
G

Games, Cartographic. Cartographic pastimes include playing cards, games (similar to board games), and puzzles. Additionally, some books included games: rules of play were described, and sometimes the relevant maps, but a playing surface was not usually provided.

Rare before 1600, and the subject of much debate among Enlightenment educational thinkers, cartographic games were published in increasing numbers in the seventeenth and eighteenth centuries. The earliest known English cartographic playing cards were printed by William Bowes (1590) from county maps by Christopher Saxton. In France, cartographic cards created by Jean Desmarets de Saint-Sorlin (engraved by Stefano Della Bella) were published in 1644. Earlier, Henry Peacham had described a French pack he considered suitable for juvenile use: “the foure suites [are] changed into Maps of severall Countries, of the foure parts of the world, . . . the Pourtraies of their Kings and Queenes [are] in their severall Countrey habits; for the Knaues, [in that of] their Peasants or Slaues; which ingenious deuce, cannot be but a great furtherance to a young capacitie” (Peacham 1622, 65). Not all playing cards displaying instructional material were intended for children, but Henry Winstanley designed and published cards (ca. 1675) “Dedicated to the Hon^{ble} James Herbert Esq. not for his Improvement, But that it was Part of his Studjs and from Whom I must own to have Received most of my Instructions in the Composing of [them].” These displayed “All the Principal Nations of the World Presented in their Habits (or Fashion of Dressing) with a Prospect of their Capital Citys and a Geographical Description of the Provinces . . . and as Much of History of all, as Could be Contained in so Small a Space” (reproduced in Wayland 1967, frontispiece). Each suit represented a continent, hearts equaling Europe, diamonds Asia, spades Africa, and clubs the Americas.

The earliest cartographic board games appear to have been those devised by Pierre Duval, *géographe du roi*. Modeled on the rules and order of play of the game of the goose, a spiral track race game played by adults across Western Europe since at least the sixteenth century, *Le jeu du monde* (1645) (fig. 250), *Le jeu de France* (1659; 1671), *Le jeu des princes de l’Europe* (1662?; 1670), and *Le jeu des François et des Espagnols pour la paix* (1660), all from different publishers, were designed for youth and ladies (Seville 2008b, 430–32; Girard and Quétel 1982, 39–49). Duval also designed *Le jeu de France pour les dames* (1652), this time based on a draughts board, with thirty-two blank squares and thirty-two squares with maps of the French provinces (Hill 1978, 7–8). Around the same time, and little more than half a century after Danish astronomer Tycho Brahe’s catalog of stars was published, Étienne Vouillemont designed *Le jeu de la sphère ou de l’univers selon Tyco Brahe* (1661). French publishers, particularly Crépy and Basset (both in Paris), continued to produce similar games throughout the eighteenth century.

Only a few years after Duval’s games, a book of a “game of the world,” probably the work of the Jesuit Matthais Kirchoffer, was published at Graz. *Orbis lusus* (1659) appears to be the earliest game in which a map served as the playing surface. The map was not provided—players were to draw it themselves on an orthographic projection (Sekolec 2009). The game was still known when the *Encyclopédie* was published (Diderot and d’Alembert 1751–72, 14:792), and may have influenced later designers of cartographic games.

French geography textbooks were popular in seventeenth- and early eighteenth-century Britain, so it is surprising that there is no record of English cartographic games similar to those of Duval until the 1750s. It is difficult to believe that the concept was neither imported nor copied in Britain for almost a century, especially given the cross-Channel trade in European maps and prints, the popularity of French fashions in England, Peacham’s reference to French cartographic playing cards, and fugitive references in this period to printed pastimes teaching reading, but no such games, copies, or derivatives of them have so far been located.



FIG. 250. PIERRE DUVAL, LE JEU DU MONDE (1645). © The British Library Board, London (Cartographic Items Maps *999.[27]).

The earliest known English cartographic board game was *A Journey Through Europe, or The Play of Geography* “Invented and sold by the Proprietor, John Jefferys . . . Writing Master, Accomp^t., Geographer, &.” for 8s. (Whitehouse 1951, 6–7). The sole surviving copy bears the imprint of Carington Bowles but the date of 1759. It must thus have originally been printed for either Thomas (II) or John Bowles. Trading on the popularity of Thomas Nugent’s guidebook, *The Grand Tour* (1749) (Shefrin 1999b, 15), the map, on which numbers were engraved at specific locations, was the playing board, and the first player to reach London won the game. This device of following a tour on a map, with the players as travelers, the counters their servants, and the rulebook written as a guidebook, was imitated by English mapsellers and children’s booksellers well into the nineteenth century.

Unlike Continental table games, which were sold as unmounted sheets, the physical format of most early English cartographic board games was modeled on contemporary traveling maps: the engraved sheet was cut into rectangular sections, mounted on linen, and folded into a cardboard slipcase. Map cartouches as well as slipcases were often decorated with emblematic vignettes of the costumes, wildlife, famous buildings, or products and manufactures of regions mapped. Nineteenth-century games sometimes additionally display representations of natural, mechanical, and cultural artifacts and events in various parts of the world superimposed on the body of the map. When the player landed on a particular location, historical, geographical, or economic information was read out from the accompanying numbered rules that were either pasted onto the linen backing at either side of the map or bound into a rulebook. Play instructions frequently reflect contemporary values. In John Jefferys’s game, “He who rests on N^o48 at Rome for kissing y^e Pope’s Toe shall be banish’d for his Folly to N^o4 in the cold Island of Iceland and miss three turns” (reproduced in Whitehouse 1951, facing 6). In the 1790 edition of *Bowles’s Geographical Game of the World*, visitors to Paris are invited to “*stay one turn to rejoice at the establishment of Liberty, the fall of Despotism, and destruction of the Bastil[l]e, at the memorable Revolution of 1789*” (direction no. 75), and *Bowles’s European Geographical Amusement*, published a year later (1791), required players to stay two turns at Paris “to contemplate the New French Constitution . . . and . . . the Bastile demolished in 1789” (direction no. 3).

The origins of dissected maps remain murky, but they were probably being made at home by parents, tutors, and governesses long before their commercial debut. An intriguing reference to the practice survives in a letter from Johann Kaspar Wettstein to Mlle. de Chaires, governess to the future George III and his siblings. In

1744 Wettstein writes that he is sending two dissected manuscript maps to the young princes (Barber 2011, 26). Eberhard David Hauber, in what appears to be the earliest published reference, recommended that geography be taught to children “in an easy and playful way . . . by cutting the provinces of the countries, depicted on a map, along their borders, mixing them up, and afterwards having the pupil sorting . . . assembling them” (Hauber 1727, 26; Heinz 2015). Commercially available precursors of dissected maps include Johann Jacob Lidl’s *Neu und accurat verfaste General Post Land-Karte des sehr grossen Welt berühmten König-Reichs Hungarn* (ca. 1750), “composed . . . with great care, principally for the benefit of teachers and youth” (Shefrin 2003, 79–80). The verso of this map is printed in eighty rectangles, each having one or more numbers corresponding to a list of place-names printed on the recto, and well as to locations on the map itself.

Later in the same decade, evidence for the sale of dissected maps in England can be found in an advertisement for a school run by Jeanne-Marie Leprince de Beaumont, a French governess and writer working in London. Among the list of school charges was a fee of one-half guinea for *les cartes de géographie en bois* (geographical wooden maps). Contemporary references suggest that Leprince de Beaumont’s dissections became a fashionable novelty. London diarist Mary Delany, in a letter written in 1759, declared: “I wish I could tell how to get a set of Madame Beaumont’s wooden maps. I think those of England, Scotland, and Ireland come to two guineas” (Shefrin 2003, 5). Two years later, Lady Caroline Fox wrote that her son learns “geography on the Beaumont wooden maps” (Shefrin 2003, 6). The earliest surviving English examples, played with by the children of George III, are tangentially associated with Leprince de Beaumont but not directly attributable to her. Created from the copperplate-printed maps of Jean Palairt’s *Atlas méthodique* (1755), like the earliest commercially available dissected maps they are mounted on thin sheets of mahogany and cut along the political borders, although the cutting is much more elaborate and delicate than those later sold by the map trade (fig. 251).

John Spilsbury was the first English mapseller to market dissected maps. In the early 1760s his puzzles ranged in price from 7s.6d. to £1.1s (Hannas 1972, 18). As with the games, the idea was soon adopted by other mapsellers. Maps sold as dissections included the work of Emanuel Bowen, Thomas Kitchin, Archibald McIntyre, John Gibson, and John Cary. The cost might be kept down by selling a dissection cut out at the borders of the country without the frame provided by the ocean or neighboring countries. Such puzzles cost less, but were actually more difficult to assemble. Just as the extent of cartographic information offered to children in the



FIG. 251. A DISSECTION CUT FROM A COPY OF THE PLATE CARTE DE L'AMÉRIQUE SEPTENTRIONALE. The cutting, including the inland bodies of water, is much more elaborate than that on commercially produced dissected

maps of the period. From Jean Palairt's *Atlas méthodique* (London, 1755). Museum of Childhood Collection. © Victoria and Albert Museum, London (B.6-2011).

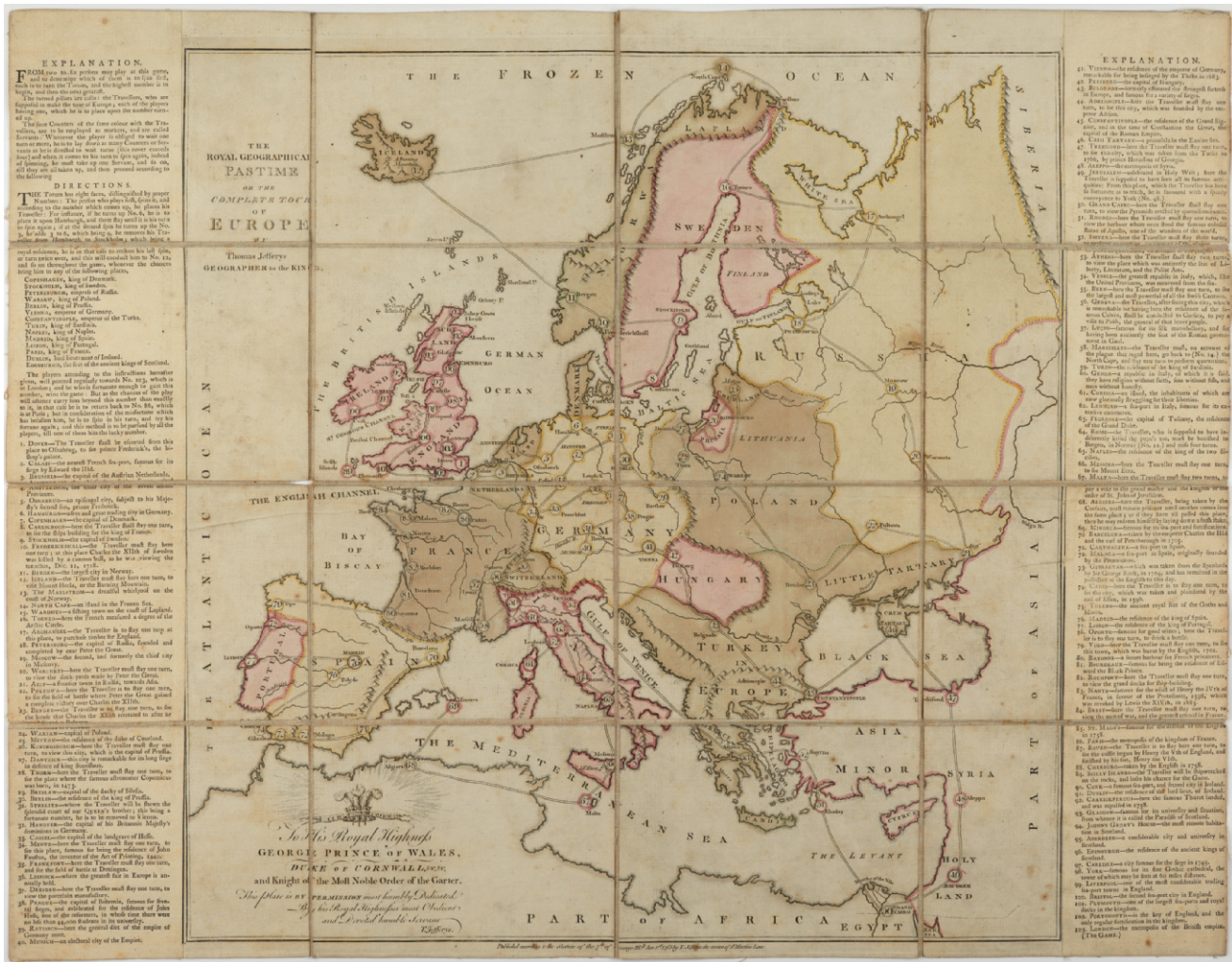


FIG. 252. THOMAS JEFFERYS, *THE ROYAL GEOGRAPHICAL PASTIME OR THE COMPLETE TOUR OF EUROPE*, 1768. Copper engraving.

Size of the original: 52 × 68 cm; folds to 17 × 13 cm. Image courtesy of the Cotsen Children’s Library, Department of Rare Books and Special Collections, Princeton University Library.

different types of pastimes varied considerably, so too did the quality. Some mapsellers probably sold off old stock of maps as dissections for children, but others, William Darton junior for one, carefully presented their juvenile dissections as current. Some dissected maps, such as the *Map of the Various Paths of Life* (1794), attributed to George Dillwyn, were allegorical.

The Dutch firm of Covens & Mortier was publishing dissections by the 1780s—if not earlier—and Francisco de Goya’s portrait of a young Luis María de Borbón y Vallabriga (1783) shows the boy standing beside a table with a partially assembled dissected map, a single piece still in his hand. By the end of the century, references to map dissections can be found in English juvenile and adult fiction, educational treatises, correspondence, diaries, and perhaps most famously in Jane Austen’s *Mansfield Park* (1814). There are also paintings and illustra-

tions, the earliest being a portrait (ca. 1770) by William Hoare of two small boys assembling a dissected map (Shefrin 1999b, 6, 21; see fig. 225).

Although John Jefferys appears to have designed only one game and Spilsbury died relatively young in 1769, the pastimes they sold must have been commercially successful. Between 1768 and 1770 Thomas Jefferys published three *Royal Geographical Pastimes: The Complete Tour of Europe* (1768) (fig. 252); *Exhibiting a Complete Tour thro’ England & Wales* (1770); and *Exhibiting a Complete Tour Round the World* (1770), all dedicated to the young Prince of Wales. In 1778 William Faden advertised a set of the three games, presumably from Jefferys’s stock, for £1.1s. (Shefrin 1999b, 19 and notes). Robert Sayer and the Bowles family sold cartographic games and dissections through the 1770s and 1780s. From the mid-1780s the firms of William

Darton and John Wallis, who sold both maps and children's books, as well as children's bookseller Elizabeth Newbery, also offered dissected maps, as did Woodman & Mutlow (advertising their shop as "Late Spilsbury's" [Shefrin 1999b, 9–10]).

Of the English cartographic puzzles and games published before 1800, Europe was most commonly portrayed dissection, followed by the other continents, country maps of England, Ireland, and Scotland, and, lastly, the world. Spilsbury offered individual dissected maps of most European countries, although none have survived, and he may have intended to produce them on demand. Similarly, the most common table game was of Europe, but followed by the world, Britain, the other continents, and other European nations. By the end of the century, the thriving English industry in cartographic games and puzzles even included *Tour through the County of Somerset, a Geographical Game* (1805), which must have had only regional interest.

