his concern with the relationship between error and distance from a standard line.

Larger maps would be compiled from plane table field charts, integrated according to a trapezoidal grid.

"In each of these sheets, it was intended to bring the results of several parallels, so that the central meridian alone should become a straight line, and all the other meridians and parallels broken lines, nearest the curve, to which they belong; the angular points of the trapezium being transferred to paper by their rectangular ordinates, from the middle right angle, calculated from the angle at the center of the projection, in the protracted axis of the earth" (HASSLER 1825, p. 407).

Note here the approximation of curved meridians and parallels by a series of straight lines to form a grid of trapezoids. Multiple cones, HASSLER reasoned, could reduce distortion to an acceptable, negligible level.

"This distribution of the projection, in an assemblage of sections of surfaces of successive cones, tangents [sic] to or cutting a regular succession of parallels, and upon regularly changing central meridians, appeared to be the only one applicable to the coast of the United States. Its direction, nearly diagonal through meridian and parallel, would not admit any other mode founded upon a single meridian and parallel without great deviations from the actual magnitudes and shape, which would have considerable disadvantages in use" (HASSLER 1825, pp. 406-407).

Note his concern that a generally diagonal coastline did not recommend a projection with a north-south or east-west belt of low distortion. Note too that nowhere in his treatise did Hassler assert the need for an indefinitely large number of infinitesimally thin conic projections, and nowhere did he present or outline the mathematical derivation of formulae for constructing projection tables.

The sentence that followed—the final sentence of his treatise—was an act of faith in the procedure's effectiveness and efficiency:

"Their union in one general map on a small scale would be exceedingly easy, and in making a minute projection, could almost be done without the aid of instruments" (Hassler 1825, p. 408).

Like many surveyors, Hassler seemed not to appreciate the need for precision in "small scale," "general" maps.

4 Coastal Charting after Hassler

The inherently slow pace of precise triangulation deferred the formal mathematical development of the polyconic projection. Charles Schott (1882, p. 293), who served as chief of the Coast and Geodetic Survey's computing division from 1856 to 1899, provided a sketchy synopsis of the projection's history for the 1880 annual report. According to Schott, the "first large chart" was a six-sheet, 1:30,000-scale map of New York Bay. Initiated by Hassler and published in 1844, a year after his death, the New York chart was laid out "simply (and necessarily)" on a rectangular projection. In 1844, Hassler's successor, Alexander Dallas Bache, supervised the design of 1:80,000-scale charts for Long Island Sound and Delaware Bay. Their projections, although not identified, but were obviously conic. Schott assumed that the charts were laid out on Bonne's projection.

Projection tables apparently were not produced until the late 1840s or early 1850s. The annual report for 1853 includes formulas and tables for a polyconic projection developed on Bessel's ellipsoid (Hunt & Schott 1854). One table covers small-scale maps of areas as large as what became the conterminous United States, and another addresses large-scale local maps. Schott provided the formulas and tables, and Lieutenant E. B. Hunt, of the U.S. Engineers, prepared the descriptive notes, which mention a rectangular polyconic projection, with right-angle intersections of meridians and parallels, as well as the equidistant polyconic, a graphic approximation "in common use in the Coast Survey office for small areas, such as those of plane-table and hydrographic sheets" (Ibid., p. 100). Annual reports for 1856 and 1859 contain projection tables developed by Julius Hilgard (1856 and 1860) for small-scale maps of continental or global extent.

For large-scale coastal charts, focused on describing details and distances, map projection was not a significant issue.

"In the ordinary Coast Survey practice of making projections for the use of topographic and hydrographic surveys it is absolutely the same whether the polyconic or the Bonne projection be used, since the curvature of the meridians never becomes sensible and that of the parallels only rarely. Indeed, the two almost merge into the rectangular projection on our plane table and hydrographic sheets, scale 1:10,000 or 1:20,000" (Schott 1882, p. 294).

According to Schott, the polyconic, the Bonne, and even the rectangular projection were essentially interchangeable.