Erasmus Darwin, writing in 1797, expressed reservations about dissected maps although he recommended abbé Gaultier's "cours de Geographie" (22), referring to Gaultier's *A Complete Course of Geography, by Means of Instructive Games* (2d ed., 1795). This was a bound volume that included maps. Darwin also approved "a compendious system of geography on cards, published by Mr. Newberry [*sic*], . . . [which] supplies a very convenient method of instructing children" (21), reminding us that cartographic playing cards for children continued to be popular throughout the period.

The low survival rate for games and pastimes generally makes it difficult to accurately assess either the popularity or the cultural impact of cartographic games. But eighteenth-century publishers were highly entrepreneurial, suggesting that the manufacture of these games and novelties would have slowed to a trickle had they not proved profitable. Their success is also indicated by the multiple editions and variants of some games, by the sheer numbers of different games and puzzles published over less than a century, and by references to their value in teaching geography. Many, particularly those produced in England, were expensive to purchase and marketed to a relatively elite audience. Of those that have survived, a number are still in private collections, and those in institutions are only slowly being cataloged and/or digitized. The only known copy of John Jefferys's game, that reproduced by F. R. B. Whitehouse (1951, 6–7), was sold at auction with Whitehouse's collection in the 1950s; its current location is unknown.

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SEE ALSO: Consumption of Maps; Education and Cartography
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Garden Plan. Gardens were richly represented in the artistic culture of medieval Europe, yet garden plans were virtually unknown there until the Renaissance, when spatial integration with architecture became a priority in garden design. The new mode privileged measurement, mathematical proportions, and symmetrical relationships, in keeping with principles of architecture,

and it engaged the forms of orthographic projection then being standardized in the visual representation of buildings, namely plan, section, and elevation.

Plans had specific strengths and limits in the representation of garden form. Most significantly, they could reveal spatial relationships not readily apprehended in other graphic formats or through real experience. Yet, until the late eighteenth century, garden plans—like maps of the same period—were limited in their ability to represent differences in elevation. Therefore, steeply angled prospects, conflating the discrete advantages of plans and views, were long preferred over true plans for presentation images, and, until the end of the eighteenth century, many plans represented trees in elevation—a practice also common in mapping—to help viewers distinguish them from other forms of land cover.

As components of larger landscapes, gardens were frequently represented on early modern maps (Boudon 1991, 125). However, the practical scales for representing gardens were typically much larger than those used for property maps, even in the case of large princely estates. Also, the purposes for which maps were commissioned rarely required that the specific and frequently changing forms of private gardens be depicted accurately. Consequently, whereas many early maps offer valuable information about the general locations of gardens and their positions relative to buildings, natural features, and infrastructure, they usually represent garden plans symbolically (e.g., a quadrant divided by two paths) and therefore cannot be relied upon for more specific design information.

Despite the high cultural value placed on gardens in early modern Europe, the practice of garden design was not professionalized there until the nineteenth century. In the absence of an established pedagogy of design, publications offered valuable practical and theoretical models and played a critical role in shaping design developments. Images of gardens circulated widely through descriptive and theoretical works, and graphic literacy developed quickly among cultural elites, for whom garden design became a subject of intellectual inquiry and patronage. In treatises, principles and methods of design were sometimes demonstrated through diagrammatic plans, as in André Mollet's *Le jardin de plaisir* (1651). In descriptive works, such as monographic folios and guidebooks, plans were usually presented first and keyed so as to situate subsequent individual views and corresponding texts.

When the ground surface of a garden was understood to be planar, and therefore like a sheet of paper, its design could be represented sufficiently in plan alone. Such images proliferated in treatises and manuals during the seventeenth and eighteenth centuries. The conventions of symmetry meant that a design could be represented

economically by showing only one half or one quarter of its plan, with the understanding that the unseen portions could be filled in through mirroring. Following that logic, two or four alternate schemes were sometimes presented on a single sheet, as if a disjointed plan.

From the Renaissance to the early eighteenth century, garden design throughout Europe was dominated by regular (i.e., rule-based) approaches. That manner reached its zenith in the royal gardens at Versailles and their many imitators (e.g., Drottningholm Palace, near Stockholm, Sweden; the Belvedere, Vienna, Austria; Peterhof Palace, Saint Petersburg, Russia). The principles of regular design were codified in Antoine-Joseph Dezallier d'Argenville's widely disseminated treatise, *La théorie et la pratique du jardinage* (1709), a section of which explained how to translate designs in plan on paper to much larger forms on the ground (Dezallier d'Argenville 1747, 103–25).

During the eighteenth century, a reaction against regular design took shape, first in Great Britain and then on the European continent. Many designers abandoned the conventions of regular design in favor of asymmetrical forms and arrangements. Histories of garden design typically frame that turn as a triumph of picture over plan, as if the new mode were synonymous with picturesque composition, inspired by landscape views. However, approaches to irregular design were highly varied and drew upon a wide range of influences, including some that were exclusively plan-based. For example, the Baron de Bouis, a map enthusiast and entrepreneur with interests in the pedagogy of geography, proposed that the Tuileries gardens in Paris be transformed into a map of Europe (fig. 253), and he later relabeled an existing map of Paris and environs to construe it as a garden plan (Besse 1995, 268–90).

Contemporary developments in topographical surveying and mapping had direct and indirect influences on irregular garden design. During the seventeenth century, regular design drew on civil and military engineering for forms (e.g., bastions, canals) and technical methods of construction. During the eighteenth century, garden designers continued to look to engineering, but the basis for that interest shifted from elements of infrastructure to topographical surveying and mapping. Surveying had long been recognized as an essential skill for civil and military engineers, and it had strong practical value for garden designers in site analysis and construction. But maps also facilitated imaginative thinking about the elements of landscape, their formal properties, and their relationships to each other. Recognizing that potential, the French *ingénieur géographe* Louis Charles Dupain de Montesson declared that engineering, architecture, and garden design were linked through the utility of maps and plans (Dupain de Montesson 1763, v).

Many individuals involved with the design, representation, and patronage of irregular gardens had exposure to surveying and mapping through contexts of civil and military engineering. For example, during the 1730s and 1740s, the London-based surveyor and mapmaker John Rocque drew and published plans of important new gardens in England. During the 1770s and 1780s, the Paris-based mapmaker and mapseller Georges-Louis Le Rouge published a monumental series of garden design prints, with hundreds of plates representing irregular schemes. Le Rouge was not a theorist of garden design, nor is he known to have had any practical experience as a gardener. Instead, his credibility and involvement were based on his expertise as a surveyor, developed through work as an *ingénieur géographe*, and his success in the map trade. In the late 1770s, when the head gardener at the Petit Trianon at Versailles, Antoine Richard, was asked to structure a method for learning how to design

irregular gardens, he included study of land surveying with Le Rouge (Hays 2002, 102–3).

Over the course of the Enlightenment, technical developments in surveying and mapping transformed the picture of land broadly speaking. By the second half of the eighteenth century, the quality of work had advanced to such an extent that theorists began to idealize maps as copies of nature. Surveyors were trained to think of mapping as a mimetic art, in which the formal qualities of the representation corresponded strictly to those of the place depicted. According to contemporary ideology, the naturalness of a map was directly proportional to the specificity and rigor of its scientific production. Following that idea, garden designers interested in emulating landscape forms could look to maps for inspiration (fig. 254).

During the Enlightenment, growing map literacy facilitated the naturalization of irregular design in gardens

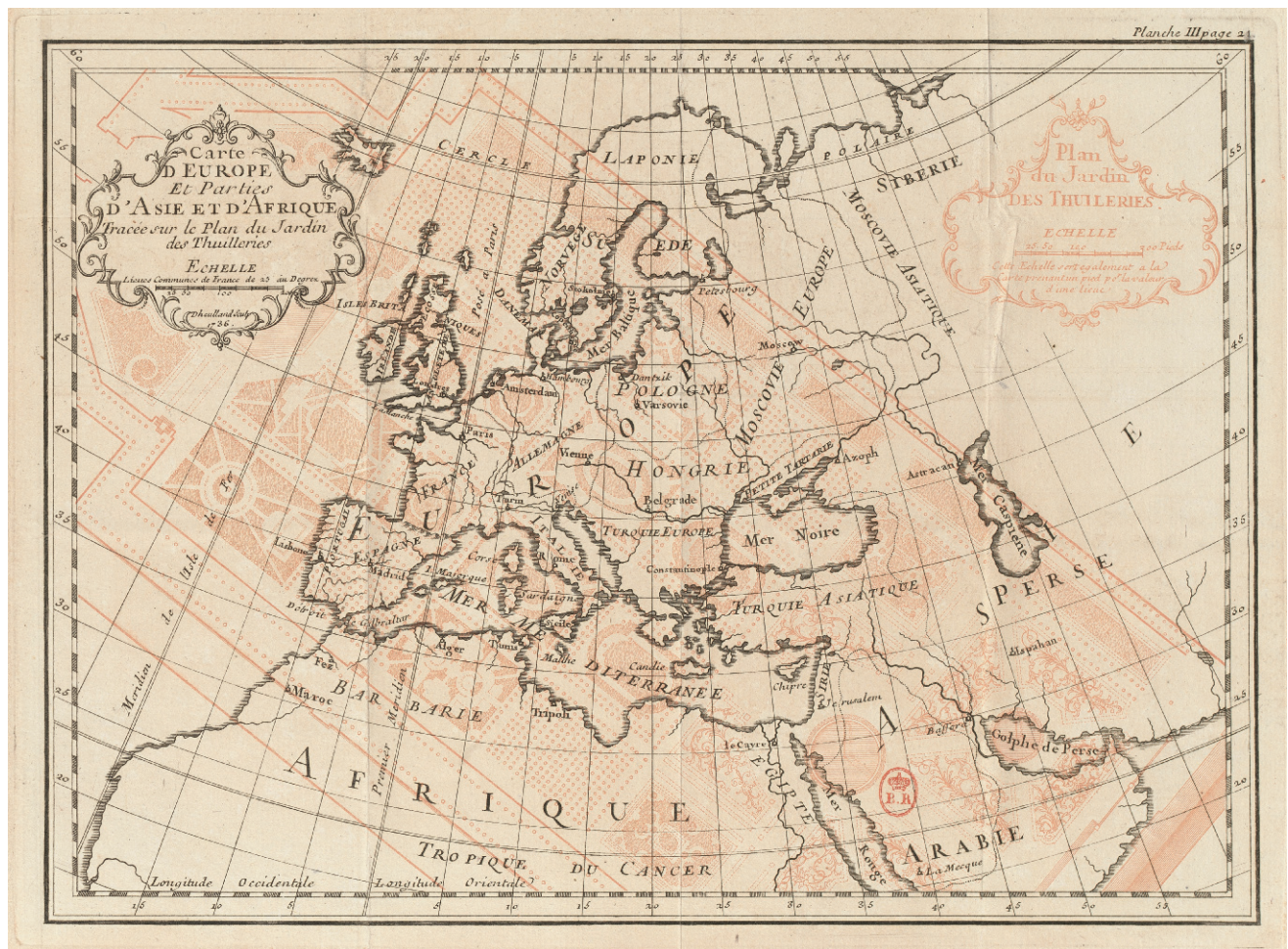


FIG. 253. BARON DE BOUIS, CARTE D'EUROPE ET PARTIES D'ASIE ET D'AFRIQUE TRACÉE SUR LE PLAN DU JARDIN DES THUILLERIES, 1736. From Bouis's *Le parterre géographique et historique, ou Nouvelle méthode*

d'enseigner la géographie et l'histoire (Paris: Nyon Fils, 1737), pl. 3, p. 21. Copper engraving in two colors. Image courtesy of the Bibliothèque nationale de France, Paris.

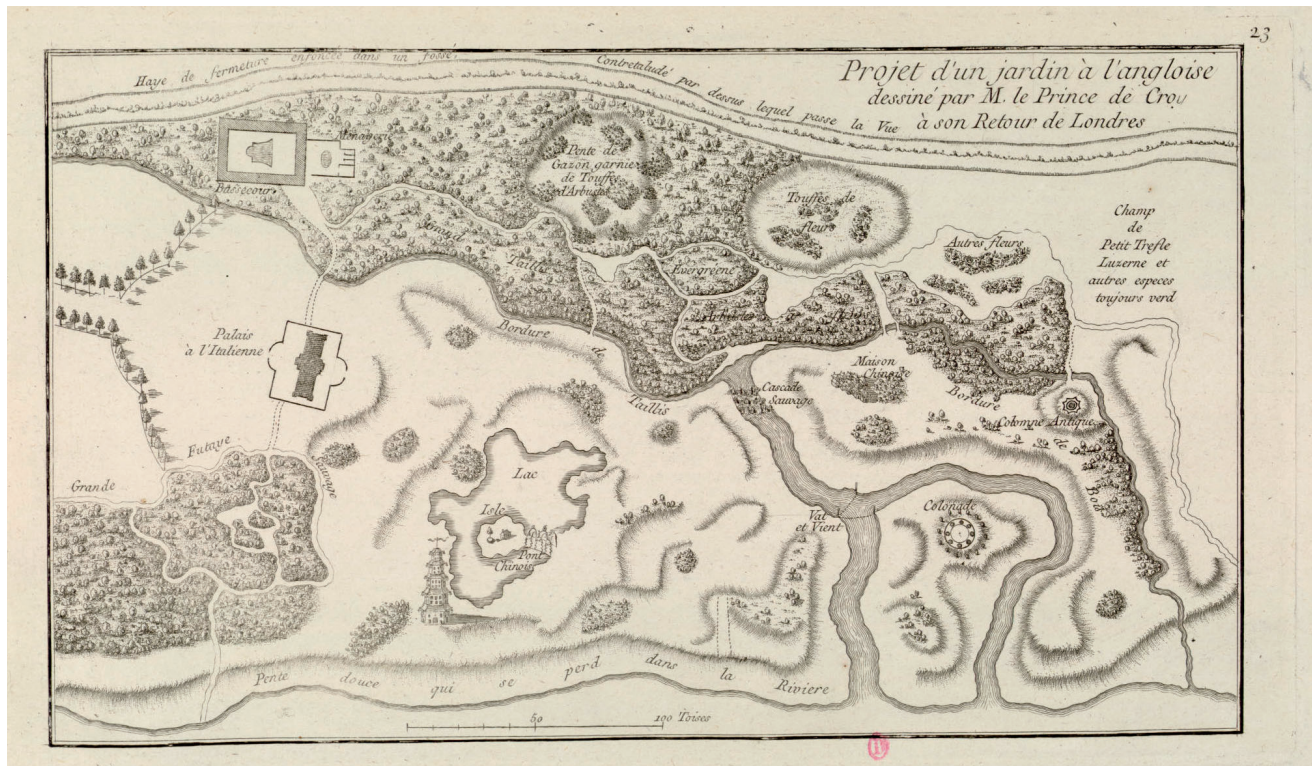


FIG. 254. *PROJET D'UN JARDIN À L'ANGLOISE DESINÉ PAR M. LE PRINCE DE CROY À SON RETOUR DE LONDRES*. From Georges-Louis Le Rouge, *Détail des nouveaux jardins à la mode* (also known as *Jardins anglo-chinois*), 21 cahiers (Paris: [ca. 1773/75]–1788), cahier 1, p. 23. Copper engraving.

Size of the original: ca. 18.5 × 33.5 cm. Image courtesy of the Bibliothèque de l'Institut national d'histoire de l'art, Paris (Collections Jacques Doucet, NUM 4 RES 216 [1]).

on the European continent and beyond. In that regard, surveying and mapping played a role equivalent to that which the ha-ha (i.e., the sunken fence) had assumed earlier in Britain (Hunt 2012, 172–85). Both were technical innovations that made it possible to “leap the fence” and mediate new relationships between concepts of the garden and the larger landscape.

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SEE ALSO: Landscape, Maps, and Aesthetics; Map Trade; Property Mapping; Topographical Surveying

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Geodesy and the Size and Shape of the Earth.

Geodesy—the measurement of the size and shape of the earth—was of persistent interest to natural philosophers, astronomers, geographers, and some mapmakers throughout the long Enlightenment. The geodetic surveys undertaken to solve the question of the figure of the earth are discussed in the following entries; this essay addresses the scientific and cartographic issues at stake. There are effectively two stories here: one of the surveying and measurement of artificial lines across the surface of the earth in order to calculate its size and shape, the other of the mathematical analysis of the precise

curvature of the earth. The two stories coincided in the 1720s and 1730s with the debate in Paris over whether the earth is flattened at the poles (fig. 255, middle) or elongated (squeezed) at the equator (fig. 255, bottom) and with the two great expeditions to Peru and Lapland in 1735–45 that were intended to resolve the issue. Historians have naturally emphasized this period. Misled by contemporary rhetoric, many have maintained that the expeditions were intended as grand experiments to prove either the Cartesian or Newtonian systems of celestial mechanics; however, they did not and indeed could not serve that function (Greenberg 1995, 83–84; Passeron 1998). And, while the expeditions might have settled the general matter of the earth's figure, they did not provide a precise solution. The expeditions therefore represent a highpoint in the history of Enlightenment geodesy, but not its culmination.

The ancient Greek doctrine that the earth is spherical was enshrined in Aristotle's natural philosophy (Grant 1994, 626–30). This idealized sphericity—idealized in that philosophers were willing to neglect variations in the earth's surface, notably mountains and seas—became a fundamental component of early modern cosmography. It was manifested both in the conventional pairing of celestial with terrestrial globes and in instructional texts that focused only on the issue that the earth is spherical, not flat (e.g., Ozanam 1711, 141–43; see Dekker 2002). This traditional corpus of knowledge was affected neither by the growing speculation after 1660 that the earth was not in fact spherical nor by the debates and new surveys that that realization engendered. Indeed, the question of the earth's shape was largely irrelevant to Enlightenment geographers and navigators (d'Alembert 1756, 761). While some geographers, notably Rigobert Bonne, did think it necessary to adjust regional maps for the earth's shape, Didier Robert de Vaugondy argued to the Académie des sciences in 1775 that the necessary corrections would enlarge the

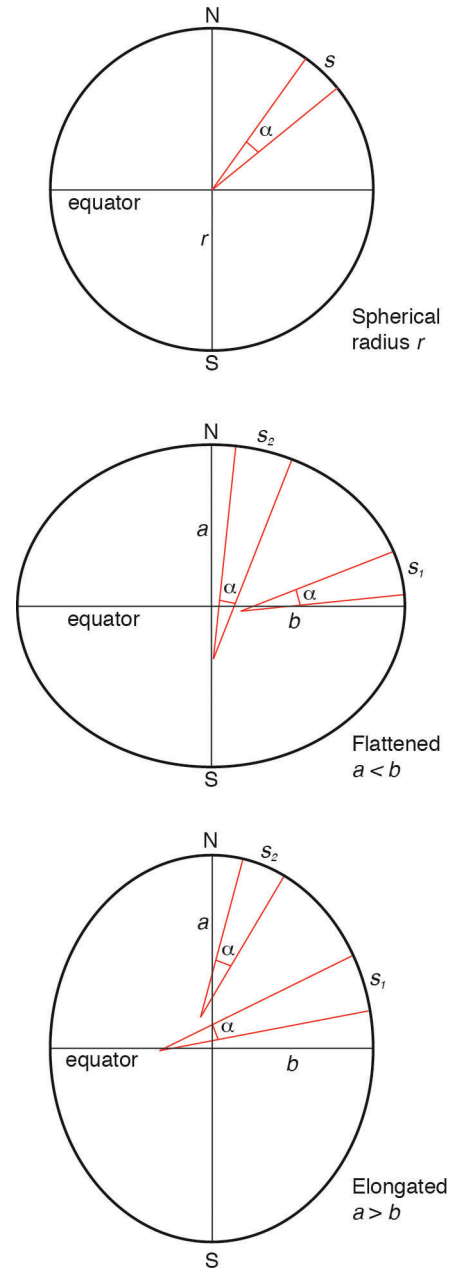


FIG. 255. CONCEPTIONS OF THE FIGURE OF THE EARTH, 1650–1800, VISUALLY EXAGGERATED FOR EFFECT. Top: cross-section of a sphere, the traditional form. The size of the sphere was calculated from the measured or calculated length s of an arc of a meridian (through α degrees of latitude), or perhaps of another great circle such as the equator. The earth's size was commonly expressed in terms of the length of one degree of latitude ($\frac{1}{\alpha}$), its circumference ($\frac{360}{\alpha}$), or its radius r (derived from circumference, $2\pi r = \frac{360}{\alpha}$). Middle: cross-section of an oblate spheroid, flattened at the poles, formed by rotating an ellipse about its polar axis when the polar radius a is less than the equatorial radius b (i.e., a is the semiminor axis of the ellipse, b the semimajor axis); the length of an arc of a meridian increases toward the poles ($s_1 < s_2$). Bottom: cross-section of a prolate spheroid, elongated (or squeezed) at the equator, formed by rotating an ellipse about its polar axis when the polar radius is greater than the equatorial radius; the length of a degree of a meridian decreases toward the poles ($s_1 > s_2$). As a spheroid, the lengths of the earth's radii (a , b) were calculated from measurements of s_1 and s_2 . Its shape was variously expressed by the fraction ($\frac{1}{n}$) of the semiminor axis by which the semimajor axis was longer ($a = b(1 + \frac{1}{n})$ if the spheroid is oblate); by the ratio of its polar and equatorial radii ($\frac{a}{b}$); or by its ellipticity (or degree of flattening: $f = \frac{b-a}{b}$). Latitude is determined with respect to local verticals. Note that “oblate” and “prolate” are used more by modern historians than eighteenth-century mathematicians and natural philosophers, who at times confused the terms, so they are otherwise avoided.

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height of a normal-size map of Europe by only $\frac{1}{2}$ ligne (0.188 mm), which would be imperceptible to the average reader; besides, paper shrank after printing by much greater amounts (Pedley 1992, 109–12; Godlewska 1999, 52–54). What mattered to geographers was the earth's size, not its shape, and once the issue of its size was settled by Jean Picard's work in France, completed in 1671, they continued to treat it as a sphere and used simple measures of the length of a degree to compare linear measures.

The Enlightenment investigation of the earth's precise figure was nonetheless important to contemporary developments in other arenas within the mapping sciences. The effects of the spheroidal earth, notably in the varying length of the degrees of a meridian, became apparent after 1700 when large-scale triangulation-based surveys, notably that for the great *Carte de France*, began to be undertaken across extensive territories. The need for precisely measured angles and distances stimulated significant developments in survey instrumentation and the practices of measurement. And the question of the figure of the earth was of major importance to the earth sciences generally. It was bound up intimately with Isaac Newton's theory of gravity and with associated speculations on what would later be called geology and geophysics. The attempt by mathematicians to formulate a precise description of how the laws of attraction acting on a revolving ellipsoid of fluid matter would result in a certain shape was an important mathematical topic through most of the century. Geodesy was also important for astronomers. A precise measurement of the earth's diameter was needed to calculate the distance from the earth to the sun, the basic yardstick for distances within the solar system, and arguments over the shape of the earth developed with the observation of other planets (d'Alembert 1756, 761). Above all, the determination and refinement of the earth's figure could be held up as a demonstration of the calculating power of science.

The Jesuit astronomer Giovanni Battista Riccioli (1661, 136–82) usefully summarized the state of geodesy in the middle of the seventeenth century. He outlined the different determinations of the size of the spherical earth that had been made, along with a table of linear measures in order to permit comparisons between the different values. The determinations fell into three groups: first, determinations of the length of an arc of a meridian, whether by calculation (Eratosthenes, second century B. C.), direct measurement by laying rods on the ground (Caliph al-Ma'mūn's astronomers in the ninth century), or indirect measurement by triangulation (Willebrord Snellius, early seventeenth century); second, calculations that combined itineraries and marine voyages with astronomical determinations of longitude; and third, measurements of the geometry formed by widely

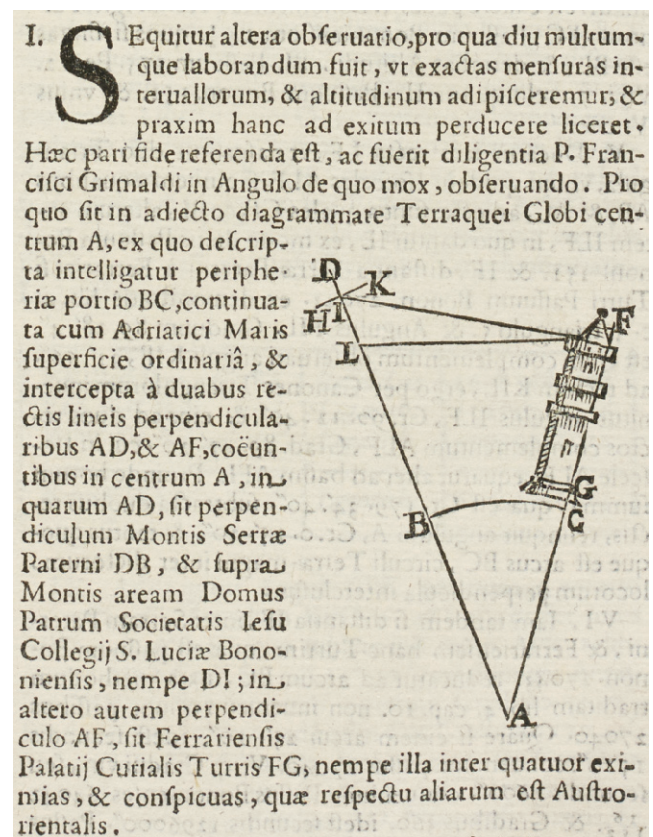


FIG. 256. GEOMETRICAL DETERMINATION OF THE SIZE OF THE SPHERICAL EARTH. In September 1654, Francesco Maria Grimaldi, SJ, observed several elements in this diagram: the angle of depression ($\angle KIF$) from the top (I) of Mount Serra near Bologna to the top (F) of the tower (FG) of the palace of justice in Ferrara, and the heights above sea level (BC) of both the mountain (BI) and the tower (CF). From these he calculated that the length of one degree of a great circle is 64,042 $^{16/152}$ passus bononienses or passi di Bologna (121.487 km), equivalent to a terrestrial radius of 3,671,203 passi (6,964.272 km). This calculation contributed substantially to Riccioli's work in 1644–56 to determine the size of the earth. Detail from Riccioli 1661, 173.

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spaced objects on the earth's surface (fig. 256). From the last, Riccioli concluded that the length of a degree of a great circle is 64,363 passus bononienses or passi di Bologna (122.096 km) and that the radius of the earth is therefore 3,689,598.5 passus (6,999.17 km) (1661, 176). These figures compare rather poorly to the modern values of 110.946 kilometers for a mean degree and 6,371 kilometers for the earth's mean radius, were it a sphere (Heilbron 1999, 140–42; Gapaillard 2002, who also precisely defined Riccioli's passo as 1.897 m). Riccioli's work exemplifies the quintessentially geometrical nature of the determination of the size of the spherical earth. The geometry was easy to grasp, but actual measure-

ment was difficult. Melchisédech Thévenot (1681, 19–20) noted that the direct measurement of a portion of a meridian was made difficult by hills, valleys, and forests getting in the way, and he had proposed, apparently in the mid-1660s, that a very long arc of a meridian comprising “fourteen or fifteen degrees” be measured on the frozen Gulf of Bothnia. He recognized that such work was too difficult to be implemented by individuals and required the support and interest of the state.

The eventual solution was developed by the Académie des sciences. To provide a foundation for Jean-Baptiste Colbert’s detailed survey of all of France, the Académie undertook to triangulate the meridian of Paris, to be executed with such care and rigor that it could also be used to determine the earth’s size (see fig. 266). In the first phase of the survey, between 1669 and 1671, Picard triangulated from a baseline just south of Paris, north to Amiens, an arc of $1^{\circ}22'55''$ amplitude; in his *Mésure de la Terre* (1671), Picard reduced his observations to a figure of 57,060 toises (111.208 km) for one degree of the meridian (Taton 1987, 212, 214), or a circumference of 20,541,600 toises (40,035.5784 km).

Yet, at about the same time that Picard was measuring the earth, natural philosophers were beginning to speculate that the earth was not perfectly spherical. Christiaan Huygens had developed his pendulum clock on the principle that the period of a pendulum was defined solely by its length, so that he could propose in the 1660s that the length of a seconds pendulum (i.e., a pendulum with a period of one second, of 36 Parisian pouces $8\frac{1}{2}$ lignes [0.9789 m]) be adopted as a universal standard of length (Huygens 1986, 167–70). But reports soon came in that the length of a seconds pendulum was slightly shorter near the equator (Chapin 1995, 24–25). If these variations were not the result of observational error, then the force of gravity must vary at different points on the earth. As early as the 1670s, Robert Hooke suggested in public lectures that gravity varied because it was offset by the centrifugal force caused by the earth’s rotation, so that the variability of seconds pendulums constituted further proof of the Copernican model of the cosmos; Hooke further suggested that the earth was accordingly shaped more like a turnip than a ball—that is, bulging at the equator where centrifugal forces were greatest (Hooke 1705, 355–57; Hall 1951, 227).

In 1671–73, Jean Richer carefully measured the length of a seconds pendulum at Cayenne ($4^{\circ}56'N$), where he was undertaking several important sets of astronomical observations for Jean-Dominique Cassini (I). Among other things, this work would allow for a calculation of the distances from the earth to Mars and to the sun, using Picard’s figure for the earth’s diameter. Richer found that a seconds pendulum in Cayenne was shortened by $1\frac{1}{4}$ Parisian lignes (2.8 mm). Richer’s observation was

subsequently confirmed by Jean Deshayes and one Varin, working in West Africa and the Antilles in 1681–83. Cassini I regarded the variations as probably due to experimental error (Dew 2008).

Together, Picard’s and Richer’s measurements permitted initial mathematical analyses of the earth’s shape, although the necessary mathematical techniques were themselves still in their first stages of development. Isaac Newton, in proposition 18 of book 3 of his *Philosophiæ naturalis principia mathematica* (1687), drew on the observed flattening of Jupiter’s poles to argue that any sphere of homogeneous fluid, under rotation and subject to universal gravitation (all particles attracting all others), would inevitably bulge at the equator and that the earth had to be similarly shaped. Having postulated, but not demonstrated, that the earth is shaped like an ellipsoid of rotation, Newton then determined its shape in proposition 19, by considering the net effect of all the gravitational and centrifugal forces at play. In proposition 20, he used Richer’s observations to corroborate his calculation. He concluded that the earth’s equatorial radius was longer than the polar radius by $\frac{1}{229}$ part of the polar radius (i.e., $\frac{a}{b} = \frac{229}{230}$ in fig. 255, middle) (Newton 1999, 821–32; Greenberg 1995, 1–14).