A significant rival, at least in principle, was the Mercator projection, the clear favorite of late-nineteenth-century mariners. In 1869, the Navy published projection tables for both the Mercator and the polyconic projections, and in their own work, naval hydrographers relied on the Mercator framework. Initially content with Coast Survey charts, the Navy eventually began to question the continued use of an obsolete projection. According to the Coast Survey's annual report for 1909/1910, a board was appointed to study the issue after the Navy "urgently requested" adoption of the Mercator framework (U.S. Coast and Geodetic Survey 1911, p. 11). Although the report argued that "the difference between the Mercator and the polyconic projections is imperceptible" on large-scale charts, the Coast and Geodetic Survey accepted the board's recommendation to adopt the Mercator projection.

"The difference between the Mercator and the polyconic projections is imperceptible on the large-scale charts, but on the small-scale charts it is very apparent, especially in northern latitudes" (U.S. Coast and Geodetic Survey 1911, p. 11).

Persistence of the polyconic projection into the early twentieth century reflects the slow pace of coastal charting, slow adoption of the charts for navigation, and increased use of somewhat smaller-scale charts, especially for steamships. Particularly telling is a sentence in the annual report for 1889 that expresses surprise that Coast Survey charts were in demand "by mariners and others who actually use them in navigation" (U.S. Coast and Geodetic Survey 1890, p. 98).

"Reference is made by Mr. Wines to the increase in the demand for charts by mariners and others who actually use them in navigation, two thousand four hundred and three more copies having been sent out to meet requests from sales agents during the preceding fiscal year" (U.S. Coast and Geodetic Survey 1890, p. 98).

Conversion was understandably slow. The annual report for 1915 identified the U.S. Lake Survey as the only holdout, but continued to deny any "practical difference" between the Mercator and polyconic projections for large-scale charts.

"Excepting the United States Lake Survey, all nautical chart-producing organizations construct their charts on the Mercator projection. There is no practical difference except in high latitudes between the Mercator projection and the Polyconic projection, in so far as the charts on a scale of 1:80,000 or larger are concerned, but the difference between the projections is appreciable for the smaller scales and is an objectionable feature of the old series of charts" (U.S. Coast and Geodetic Survey 1915, p. 141).

Although less than half the charts had been switched to the Mercator projection by 1920 (U.S. Coast and Geodetic Survey 1920, p. 26), conversion was essentially complete by 1930, except for the Great Lakes charts, which were maintained by the Army Corps of Engineers.

The Corps maintained the lakes charts until 1970, when the Coast and Geodetic Survey, the National Weather Service, and several other agencies were combined to form NOAA, the National Oceanic and Atmospheric Administration (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service 1997, pp. 2-9 through 2-11). For whatever reason, conversion was not a priority for either the Corps or NOAA. As of summer 2002, a few of the Great Lakes charts were still on polyconic projections (Wilson 2002).

In the pantheon of bureaucratic inertia, the slow conversion of the Great Lakes charts is overshadowed by the U.S. Geological Survey's commitment to the polyconic projection in practice through the late 1950s, and in name at least a decade longer. According to John Snyder (1982, pp. 2-3), the Geological Survey "apparently chose the polyconic projection for its [topographic] mapping program . . . soon after [its founding] in 1879." Although the first USGS maps did not identify the projection, the name "polyconic" appeared as early as 1886, and in 1904 the Survey published tables of rectangular "coordinates of curvature" that were actually polyconic tables based on a 1884 Coast and Geodetic Survey publication (Snyder 1982, pp. 126-127). In the late 1950s, USGS began casting new topographic maps on the projection designated for the locality's State Plane Coordinate zone, that is, on either a Lambert Conformal Conic or a Transverse Mercator projection. But according to Snyder (1982, p. 127), "some of the quadrangles prepared on one or the other of these projections have continued to carry the polyconic designation."

In its approach to map projection the Coast and Geodetic Survey was more forward looking than its topographic counterpart. In the early 1930s Oscar S. Adams, the agency's geodetic expert, designed the State Plane Coordinate System (Adams 1934, Dracup 2002). And in the late 1920s the Coast Survey selected the Lambert Conformal Conic projection for the nation's civilian aeronautical charts (Deetz & Adams 1945, pp. 82-85).