Newton’s mathematical treatment of gravity—in which he modeled the effects of attraction between distant objects with no explanation of how that attraction worked—ran counter to René Descartes’s celestial mechanics, which held that vortices in the ether provided a mechanical cause for planetary movement. Huygens, in his *Traité de la lumière* (1690), used a modification of Cartesian mechanics to postulate that gravity was the effect of pressure exerted on all particles by the ether toward the earth’s center of mass. This model made the mathematics of a rotating homogeneous fluid much simpler, and Huygens was able to calculate that for the rotating earth to be in equilibrium it had to be flattened, although it was not an ellipsoid of rotation, and that its equatorial radius was just $\frac{1}{578}$ longer than the polar radius (i.e., $\frac{a}{b} = \frac{578}{579}$) (Huygens 1690, 145–59; Mignard 1987).

These theories were eventually challenged and refined in Paris (a full account of the course of the debate can be found in Iliffe 1993, Greenberg 1995, and Terrall 2002). The challenge came from Jacques Cassini (II), who in 1718 finally completed the triangulation of eight degrees of latitude through France along the Paris meridian. In his *De la grandeur et de la figure de la Terre* (1720), he presented the lengths of degrees at either end of the meridian: 57,097 toises in the south and 56,960 toises in the north. These figures confirmed Cassini II’s preliminary conclusion, made in 1701, that the earth is not flattened but actually elongated at the equator such that degrees of latitude shorten toward the pole (a form

that had already been suggested by Thomas Burnet and Johann Caspar Eisenschmidt: Greenberg 1995, 86–87). Bernard Le Bouyer de Fontenelle, permanent secretary of the Académie des sciences, asserted that Cassini II's results coincided with Cartesian mechanics, but this was only one more rhetorical move in his campaign to dissuade younger Parisian scholars from their increasing interest in Newton's questionable metaphysics; there was in fact nothing about an elongated earth that either supported or was predicted by the existence of vortices (Iliffe 1993, 337–38, 342). Criticism of Cassini II's results went unheeded. Both Joseph-Nicolas Delisle, in a manuscript memoir from 1716, and his correspondent Giovanni Poleni in Padua, in a letter published in 1724, argued that the smallness of the difference in degree lengths calculated by Cassini II was most likely the result of observational error; they also both suggested that better results would stem from the measurement of degrees of longitude along arcs of parallels (Greenberg 1995, 118–19).

Attempts by Jean-Jacques Dortous de Mairan in Paris in 1720 to harmonize Cartesian mechanics with Cassini II's empirical results and by J. T. Desaguliers in London in 1725 to counter Mairan and prove Newton's mechanics were both very confused (Greenberg 1995, 15–78). But Mairan's work prompted Pierre Louis Moreau de Maupertuis to take up the mathematical analysis of the shape of homogeneous rotating bodies in order to refine and advance Newton's analytical tools and to resolve some of the flaws and obscurantism that made the *Principia* so difficult to understand. Maupertuis finally went public with his pro-Newtonian sentiments in his *Discours sur les différentes figures des astres* (1732), in which he explained and contrasted Cartesian and Newtonian mechanics, argued that the Cartesian force of impulse was actually as metaphysically indeterminate as the Newtonian force of attraction, and demonstrated that Newton's system of gravity perfectly described not only the orbits of the planets but also the observed shapes of the planets. By 1733, Maupertuis had concluded that the earth was flattened, but he could not determine its shape from strictly mathematical principles (Greenberg 1995, 80, 119–31; Terrall 2002, 53–78).

Coincidental developments redirected Maupertuis's geodetic investigations. A review of the second edition of Poleni's letter (1729) appeared in January 1733 in the Dutch *Journal Historique de la République des Lettres*; probably written by the journal's editor, Elie de Joncourt, the review significantly expanded Poleni's argument for new surveys along arcs of parallels, just as Cassini II and César-François Cassini (III) de Thury were preparing to continue the triangulation for the *Carte de France* with a survey of the arc of the parallel through Paris. Faced with the inability to achieve certainty about

the earth's shape from mathematics alone and with the imminent prosecution of new arc measurements, Maupertuis argued in June 1733 that only precise measurements undertaken without reference to any preconceived notion of the nature of gravity would resolve the issue. His paper sparked a rash of similar papers by other mathematicians and astronomers. In November, Cassini II announced the preliminary result that the measured arc of the parallel of Paris was shorter than if the earth were spherical, thereby reinforcing the hypothesis of an elongated figure for the earth. But the difference was small and seemed to be less than the probable instrumental and observational errors in the triangulation. Several academicians argued that the matter could be settled only by the measurement of widely separated arcs; furthermore, Pierre Bouguer demonstrated that the determination of longitude by Jupiter's satellites was too imprecise to permit its use in geodetic surveys of arcs of parallels (Greenberg 1995, 89–106; Terrall 2002, 90–94). The result was the decision to send an expedition to the Viceroyalty of Peru to measure an arc of the meridian at the equator. The expedition, led by Charles-Marie de La Condamine, Louis Godin, and Bouguer, left Paris in May 1735. Shortly thereafter, having worked out the formulas for determining the shape of the earth from distant arc measures, Maupertuis suggested that a second expedition be sent to the northern end of the Gulf of Bothnia to measure an arc of the meridian close to the Arctic Circle. Maupertuis, Alexis-Claude Clairaut, and Anders Celsius accordingly left Dunkirk in May 1736 and returned to Paris in August 1737, well before Bouguer and La Condamine could return to Paris from South America in 1744 and 1745 respectively.

The results of the Lapland expedition, explained in detail by Maupertuis in his *La figure de la Terre* (1738, English translation 1738, German translation 1741), was that a degree near the Arctic Circle was much longer, at 57,437.9 toises, than that at Paris, at 56,925 toises, now corrected for refraction, aberration, and precession in the astronomical observations for latitude (Maupertuis 1738, 125; Iliffe 1993, 356–57). Cassini II and the older generation criticized the quality of Maupertuis's instruments and observational practices. In response, Maupertuis questioned the quality of the survey of the Paris meridian; in 1739 he and his colleagues repeated Picard's astronomical observations with modern equipment, and in 1739–40 Cassini III and Nicolas-Louis de La Caille resurveyed the southern portion of the meridian of Paris with new instruments and reduced the results according to Maupertuis's own formulas. In April 1740 Cassini III announced to the Académie that his observations confirmed the results of the Lapland expedition; his report on the further resurvey of the arc appeared as *La meridienne de l'Observatoire royal de Paris, vérifiée dans*

toute l'étendue du royaume par de nouvelles observations (1744) (Iliffe 1993, 357–64; Terrall 2002, 94–172). The earth was clearly flattened.

While the debate over the earth's form, whether flattened or elongated, was effectively over, there remained much room for further investigation of the earth's precise curvature. New theoretical analyses sought to relate the empirical results of the surveys with variations in gravity and the earth's constitution. Colin Maclaurin in his *A Treatise of Fluxions* (1742) proved that a flattened spheroid was one form of equilibrium, for which he calculated a ratio of axes of $^{229}/_{230}$, duplicating Newton's value. Clairaut, in his *Théorie de la figure de la Terre* (1743), established that the earth's shape is properly defined by an equipotential surface, a surface of equal gravitational attraction or what is today called the geoid (Greenberg 1995, 426–619). He also demonstrated that a stratified earth, denser at the center, would have a shape somewhere between the extremes represented by Newton's and Huygen's calculations (i.e., with an ellipticity between $1/_{230}$ and $1/_{578}$). The problem was that the Lapland and French arcs together gave an ellipticity of $1/_{177}$, a value that fell outside Clairaut's range. The conflict was not resolved by the arc measurement in Peru, which determined that, corrected to sea level, one degree at the equator measured 56,753 toises (Bouguer 1749, 272, 274) or 56,749 toises (La Condamine 1751, 229). While the Peru arc confirmed the earth's flattening, Jean Le Rond d'Alembert found in 1749 that its inclusion in calculations for the earth's ellipticity gave a value of $1/_{174}$, which was still too large (Chapin 1995, 30–31).

But with so much energy and money having been expended on the expeditions, there was little institutional will in France to refine geodetic measures still further. Cassini III had completed the triangulation of France, had pushed it into the Southern Netherlands and across the German states to Vienna in 1745–48, and was now focused on the detailed topographical survey for the *Carte de France*. Further geodetic work was therefore sporadic and accomplished by astronomers seeking to emulate the grand science of the French surveys. A circle of scholars who had gathered around Pope Benedict XIV sought to contribute to the debates in Paris, leading to Christopher Maire and Ruggiero Giuseppe Boscovich's 1750–51 triangulation of an arc across mountainous territory from Rome to Rimini, giving a degree of 56,979 toises at 43°N. Shortly thereafter, La Caille used the opportunity of his astronomical expedition to the Cape of Good Hope in 1751–53 to undertake a small arc measurement, giving a degree of 57,037 toises at 38°S; this remarkable figure was equivalent to a degree at about 45°N, yet it was apparently incontrovertible because of La Caille's acknowledged skills as an observer (Airy 1845, 170). D'Alembert (1756, 755) included La Caille's

result in his comparison of all arc measurements to date, concluding that they could not be reconciled into a single elliptical figure for the earth.

Further small arcs were measured by Joseph Liesganig in Austria (1762) (see fig. 263), Giovanni Battista Beccaria in Piedmont (1762–64), and Charles Mason and Jeremiah Dixon in Maryland (1764). The discrepancies between these and previous arcs led Nevil Maskelyne to consider, following from Bouguer's work, whether the surveys' errors stemmed in part from the gravitational effects of mountains: the deflection of the local vertical would misalign surveyors' instruments and so affect all their observations. In 1774 Maskelyne therefore undertook a detailed survey of an isolated mountain, Schiehallion in Scotland, to measure the lateral deflection of the plumb line with precision for the first time (Reeves 2009), with the results seen in a map published in 1778 (see fig. 267).

At the end of the eighteenth century, newly concerted efforts to refine scientific knowledge of the earth's figure again featured a combination of theoretical and practical work. On the theoretical side, starting in 1783, Adrien-Marie Legendre and Pierre-Simon de Laplace developed Clairaut's ideas of modeling the equipotential surface of the earth's gravity. In the second volume of his *Traité de mécanique céleste* (1799), Laplace sought to reconcile the existing arc measures to the theoretical model, to conclude that the earth's actual shape must differ substantially from the ellipsoidal (Chapin 1995, 31–34). On the practical side, geodetic surveys were restarted by Cassini III's 1783 *mémoire* to the British government, calling for a joint Anglo-French survey (1784–90) to measure the east-west distance between the royal observatories at Greenwich and Paris in order to better connect the observational programs of those two institutions and so improve the astronomical determination of longitude. Shortly thereafter, the Enlightenment quest for standardized measures led the revolutionary French state to resurvey the Paris meridian (1792–99) as the basis for determining the length of a meter, as one ten-millionth of the length of a meridian from the equator to the pole. The success of these two triangulations was in large part due to the high quality of the instruments that were specially commissioned for them, both for measuring angles and for measuring the baselines (Widmalm 1990). These two surveys set the stage for the great nineteenth-century projects to measure long arcs as part of the larger Humboldtian quest to examine and measure all aspects of the physical world. Only then were new tools of mathematical and statistical analysis developed to manage the observations and to develop best-fit ellipsoids to serve as the foundation of each national mapping project.

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SEE ALSO: Academies of Science: Académie des sciences (Academy of Sciences; France); Bouguer, Pierre; *Carte de France*; Cassini Family; Geodetic Surveying; Greenwich-Paris Triangulation; Lapland and Peru, Expeditions to; Longitude and Latitude; Meter, Survey for the; Science and Cartography

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Geodetic Surveying.

ENLIGHTENMENT

AUSTRIAN MONARCHY

DENMARK AND NORWAY

FRANCE

GERMAN STATES. SEE TOPOGRAPHICAL SURVEYING

GREAT BRITAIN

ITALIAN STATES

PORTUGAL

SPAIN

SWEDEN-FINLAND

SWITZERLAND

Geodetic Surveying in the Enlightenment. Geodetic surveys were the most expensive and complicated form of institutional field science during the Enlightenment. Astronomers and mathematicians took to the field with the latest high-precision instruments and heroically endured great hardships to determine the size and shape of the earth. Historians have generally focused on the

scientific function, institutional histories, and social contexts of the several geodetic surveys undertaken between 1650 and 1800 (e.g., Bialas 1982, 95–196; Levallois 1988, 13–90). Those subjects are of course discussed elsewhere in this volume: the preceding entry considers why the surveys were undertaken and how their results were used; the following entries discuss particular surveys in their national contexts. Professional historians of geodesy have been especially interested in assessing the accuracy of each survey and in tracing the development of issues of concern to modern geodetic science (Smith 1986, 71–193). Historians of science have recently assessed the rhetorical style—textual, mathematical, and graphic—of geodesists’ published accounts of their labors (Widmalm 1990; Bennett 2006; Terrall 2006; Safier 2008). In contrast, this entry draws on the published accounts of the major geodetic surveys undertaken after 1650 and before 1800 to understand the process of geodetic surveying in the Enlightenment by considering how geodesists combined observational and computational techniques. Even though Enlightenment geodesists continually augmented and refined their techniques, their work nonetheless possessed a historically distinctive character.

The principle for determining the size of a spherical earth is simple. The length of a portion, or arc, of the earth’s circumference is measured along a meridian; the angle subtended by the arc at the center of the earth is simply the arc’s latitudinal extent, which is readily determined. Comparison of the two gives the earth’s circumference—generally expressed as the length of one degree of latitude—from which may be derived its radius (see fig. 255). This calculation assumes that the length of the meridional arc is determined along the surface of the idealized figure of the earth, as defined by sea level. The late seventeenth-century realization that the idealized figure of the earth is not a sphere, but a spheroid, changed only the need for geodetic surveys but not their design nor the fundamental techniques employed.

Early geodesists measured meridional arcs by estimation, pacing, or laying down measuring rods. Such direct measurement was open to substantial error, not least because it determined the length of the arc across the earth’s actual and uneven surface. But direct measurement was conceptually simple to undertake and was still used even in the eighteenth century. In 1702, the Kangxi emperor decreed that the li should be $\frac{1}{200}$ of a degree; Chinese and Jesuit surveyors accordingly measured a meridional arc of 200 li with an iron wire one li (558 m) in length, as defined by the imperial standard chi (0.31 m; 1 li = 1,800 chi); the arc encompassed $1^{\circ}1'32''$ of latitude, so the emperor had the standard chi shortened accordingly (Cams 2017, 76–82). In 1767, Charles Mason and Jeremiah Dixon directly measured a short meridional arc,

as part of the border between Maryland and Delaware, with large and robust wooden frames (see fig. 531).

Otherwise, Enlightenment geodesists used chains of triangulation to measure the lengths of meridional arcs indirectly. The technique had been pioneered for geodesy by Willebrord Snellius. His survey design and instruments were both relatively simple, and, working before the development of logarithms, his calculations were inexact (Haasbroek 1968, 59–119; Smith 1986, 57–66). Even so, Snellius demonstrated that triangulation possessed the flexibility and rigor necessary for generating the high-quality results desired by natural philosophers.

Because they comprised triangulations, pre-1800 geodetic surveys appear modern in form. Historians of geodesy, for example, have treated Jean Picard’s pioneering survey of the Paris meridian as a single, coherent chain of triangles (Levallois 1983; Smith 1986, 71–77), but Picard actually undertook that survey as separate sets of triangles that were computed and checked in an idiosyncratic manner (fig. 257). Picard’s work exemplifies how Enlightenment geodesists lacked the tools to correct observational errors across an entire triangulation and instead used a mix of mathematics and logic to massage approximate observations into a semblance of coherence (Delambre 1798, vi). In this respect, the technical history of Enlightenment geodetic surveying comprises a long and complex narrative of one new observational or computational refinement after another. (Lafuente and Delgado 1984 detailed the state of corrections at midcentury; Delambre 1798, 17–176, summarized a century’s worth of mathematical tinkering).

This narrative is further complicated by a four-decade hiatus between the early degree measures—in France (Picard 1671; Cassini II 1720; Cassini III 1744), Peru (Bouguer 1749; La Condamine 1751a, 1751b), and Lapland (Maupertuis 1738)—and the post-1784 surveys to connect the observatories at Greenwich and Paris (Legendre 1787; Cassini IV, Méchain, and Legendre [1791]; Roy 1785, 1790) and to define the meter (Delambre 1798; Méchain and Delambre 1806–10). The later surveys introduced markedly new instruments and a new obsession with precision measurement. Although still approximate, they laid the foundations for recognizably modern geodetic practices.

Picard established the basic processes and inherently approximate nature of Enlightenment geodetic surveying with his triangulation of 154 kilometers, or $1^{\circ}22'55''$, along the meridian between Paris and Amiens. His plan was to determine the length of three long triangle sides (EG, GI, and IN in fig. 257a) that together approximated a north-south line from which he could compute the desired length of the arc of meridian ($N\alpha$). He calculated each of the three desired triangle sides from one section of the triangulation (fig. 257b–d) whose observational

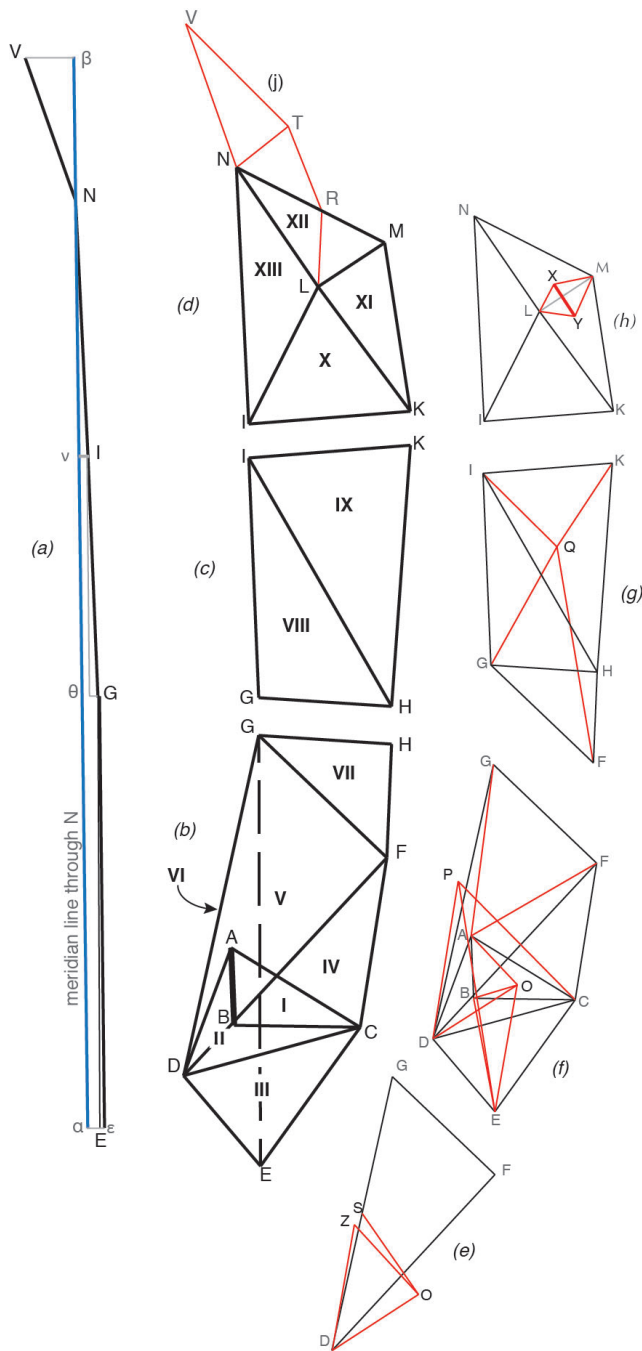


FIG. 257. CLARIFICATION OF PICARD'S DEGREE MEASURE, 1668-70. (a) In blue, the final reduction of the survey's three *desiderata*—the triangle sides EG, GI, and IN—to their meridional components; EG was not observed but only calculated. (b-d) In black, the three stages of the main triangulation, graphically separated here but forming a single chain of triangles; together these comprised thirteen triangles and the primary baseline, AB. (e) The extension within the first stage—*b*—to locate the cathedral of Notre Dame de Paris, S, and the Paris Observatory, Z. (f-h) In red, the three sets of verification triangles and the second baseline, XY, matching the main triangulation. (j) The verification extension to Amiens, V. All labels are Picard's. Based on Picard 1671, pl. 2.

errors were corrected by a separate set of verification triangles (fig. 257f-h); he extended the triangulation to Amiens in order to verify his final result (fig. 257j). Picard also observed some lesser triangles to connect his survey to key sites in Paris (fig. 257e).

Picard began the survey with the direct measurement of a baseline (AB in fig. 257b) whose length would be carried through the triangulation by calculation. He measured the baseline by laying wooden rods along a straight level road south of Paris once in each direction; the two measurements differed by just 1 pied, and he adopted the second measurement of 5,663 toises (11.04 km) as the length of the base (Picard 1671, 3-4). He then measured the angles within each triangle with a large quadrant that read to 1' of arc (see fig. 265), which he tried to read to just 5" (Picard 1671, 5-7). In calculating the lengths of the sides of each triangle, Picard haphazardly blended the two sets of triangles. In the first section (fig. 257b, f), Picard averaged the two values he had calculated for the desired length EG from the principal and verification triangles, and rounded the result to the nearest toise. In the second (fig. 257c, g), he rejected the length of GI calculated from the primary triangles and adopted the length from the verification observations. In the third, he decided to measure a second baseline of 3,902 toises (ca. 7.6 km; XY in fig. 257b), which gave a length for LM 0.01 percent longer than that calculated via the first and second sets of triangles; Picard applied this factor as a correction to the calculated length of IN and, because he was still uncertain about the quality of the second section, to GI as well (Picard 1671, 7-14). In working through this convoluted multistage process, Picard followed intuition rather than logic. He was not explicit about some of his reasoning, particularly why he averaged some values and prorated others. And he was content to work at a relatively low level of precision.

Having measured his triangles, Picard defined the direction of the local meridian through each of G, I, and N and measured the angles (azimuths) between these local meridians and each of the three desired triangle sides, which permitted the reduction of the three lengths to their meridional components (εG , θI , and νN in fig. 257a). Picard admitted that the sum of these components did not precisely match the desired length of the arc of the meridian, but the difference was minimal, at least at the low level of precision at which he worked, so he added them to give 68,347 toises 3 peds for $N\alpha$ (Picard 1671, 15-16). The astronomical determination of latitude had too many uncertainties to be used, so at the end stations N and E, Picard used his new zenith sector to measure the angular distance from the zenith ("zenith distance") to a particular star (δ Cassiopeia) as it crossed the local meridian; the difference between the two zenith distances gave the difference of latitude.

Picard also observed δ Cassiopeia from Amiens (V) for use in verifying the whole work. From $N\alpha$, 1° of latitude contained 57,064 toises 3 pieds; the extension to Amiens permitted the calculation of a longer arc ($\beta\alpha$), from which he calculated that 1° contained 57,057 toises. Picard split the difference to yield a final value of 57,060 toises (111.208 km) for the length of 1° of latitude along the (spherical) meridian (Picard 1671, 18–23).

Subsequent geodesists followed very similar processes, all the time refining them in response to increasingly precise instrumentation. Some refinements were pragmatic. Simultaneous observations of stars from either end of the main segments of a triangulation chain eliminated many of the observational errors endemic to individual astronomical observations, and all geodesists were concerned with modeling the effects of refraction (the bending of light rays as they pass through the atmosphere) when measuring vertical angles. The rigorous conditions of the Peruvian expedition made apparent the potential for delicate instruments to be damaged in travel; the geodesists spent a month testing and calibrating their quadrants (Bouguer 1749, 61–68), and thereafter it became standard to check instruments before and after use. One refinement proved to be of fundamental importance to all geodetic operations: Pierre Bouguer (1749, 327–94) first noted the deflection of the plumb bob caused by the gravitational attraction of the Andes, and all subsequent work sought to control for such variation.

Geodesists continually sought to refine the corrections that had to be applied to the angle measurements made by their quadrants. It was never possible for a quadrant to be placed in the exact same location as the survey station's signal—whether prominent pieces of architecture, such as church spires, or artificial targets erected on hill-tops, generally in the form of tripods or squat pyramids made from local materials (Bouguer 1749, 72, 101; Méchain and Delambre 1806–10, 1a:46, 103–12)—and the signal was not necessarily taken as the station's central point (Bouguer 1749, 73). One example from the 1790s illustrates just how complex circumstances could be (fig. 258). On the tower of Dunkirk, the center of the station (P) was atop a hut, the quadrant was set up some two toises away, and distant observers sometimes used the tips of the corner turrets at S and V instead of the proper signal at P (Méchain and Delambre 1806–10, 1b:1–15). This problem reoccurred with the siting of a zenith sector when conducting the necessary astronomical observations at stations at either end of the chain of triangles. Picard had not anticipated that his instruments would be so precise that the errors caused by the separation of the instrument from the station's center would actually be appreciable, and he had a difficult time accounting for them. But his successors ensured that they

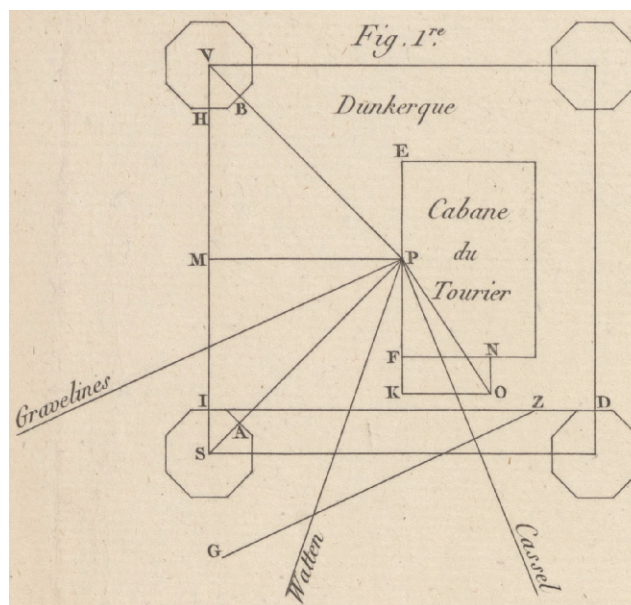


FIG. 258. STATION I IN THE SURVEY FOR THE METER. The tower of Dunkirk featured a hut and octagonal turrets at each corner (two are labeled S and V). The stem of a rooster atop one of the hut's doorjamb, like a weathervane, defined the center of the station (P), as it had also in 1787 for the Greenwich-Paris triangulation. Even when augmented by bails of straw, the stem was not particularly visible as a signal, and observers sighted instead on the turrets S and V. This is, however, a neat diagram that does not show where the quadrant had been set up, somewhere between P and M; instead, the sightlines to the neighboring stations had already been reduced to P. From Méchain and Delambre 1806–10, vol. 1, pl. II, fig. 1.

Image courtesy of the Bibliothèque nationale de France, Paris.

took enough observations to be able to reduce all observed angles to the center of each and every station. The use of quadrants required a further set of corrections for each observation; when measuring the angle formed between two distant stations, a quadrant was aligned so as to lie in a plane defined by the instrument and the distant targets; using zenith distances to each target, geodesists converted observed angles to the horizontal, as needed for the trigonometrical calculations. French geodesists were understandably obsessed with refining both sets of routine corrections (Delambre 1798, vi–viii).

Geodesists also refined the design of each triangulation. For the extension of Picard's triangulation south of Paris, Jacques Cassini (II) both integrated the secondary baseline into the triangulation as a means to verify the overall quality of the work and undertook a preliminary reconnaissance to ensure that each station was intervisible with its neighbors and to assist the coordination of the separate parties that set up signals and made observations. By the 1730s it was clear that triangles for a geodetic survey should be "well-conditioned": a small

error in observing a strongly acute or obtuse internal angle produced an unduly large error in the calculated length of the opposing side, an error that would then propagate through the rest of the triangulation; every triangle should be as close to equilateral as possible (Bouguer 1749, 86–91; La Condamine 1751b, 10–11).

At the same time, independent verification triangles continued to be an element of early geodetic surveys, both in France (fig. 259) and in Peru (La Condamine 1751b, 86). The use of verification triangles had the added benefit of defining the locations of multiple stations that could help control the topographical mapping of France (Cassini II 1720, 50). Geodesists in France were attuned to the benefit of taking further observations to fix the geographical positions of other places. By the 1790s, they differentiated between geodetic triangles, all of whose internal angles were measured and carefully corrected, and secondary triangles that were not completely observed but partially calculated (Méchain and Delambre 1806–10, 1b:542–43, 2:1). This distinction would become more clearly institutionalized after 1800 with the proliferation of systematic surveys that used a primary triangulation, of geodetic quality, to cover large regions and then secondary triangulations, controlled by the first and so undertaken by less skilled observers with lesser-quality instruments, to define a greater density of topographical control points.

The geodesists' continuous application of refinements is particularly evident in efforts to improve baseline measurement. Picard established the basic procedure. He directly measured his baselines by laying two wooden rods, each four toises in length, directly on the ground, end-to-end, guided by a thin cord stretched along the length of the base (fig. 260). He had carefully calibrated the rods against the Parisian standard, the *toise du Châtelet* (1.949 m, divided into six *pieds*, each of twelve *pouces*, each of twelve *lignes*). Great care was taken both to keep each rod in place as the next was touched to it and to keep correct count of the number of times the rods were laid on the ground. Cassini II introduced supports to carry his wooden rods over irregular or marshy ground and, as a precaution against inadvertently using a damaged rod, he checked them daily against a carefully and precisely graduated iron ruler, four *pieds* in length, that had been calibrated against the *toise du Châtelet*. Whereas Picard was reluctant to be more precise than a *toise* in the length of a base, Cassini II gave results to the nearest *pie* (or 0.325 m; Cassini II 1720, 97–104, 217–21).

In Peru and Lapland, the geodesists sought to measure baselines with still greater precision, to the nearest *pouce* (2.7 cm). At such precision, the effects of the expansion and contraction of measuring rods with changes in the ambient temperature became appreciable. During the

measurement of the baseline on the flat frozen surface of the Torneå River, the geodesists in Lapland routinely compared their thirty-pied rods against the iron one-toise standard (the *toise du Nord*), which was kept under cover and at about the same temperature at which it had originally been calibrated against the *toise du Châtelet*. They found that the length of the wooden rods did not vary appreciably in the cold dry air (Maupeituis 1738, 34, 49–50, 65–66, 86–87).

The difficult conditions of the Andes, however, made it necessary for the geodesists in Peru to apply multiple corrections to their two baselines, at Yaruquí in the north (primary) and at Tarqui in the south (secondary). Daily comparisons of their twenty-pied rods against the standard they had brought from Paris, the *toise du Pérou*, which was kept sheltered and at a constant temperature, revealed significant variations in the rods' lengths. The bases were also uneven. The geodesists partially controlled for this by inserting wedges underneath each rod to level it and, if rods were at different levels and could not touch directly, they used plumb lines to align their ends. (Measurement of the Tarqui base also required floating the rods across large areas of standing water.) Even so, it was still necessary to reduce each segment to the horizontal (Bouguer 1749, 37–58; La Condamine 1751b, 4–10, 71–85). Furthermore, for the first time, the lengths of baselines were reduced to sea level. The measured length of a baseline is longer than the length between the endpoints projected to sea level, but it is the latter that is needed to determine the length of a meridional arc across the surface of the idealized figure of the earth. Previous baselines had all been situated close to sea level, so that the difference between their measured lengths and their sea-level equivalent was deemed to be minimal (e.g., Picard 1671, 23). But high up in the Andes, the geodesists could not ignore the correction, which they accomplished after a complex series of geometrical and barometric height determination (Lafuente and Delgado 1984, 87–108; Smith 1986, 139–42).