Even so, federal hydrographers continued to use the polyconic framework for their "smooth sheets," defined as large-scale plots for recording soundings, control data, feature names, and other field data (Shalowitz 1964, vol. 2, p. 87). According to the first edition of the agency's Hydrographic Manual, "polyconic projections shall be used for all hydrographic surveys" (Hawley 1931, p. 3). As a passing reference to the appropriate tables observed, "the usual procedure is to construct the projection in pencil" (Hawley 1931, p. 31). A revision published in 1942 clarified the relationship between the Mercator and the polyconic projections.

"Although most nautical charts are constructed on the Mercator projection, all original field surveys are plotted on the polyconic projection which is especially useful for this purpose" (Adams 1942, p. 7).

The 1942 Manual noted that the agency had not only adopted the polyconic framework for its field plots but also named the projection after itself.

"The Coast and Geodetic Survey has adopted for all surveys a projection, known as the Coast and Geodetic Survey polyconic projection. All surveys must be plotted on this projection" (Adams 1942, p. 667).

In 1960, the third edition reiterated both the requirement and the name (Jeffers 1960, p. 4). By contrast, the fourth edition, published in 1976, recognized the transverse Mercator and the polyconic projections as "essentially equivalent" but called for the polyconic unless the project specifically required a transverse Mercator framework.

"Hydrographic survey data shall be plotted either on the modified transverse Mercator or on a polyconic projection. At the relatively large scales required for hydrographic surveys, the two projections are essentially equivalent and may be used interchangeably for comparisons and transfer of hydrographic data" (Umbach 1976, p. 1-6).

Manual plotting on polyconic field charts continued until the late 1990s, when digital measurement technology obviated this intermediate step (Wilson 2002).

5 Emblems and Signatures

The need to codify mapmaking procedures forced the selection of standard projections. The Coast

Survey adopted the polyconic for its nautical charts and phased it out reluctantly, starting in 1910, after Navy hydrographers aggressively argued for their own emblematic projection, the Mercator. Meanwhile, the Geological Survey, which apparently embraced the polyconic because the mathematical infrastructure was conveniently available (GANNETT 1893, p. 129 and 1906, p. 85; U.S. GEOLOGICAL SURVEY c. 1955), continued to use it several decades after the Coast Survey had endorsed conformality. The U.S. Lake Survey, heavily invested in a polyconic framework, was another prominent holdout.

Adoption of the polyconic projection is very much a part of the discourse on cartographic accuracy (e.g., EDNEY 1997, HARLEY 1991). As various Coast Survey publications assert, several mathematically distinct, locally centered projections would suffice for very-large-scale maps like field plots. Simply put, the distortion associated with earth curvature can be far less significant than the combined errors associated with paper shrinkage, survey instrumentation, and manual plotting. Although geometric distortion is measurably greater with coastal charts and topographic maps, for most applications and most users a theoretically suboptimal map projection would have little effect on usability or reliability, especially in the nineteenth and early twentieth centuries, when mapmakers largely dismissed conformality (e.g., HINKS 1912, p. v). In this milieu, selection of a nonconformal map projection like the polyconic could be governed by its historical link, however tenuous, to the Coast Survey's founding superintendent, and its emblematic application could survive until electronic data acquisition made field plots obsolete.

In addition to providing a framework for cartographic display, a map projection can become a signature—an optional flourish embedded in the identity of product or producer. For small-scale maps, the signature can be visually blatant, as in the case of the Peters projection. For large-scale maps, the signature might be most apparent as a label in the legend—and thus sustain cartographic forgeries like the Geological Survey's falsely labeled polyconic topographic maps of the 1960s. In this sense, the polyconic framework's continued use, real or claimed, is at least partly emblematic.

Unlike federal agencies, for which conversion of a large-scale map series is tedious and expensive, atlas publishers can readily adopt new cartographic perspectives. Although design changes are touted as improvements in usability, commercial cartographers also want to make their products appear fresh and themselves progressive. Recent examples include the National Geographic Society's adoption of the Robinson projection in 1988 and, with less fanfare, the Winkel tripel projection ten years later. Much the same motives no doubt underlie the demise in the late 1940s of the equatorially centered Mercator world map as an emblem of cartographic authority.

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7 List of figures