The function of a secondary baseline was to verify the quality of the triangulation. Its measured length was compared to that calculated through the chain of triangles from the primary baseline; if the difference was small, then the survey had been properly accomplished and no corrections were necessary. And, in general, the difference was found to be acceptable and the triangulation accepted without change. Consider the late example of William Roy's analysis of his work vis-à-vis the French baseline at Dunkirk. Roy found unacceptable the difference of seven feet (2.13 m) between its measured length (actually undertaken decades earlier) and that calculated from his baseline on Hounslow Heath. Yet his calculated length for the Dunkirk baseline was

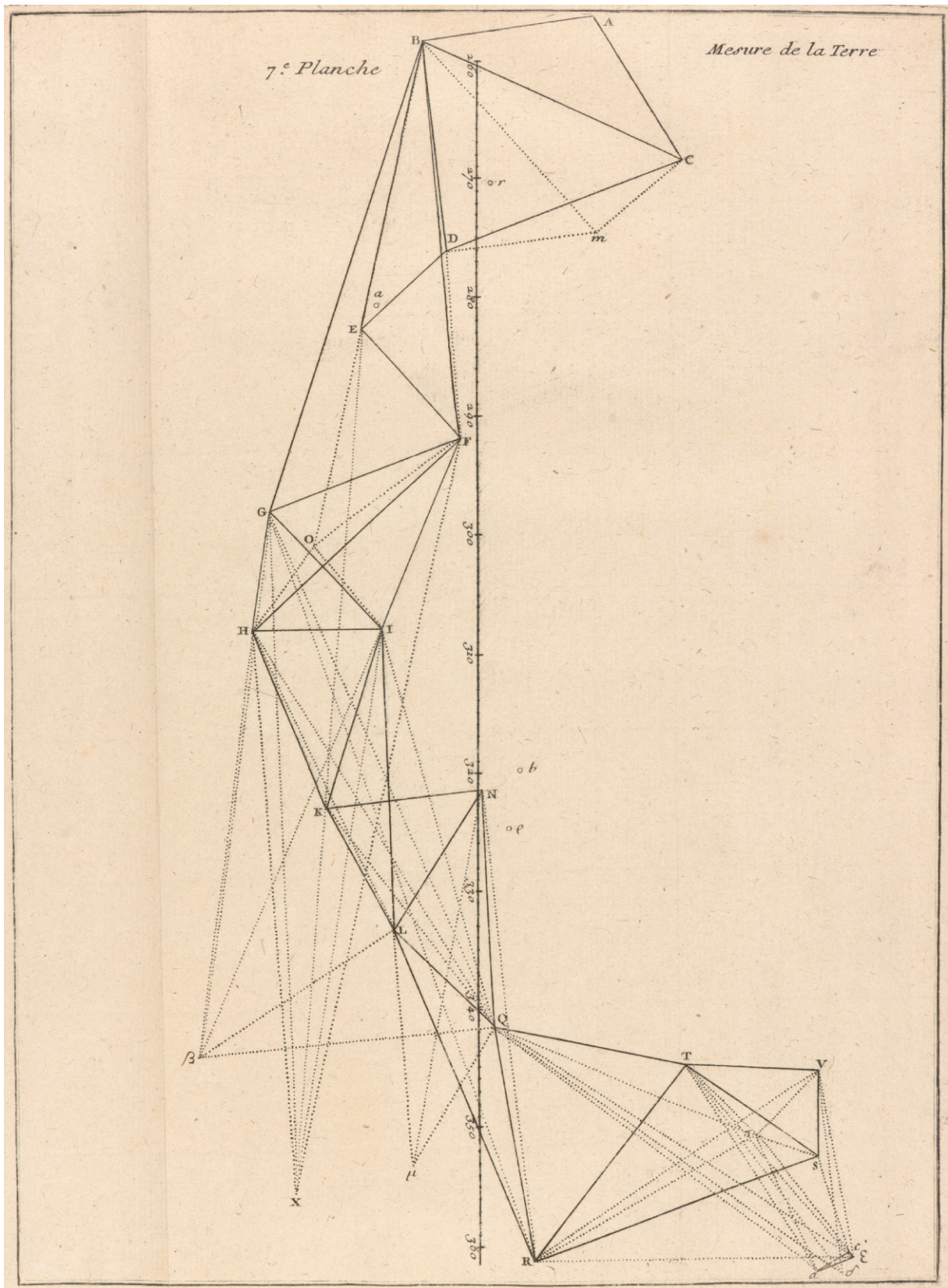


FIG. 259. THE SOUTHERNMOST PORTION OF CASSINI II'S GEODETIC SURVEY OF THE PARIS MERIDIAN. This diagram shows how Cassini II used the same surveying process as Picard. Here, solid lines indicate the main triangles that describe the arc of a meridian, dashed lines the verification

triangles. This is the last of five maps delineating the triangulation, showing the end of the arc at Perpignan. From Cassini II 1720, pl. 7. Image courtesy of the Division of Rare and Manuscript Collections, Cornell University Library, Ithaca.



FIG. 260. MEASURING A BASELINE WITH WOODEN RODS. This illustrative vignette shows the early method of measuring a baseline by laying wooden rods on the ground, one set against another, along a stretched-out rope; each rod

was managed by its own team of surveyors. By measuring the baseline close to the sea, no corrections needed to be made to reduce the length to sea level. From Cassini III 1744, 119.

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just fifteen inches (0.38 m) different from the mean of the lengths calculated, via the triangulation of the Paris meridian, from baselines at Paris and Amiens. This “very near agreement” meant that Roy’s own triangulation could stand unaltered as a testament to the “wonderful degree of accuracy” of which geodetic triangulations were capable (Roy 1790, 183–85). That the purpose of secondary baselines was more rhetorical than functional is evident from the failure of Pierre Louis Moreau de Maupertuis to even include a secondary baseline in the Lapland triangulation. By contrast, Charles-Marie de La Condamine did take seriously the 1.03 toise (2.01 m) difference between the measured and calculated lengths of the Tarqui baseline in Peru. Struggling to understand what this meant for the quality of the triangulation as a whole, he could only conclude that such an error guaranteed that the overall length of the meridian was also too long. He therefore developed two algebraic methods to determine a correction that he could apply to the final result for the arc measurement (La Condamine 1751b, 87–101).

The post-1784 geodetic surveys were in essence little different from their precursors. However, four decades of sustained improvement in instrument construction

meant that the later surveys were equipped with extraordinarily precise angle-measuring devices, whether French quadrants or British theodolites. As a result, issues of precision and error management were central to both the Greenwich–Paris triangulation and the Survey for the Meter.

The new degree of angular precision had to be matched by new techniques of baseline measurement. For the Greenwich–Paris triangulation, the French team simply based their work on the existing triangulation of the Paris meridian and on César-François Cassini (III) de Thury’s baseline at Dunkirk (Cassini IV, Méchain, and Legendre [1791], xvi, 51). But in Britain, Roy fussed extensively over his primary baseline on Hounslow Heath. He eliminated basic errors by lifting his rods completely off the ground, laying them in long, leveled coffers set on tripods, and overlapping their ends that he aligned with a plumb line. He initially used twenty-foot (3.66 m) wooden rods, but he found that their length varied erratically with changes in humidity. He then tried rods made of glass, specially commissioned from Jesse Ramsden. These proved stable and precise and Roy used them to calculate the length of the baseline. In this work, which included accounting for the rods’ slight expan-

sion with temperature and the reduction of the baseline to sea level (via a leveling survey to the head of the River Thames's tidal reach), Roy gave his calculations to a precision of one ten-thousandth of a foot (0.003 cm). At the end, however, he decided to "throw away some useless decimals" and gave the final length with a precision of just one tenth of a foot (3.05 cm): 27,404.7 feet (8,352.95 m) (Roy 1785, 478; Widmalm 1990, 199–200; Bennett 2006). Roy soon found that the glass rods were too delicate to ship, so for his secondary baseline on Romney Marsh, he resorted to his 100-foot (30.48 m) surveyor's chain by Ramsden, which he found to be both sufficiently precise and stable (Roy 1790, 121–34).

Étienne Lenoir's baseline apparatus for the Survey for the Meter was truly innovative. He designed the measuring rods like metallic thermometers; each rod comprised a primary strip of platinum, two toises in length, and a copper rod shorter by six pouces. Joined by screws at one end only, both strips were free to expand in the same direction. Vernier scales at their free ends, read by a microscope, indicated the relative lengthening of the copper with respect to the platinum, which in turn indicated the absolute length of the platinum rod. A sliding platinum tongue, also marked with a vernier scale read by a microscope, extended from the end of each rod to just touch the next rod without disturbing it. A wood frame, mounted on tripods, gave structure to each rod and allowed the mounting of microscopes and levels; once calibrated, the latter ensured that the base was measured in the horizontal. Lenoir's complex rods could measure lengths to one hundred-thousandth of a toise (0.001949 cm). At such great precision, almost every aspect of the measurement needed careful regulation and correction, including the reduction to sea level. After extensive adjustments, Pierre-François-André Méchain and Jean-Baptiste-Joseph Delambre determined the lengths of the baselines at Melun and Perpignan to be 6075.900069 and 6006.247848 toises, respectively. But even Delambre had to acknowledge that such precision was "imaginary" and so limited the results to just one hundredth of a toise (1.949 cm): 6075.90 and 6006.25 (Méchain and Delambre 1806–10, 1a:20–21, 2:2–56 and pls. 1–2).

Should any dispute have arisen about the distance between the royal observatories or the precise length of the meter, the respective surveys would have had to be repeated or corrected. Complex structures were therefore installed to demarcate the precise endpoints of the baselines before the actual measurement in order to preserve them. This practice was quite distinct from La Condamine's symbolic construction post facto of pyramids topped with the fleur-de-lis over each end of the Yaruquí and Tarqui baselines in Peru. He did so as part of his collection of monumental inscriptions that com-

memorated the work of the French scientists working under the orders of the French king; the local authorities quickly recognized the political nature of the Yaruquí pyramids and razed them (La Condamine 1751a, 219–71; Safier 2008, 23–56).

Roy defined each end of his baseline on Hounslow Heath with a precise mark inscribed into the lid of a copper cup inserted into a small bore drilled into a solid wooden rod (six feet long, one foot in diameter) that was placed vertically in the ground and stabilized by having its lower end inserted and bolted into the hub of a horizontal wagon wheel, the whole assembly being buried to the very top of the rod and the copper cup (Roy 1785, 414–16). Delambre constructed much more elaborate monuments for the Melun baseline. The endpoint was inscribed on the end of a copper cylinder, sealed within dressed stone set directly on bedrock. During the survey, while the surveyors might have needed to revisit the baseline, whether to verify it or to define secondary triangles, the cylinder itself was protected by a lead plate over which stood a large signal, which protected vehicles and animals from encroaching on the site; after the survey was completed and checked, the signals were removed and a larger, permanent monument constructed (fig. 261). Local unrest prevented similar monuments from being constructed at the extremities of the Perpignan baseline, so Méchain instead covered the ends with squat brick pyramids, coated with cement against rainwater, and then covered by a large pile of earth "to protect them from insult" (Méchain and Delambre 1806–10, 1b:415, 2:59–62).

Further attention was given to improving the precision of targets on which the geodesists sighted. Roy found it best to observe lights at night when the warm ground did not generate haze: even "the most faint looming of the land in a very clear day [could] be discerned . . . in a dark night, when the air was perfectly clear" (Roy 1790, 226). The type of light was important (fig. 262). Globe lamps were visible over only six or eight miles (10–13 km) in clear weather. Reverberatory lamps could be seen for twenty to twenty-four miles (32–38 km) but required careful tending and cleaning. "White lights" of burning sulfur were best; Roy thought they would be visible over eighty or a hundred miles (130–160 km), and they burned well in all weathers, yet they were short-lived. But nighttime observations required careful long-distance coordination between observers and the signal tenders, and the light and smoke of London would always be difficult to overcome. Ultimately, Roy preferred to observe in daytime and in good weather when the observer had the time to sight a flag-staff target and take multiple readings without having to hurry for fear that the light would burn out too soon (Roy 1790, 113–15, 162–64, 170, 253, 265–66).

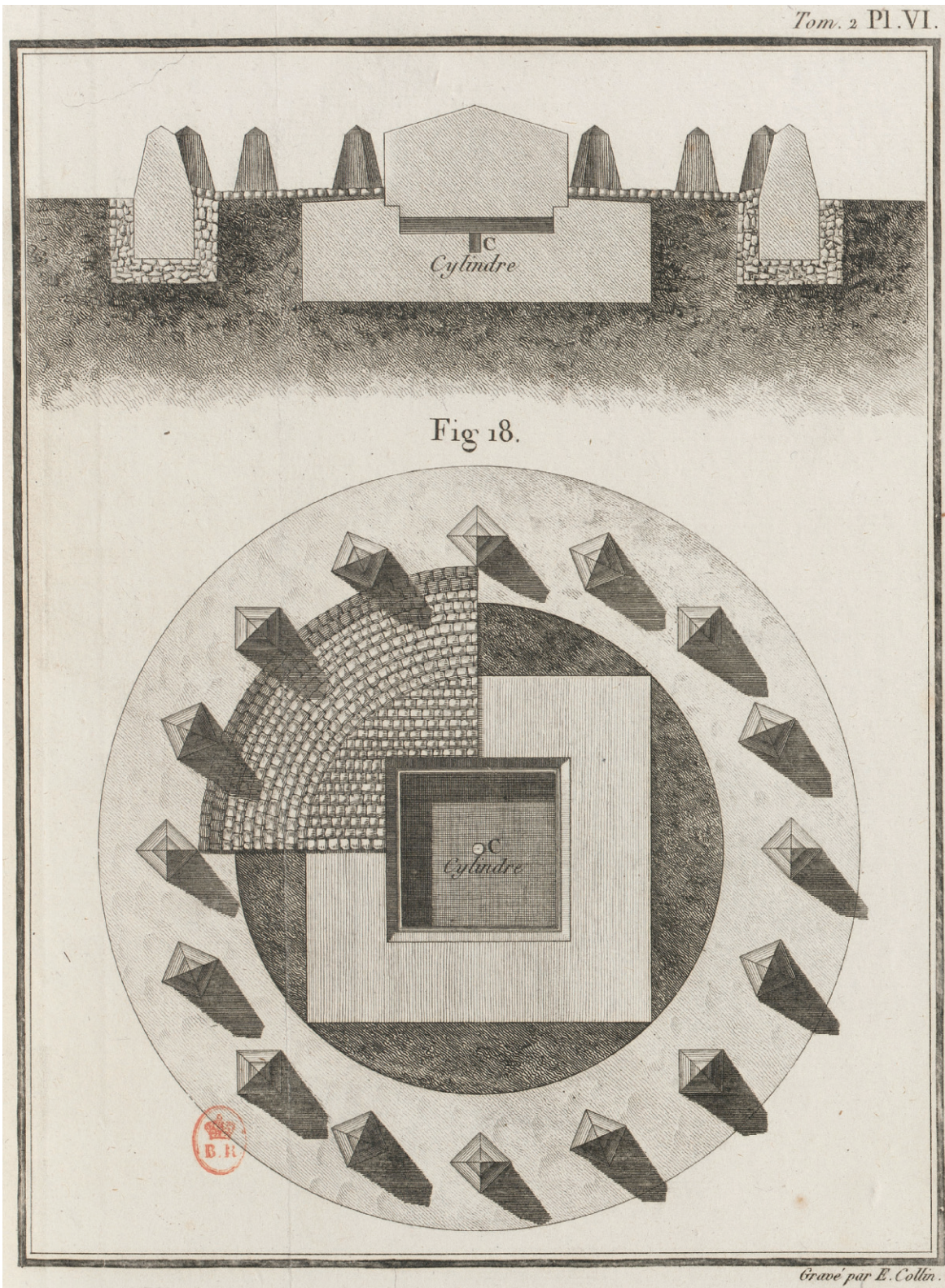


Fig 18.

FIG. 261. DELAMBRE'S MONUMENT AT THE SOUTH END OF THE MELUN BASELINE. The center of concentric circles on the top of the C cylinder marked the endpoint of the base; the cylinder itself was set in place, sealed by lead into a square of dressed stone, 2.43 meters on a side, before the baseline was measured in 1792. In 1799, the foundation was built up and a single dressed stone added as a protective superstructure, leaving a ten-centimeter space so as not to

disturb the cylinder; the surrounding pavement was sloped to ensure drainage away from the site, and the whole protected by sixteen standing stones set within a trench drain. The inner monument remains in situ, although now buried under a traffic island in the middle of a road junction. Méchain and Delambre 1806–10, vol. 2, pl. VI.

Image courtesy of the Bibliothèque nationale de France, Paris.

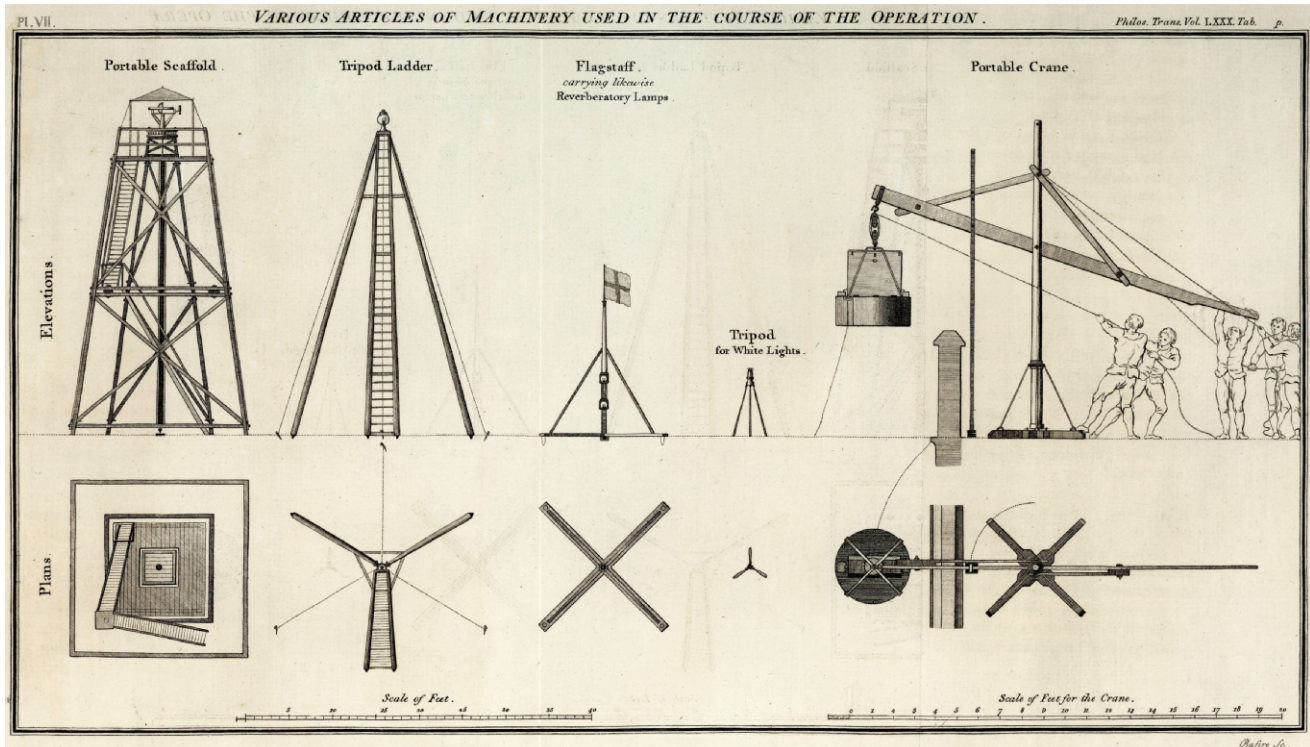


FIG. 262. WILLIAM ROY'S SCAFFOLDS AND LIGHTS. Large scaffolds (left) held the large theodolite on a central support surrounded by a separately supported walkway to prevent the observer's movements from affecting the theodolite; a scaffold ladder could hold a globe lamp; smaller flagpoles could also hold reverberatory lamps, which Roy hung in pairs

to distinguish them from other lights close to the ground; a small tripod could hold the "white lights" of burning sulfur, and a crane (right) was needed to lift the large theodolite to the top of the scaffold. From Roy 1790, pl. VII.

Size of the original: 22 × 37 cm. Image courtesy of the David Rumsey Map Collection.

Nightlights proved especially useful for the long sightlines—up to seventy-five kilometers—of the cross-Channel observations, for which Roy gave a number of lights to his French colleagues (Cassini IV, Méchain, and Legendre [1791], 2; Roy 1790, 113). For the Survey for the Meter, Delambre liked "*réverbères*" with parabolic mirrors because observers could sight them accurately over long distances, even in poor weather, but they required too much coordination, too consistent a construction, and too many skilled attendants. It was simply not worthwhile to use them for the relatively small triangles in France, all of whose sides were less than fifty-eight kilometers with almost all being under forty kilometers in length. But for Méchain's extension of the arc to the Balearic Islands, nightlights proved essential (Méchain and Delambre 1806–10, 1a:21, 46, 103–12, 2:800–839).

In addition to nightlights, Roy introduced another significant innovation in observational techniques. His great theodolite, made by Ramsden, eliminated the computational corrections that the French had to apply to observations with their quadrants (see fig. 412). Its

sturdy frame, needed to keep the full circle from twisting and distorting, made it unwieldy, and it could not be carried up to the top of towers. So rather than using existing structures as stations, the engineer Roy built his own towers on open ground atop hills (see fig. 262 left). An inner scaffold supported the theodolite; a separate outer scaffold supported the observer so that vibrations would not upset the instrument. Roy's French colleagues seemed to envy the fact that this technique permitted Roy to place his signals and theodolite over the same precise spots, thereby eliminating the need to reduce every observation to the survey station's center (Cassini IV, Méchain, and Legendre [1791], 58). Moreover, the theodolite measured horizontal angles directly and so avoided any need for reducing observations to the horizontal.

In admitting that they had carried on corrections to their baselines with "imaginary" levels of precision, both Roy and Delambre implicitly acknowledged that they were letting mathematical theory outstrip observational practice. This is apparent, too, in the treatment of spherical excess, the amount over 180° in the sum of the inte-

rior angles of a spherical triangle. Directly proportional to the size of the triangle, it is a very small increment, rising above 2" only in large triangles, such as those across the English Channel. Through the 1740s, geodesists had simply ignored spherical excess as insensible; they made all calculations with plane trigonometry. Enamored with the precision of his great theodolite, Roy expected to be finally able to measure spherical excess. Yet the theodolite was still insufficiently precise, so he inverted the correction. He first determined the spherical excess for each triangle from its calculated area and then apportioned it among the triangle's angles as he saw fit to make their sum 180° (Roy 1790, 168–71). French geodesists adopted markedly different approaches to the issue. Delambre used spherical trigonometry and algebraic series to convert both the interior angles and the sides of spherical triangles to the horizontal plane (Delambre 1798, 40–47). By contrast, Adrien-Marie Legendre derived the now-fundamental theorem to convert a spherical triangle to a plane triangle by subtracting one-third of the observed excess from each interior angle (Legendre 1787, 7; Legendre in Delambre 1798, 1–16).

Delambre's exhaustive analytical methods represent the culmination of the Enlightenment approach to managing and correcting approximate geodetic observations. In hindsight, they constituted an overly baroque mathematical cul-de-sac. An alternative was to implement what La Condamine had anticipated decades earlier, specifically the modeling of error across an entire observational system. This alternative was achieved with the method of least squares, in which observations are adjusted so that the sum of the squares of their indeterminate errors is minimized. Verification baselines acquired a new significance, as the difference between their measured and calculated lengths can be redistributed across an entire triangulation. Legendre developed and used the method for his 1806 analysis of comet orbits, but Carl Friedrich Gauss had independently developed it as early as 1795. Gauss used the method to adjust an experimental triangulation of one hundred stations around Braunschweig in 1803–7 and then in his official triangulation of Hanover in 1818 (Dutka 1995; Sheynin 1994, 1999).

The adoption of least-squares analysis, together with the general adoption of Roy's simplified observational procedures, formed a sharp watershed between Enlightenment and modern geodetic surveys. From Picard's initial triangulation of the Paris meridian to the Survey for the Meter, Enlightenment geodetic surveys possessed a distinctive style that marks them as decidedly early modern.

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SEE ALSO: Bouguer, Pierre; Cassini Family; Geodesy and the Size and Shape of the Earth; Height Measurement; Instruments for Angle Measuring: (1) Repeating Circle (Repeating Theodolite), (2) Great

Theodolite; La Condamine, Charles-Marie de; Modes of Cartographic Practice; Picard, Jean; Roy, William; Science and Cartography; Zach, Franz Xaver von

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Geodetic Surveying by the Austrian Monarchy. Before the eighteenth century, no surveys with trigonometric foundations were conducted in Austria. Even the Josephinische Landesaufnahme, which mapped more than 570,000 square kilometers of the Habsburg Empire between 1763 and 1787, did not make use of a triangulation network and was mainly conducted by means of plane tables (Dörflinger 2004, 78).

Father Joseph Liesganig, SJ, is in fact considered the Austrian pioneer of triangulation surveying. In 1759, impressed by the achievements of the Jesuits Ruggiero Giuseppe Boscovich and Christopher Maire in the Vatican State, Empress Maria Theresa commissioned Liesganig with preliminary work for the first Austrian arc measurement on the Vienna meridian. In tackling this task, Liesganig benefited from his collaboration with César-François Cassini (III) de Thury, who in 1761 cooperated with Liesganig in setting up a triangulation network in the environs of Vienna, a project that continued the perpendicular from Paris via Strasbourg to Vienna. This effort produced the manuscript map "Carte des triangles qui sont servi à déterminer la position des plusieurs lieux aux environs de Vienne" (1761; 1:170,000), drawn by the Austrian engineering officer J. B. d'Avrange. One year later, Liesganig extended these surveys to the environs of the town of Krems, resulting in the 1763 *Carte des environs de Vienne* (Dörflinger 1977, 31). In 1775, in Paris, Cassini III duly published his own results, including nine map sheets in his book *Relation d'un voyage en Allemagne* (Zeger 1992, 118–19).

In 1762, Liesganig embarked on more extensive surveys along the Vienna meridian. After the accurate determination of two baselines between Neunkirchen and Wiener Neustadt (southern Lower Austria) and in the Marchfeld plain between Seyring and Glinzendorf (north and east of Vienna), he set up a triangulation net-

work extending across almost three degrees of latitude (with twenty-three main triangles) from Sobieschitz near Brünn (Soběšice near Brno) to Varaždin in Croatia (fig. 263). Because he worked from Cassini III's triangulation, Liesganig calculated his work using the French toise as the unit of measurement. For the vertices of his triangles, Liesganig mainly used church spires, but also landmark trees. Above the two baseline endpoints in Wiener Neustadt, five-meter-high stone monuments designed by Prince Wenzel Anton von Kaunitz were erected; they featured both a Latin inscription and a geodetic point. The northern monument, which can still be seen in Wiener Neustadt, bears the following inscription: "For the northern boundary. Joseph Liesganig, SJ, set up this northern limit of the baseline, having measured three degrees of the Vienna meridian, by order and under the auspices of the most noble Francis and Maria Theresa. 1762" (Zeger 1992, 124). There was also a monument built at the south endpoint with the following inscription: "For the southern boundary. From the center of this southern marker to the center of the northern marker [are] 38,465 Viennese feet, 5 inches" (Zeger 1992, 124). The distance between the two points at the southern and northern ends of the base equaled the length of the baseline. Liesganig proposed the Marchfeld base for extending the measurement of the Paris degree of latitude, a project conducted roughly at the same time by Cassini III. In the course of his surveying activities, Liesganig maintained continuous contacts with other geodesists and astronomers, such as Boscovich (Embacher 1951, 19; Zeger 1992, 119, 121–25). In 1769, Liesganig carried out an arc measurement extending over more than one degree of latitude, with twenty-six main triangles located in Hungary between Kis-Telek (Kistelek) and Czurok (Čurug). He then published the results of his work in 1770 in his book *Dimensio graduum meridiani Viennensis et Hungarici* (Zeger 1992, 131; Dörflinger 2004, 81).

A comparison of Liesganig's surveys with modern findings reveals some minor deficiencies, for example, the value for one meridian degree determined by him was too high. However, if compared with other triangulations carried out in the eighteenth century (e.g., in France), the quality of those surveyed by Liesganig can hardly be called very inferior (Embacher 1951, 22, 55). The deficiencies in Liesganig's work have also been attributed to his simple instruments, most of which he built himself (Zeger 1992, 130–31). Remeasurements of the Wiener Neustadt baseline revealed a deviation of only seven millimeters per kilometer (Dörflinger 1977, 31). However, Liesganig did commit a major blunder in the triangle Wildon–St. Magdalen–St. Urban (near Maribor, Slovenia) because he mistook St. Magdalen for Oberradkersburg Castle. Internationally, Liesganig's

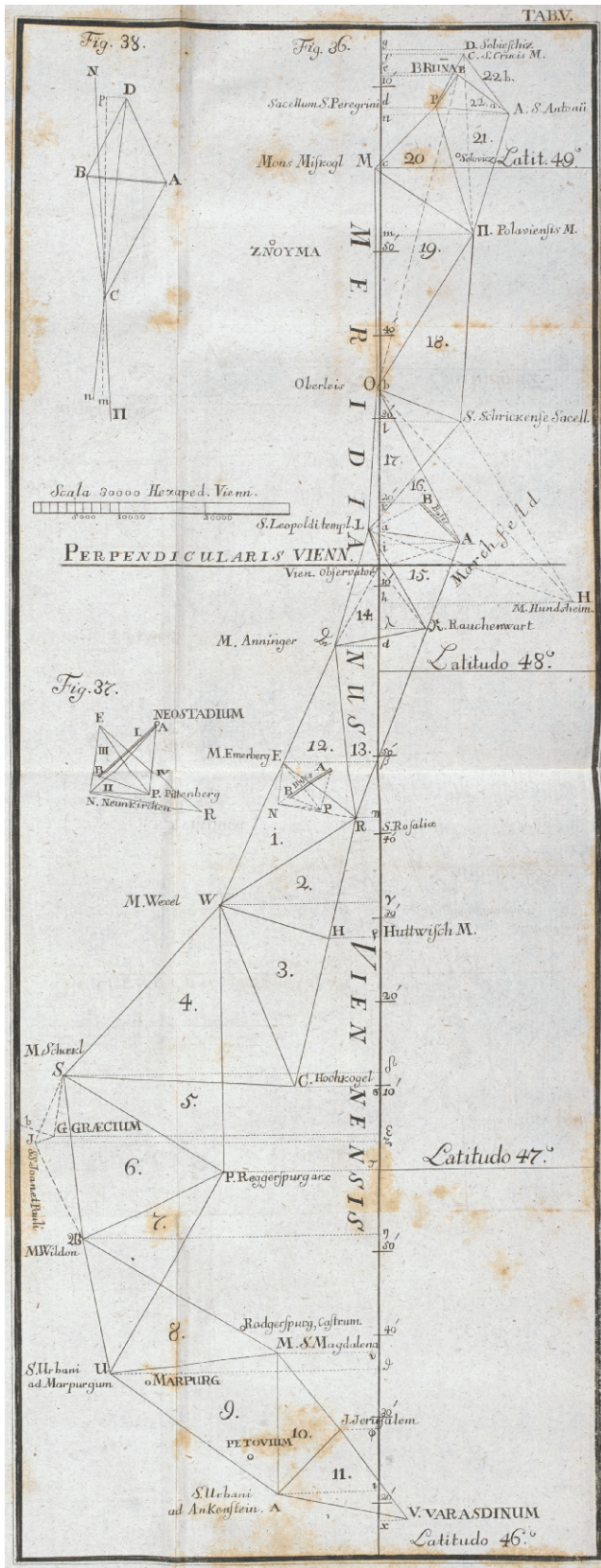


FIG. 263. JOSEPH LIESGANIG, TRIANGULATION SYSTEM BETWEEN SOBIESCHITZ AND VARAŽDIN. Copper engraving; 1:864,000. From Joseph Liesganig, *Dimensio graduum meridiani Viennensis et Hungarici* (Vienna, 1770), Tab. V.
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surveys were lauded by Pierre-Simon de Laplace, who made recourse to the arc measurement results on the Vienna meridian in his efforts to obtain generally applicable values for the dimensions of the earth (Zeger 1992, 130). Georges Perrier's treatise *La figure de la Terre* (1908) likewise expressed notable appreciation for Liesganig's work (Embacher 1951, 55).

Another imperial surveying commission was entrusted to Liesganig in 1772 with respect to the region of Galicia and Lodomeria, which had been annexed to the Habsburg Empire following the First Partition of Poland-Lithuania. All surveying tasks were carried out over a period of eighteen months with three baselines determined (near Lemberg, Rzeszów, and the Silesian border), and the region was mapped with a triangulation network. The surveys involved Georg Ignaz von Metzburg, professor of mathematics at the University of Vienna, who owed his reputation in part to the production of post-route maps such as the *Post Charte der Kaiserl. Königl. Erblanden* (1782) (see fig. 85). The surveying project was concluded in 1774 (Zeger 1992, 132–33).

The map resulting from these surveys, which originally was merely to serve as a tool for administrative purposes, was then drawn at a scale of 1:72,000. Since this map did not feature any terrain representation, terrain data were later added in the context of the military survey initiated in 1776. This improved version was again detailed at a scale of 1:72,000 and finally printed at a scale of 1:144,000. Under an imperial order dated 3 November 1784, the engineer Johann von Liechtenstern was commissioned with preparing a smaller-sized edition, which was published in 1794 with the title *Regna Galiciae, et Lodomeriae* at 1:288,000. For the representation of Bukovina, Liechtenstern drew on the survey conducted by Captain Hora von Otzellowitz as a basis. A particularly impressive feature is the beautifully designed title cartouche, which shows an allegory of the main rivers of Galicia, its abundant natural resources, its inhabitants, surveyors working with a plane table, as well as the coats-of-arms of Galicia and Lodomeria (see fig. 439), all based on a design by the renowned painter Franz Anton Maulbertsch. In 1824, the map was again slightly improved and republished by the quartermaster general's staff (Zeger 1992, 134; Dörflinger 2004, 115; 1989, 95).

SEE ALSO: Austrian Monarchy; Liesganig, Joseph

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Geodetic Surveying by Denmark and Norway. The first triangulation of Denmark began after 1761, when the king approved plans by the academy of sciences and letters, the Kongelige Danske Videnskabernes Selskab, to undertake a large-scale survey of Denmark. The maps were to serve civilian and economic purposes and were to be among the best in Europe.

The survey was overseen by a commission of academy members, headed by Christen Hee of Copenhagen University, but the work itself was directed by Thomas Bugge. The academy seems to have initially thought that purely astronomical control for the detailed mapping would suffice. To that end, Jørgen Nicolai Holm, who had participated in the border surveys between Norway and Sweden, was tasked with planning the improvement of the instruments and conditions at the observatory; the academy also enticed the Swedish instrumentmaker Johan Ahl to Copenhagen. Plans for the survey soon developed, prompted by Holm, so as to emulate the *Carte de France* by undertaking a comprehensive triangulation on which to base the detailed topography. However, detailed plane table surveys began in 1762 before the triangulation had been started. After Bugge's test triangulation in 1763, the academy commissioned Ahl to construct a new "geographical circle" to serve as the primary angle-measuring instrument for the full triangulation. The circle, delivered in 1764, was based on a design developed by Ahl's teacher, Daniel Ekström (Bugge 1779, 21–29 and pl. 1; Pedersen 1992, 96–99; Branner and Johansen 1999, 16; Amelin 2001) (see fig. 406).

The island of Sjælland (Zealand) was surveyed in the

seven field seasons between 1764 and 1770, first by Bugge and then from 1768 by Ole Christopher Wessel. Bugge began by measuring, with 12-fod (6-alen; 3.7662 m) rods, a baseline of 14,514.775 alen (9.0384 km) just west of Copenhagen (Bugge 1779, 33–34, 49–50, and pl. 2, fig. 15); from this he extended a primary triangulation of some eighty triangles and several more baselines, together with a secondary network to fix the location of some churches and windmills. As in the French surveys, the locations of the triangulation stations were calculated with respect to the observatory. Bugge's map of the triangulation included a list of key places on the island and their calculated coordinates (fig. 264). After 1777, Bugge would supervise the refitting of the observatory, complete with new instruments by Ahl (Amelin 2001), and determine its latitude and longitude with respect to Paris. Other surveyors completed the triangulation of the country: Niels Morville surveyed Fyen (Funen) and parts of eastern Jylland (Jutland) in 1772–77; Caspar Wessel, Jylland in 1779–81 and 1786–96; Hans Skanke, Jylland in 1782–85, when Wessel was off triangulating Oldenburg. Finally, Thomas Bugge, Jr., conducted the triangulation of Bornholm in 1806 (Pedersen 1992, 131–32; see Nørlund 1942, pl. 101, for a diagram of the entire work to 1806).

In his work, Bugge carefully discussed observational errors and distinguished between random and systematic ones. But he lacked a theory for accumulated errors. Moreover, as with the French surveys, his angle measurements were relatively imprecise. Regardless of nineteenth-century criticism, Bugge's use of plane rather than spherical trigonometry for calculating the triangulation was quite appropriate (Andersen 1968, 53–81; Kristensen 2001, 82–89). By contrast, Wessel had by 1787 developed an entirely new technique for determining coordinates—by means of complex numbers. A complex number has two parts, one real and one imaginary (based on the square root of negative one); Wessel realized for the first time that they could be expressed geometrically and that, conversely, calculations in two dimensions could be transformed into operations on complex numbers. Wessel's application of complex numbers did not simplify the calculations necessary to reduce a triangulation to coordinates, but it entailed a mathematical abstraction that proved deeply satisfying to him. Now celebrated, Wessel's work on complex numbers would not be recognized for over a century (Branner and Johansen 1999, 9, 44–49).

Triangulation surveys were introduced into Norway only after 1772, when General Heinrich Wilhelm von Huth determined that there were few good maps of the border areas with Sweden. He initiated a military survey of the border from Frederikshald (Halden) to Trøndelag. This marked the start of what became Norway's

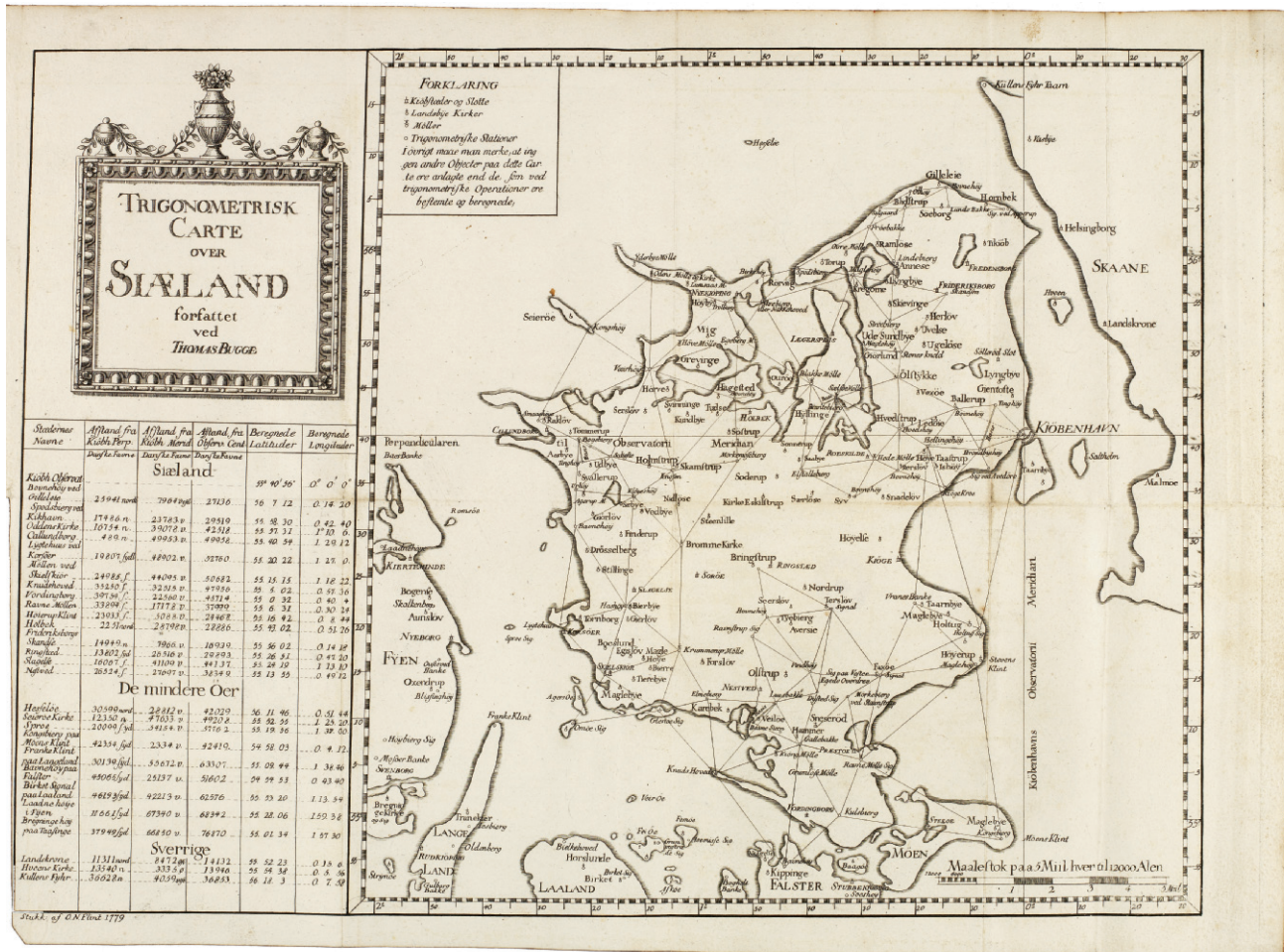


FIG. 264. THE TRIANGULATION OF ZEALAND. Thomas Bugge, *Trigonometrisk carte over Sieland*, in his *Beskrivelse over den opmaalings maade, som er brugt ved de danske geographiske karter* (Copenhagen: Gyldendals Forlag, 1779). The Copenhagen Observatory marked the origin of a coordinate system defined by the observatory’s meridian and its perpen-

dicular; the table at left gives the trigonometrically calculated coordinates of each station in the triangulation, the calculated distance from the observatory, and thus each station’s longitude from the observatory and latitude. Image courtesy of Det Kgl. Bibliotek; The Royal Danish Library, Copenhagen (KBK 1111-2-1767/1b-c).

geographical surveys (the modern-day Statens Kartverk). Plane table surveying began in 1773, and in 1779 the work was expanded to include triangulations by Johan Jacob Rick and Ditlev Wibe, under Bugge’s direction. The triangulation started at the fortress of Kongsvinger, and the original reference point was the flagpole of the fortress. In Trondheim, where the triangulation ended, an interim observatory was established and used to define a Norse prime meridian. After 1785, Bugge secured an extension of the triangulation back along the coast, from Trondheim to Frederikshald, to serve as the basis for new hydrographic surveys. This further triangulation provided the basis for seven sea charts at the scale 1:225,000, which Carl Frederik Grove published in 1791–1803. The full circuit of Norse triangulation was completed in 1805 with the completion of a chain of tri-

angles from Christiania (Oslo) to Kongsvinger (Pettersen 2009, 2014; Hoem 1986, 79).

NILS VOJE JOHANSEN

SEE ALSO: Bugge, Thomas; Denmark and Norway; Videnskabernes Selskabs kort (Academy of Sciences and Letters map series; Denmark)

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Geodetic Surveying by France. The term *geodesie*, attested from 1570 in England (*Oxford English Dictionary*), appeared around 1644 in France and meant to divide the land (*Le grand Robert de la langue française*). Antoine Furetière's *Dictionnaire universel* (1690) indicated that people called it *arpentage* (surveying surfaces). Operations to determine longitude and latitude of locations were the domain of geography. Geodesy per se is concerned with determining the form and dimensions of the earth. French scholars engaged in geodetic surveying relied on methods and instruments developed in the sixteenth century. In 1533 Gemma Frisius had explained how to construct a network of triangles covering large areas (Pogo 1934–35). Frisius also constructed the goniometer, or square, in 1537, and improved it by adding a compass; this device helped standardize triangulation, which spread quickly throughout Europe. In France, Philippe Danfrie's *Déclaration de l'usage du graphomètre* (1597) explained another invention, the graphomètre, which was used until the nineteenth century. By the middle of the seventeenth century, Dutch circles, plane tables, and graphomètres were commonly used for mapping at large, medium, and small scales using Frisius's method.

The Académie des sciences, a royal foundation created in 1666 following the example of the Royal Society of London (founded 1662), provided an institutional framework for scientific research. Jean-Baptiste Colbert summoned the Dutch scholar Christiaan Huygens to participate in the Académie's program: "To measure the dimensions of the earth. To advise on the means of making geographic maps with more exactitude than before" (Taton 1987, 208). The creation of an astronomical observatory was imperative. In the spring of 1667

Louis XIV decided to establish the Paris Observatory, to be designed by Claude Perrault. The main axis of the building became the basis of the future meridian for the astronomical observations indispensable to geodesy. Having received its royal charter in 1699, the Académie henceforth decided disputes among geographers over questions of geographic outlines and location of places (Pastoureau 1988, 295–302).

One of the Académie's first projects was to measure anew the arc of the meridian. Previous work by Willebrord Snellius in 1617, Richard Norwood in 1635, and Giovanni Battista Riccioli in 1661 had produced contradictory results for the length of the terrestrial degree. The Académie adopted a method of triangulation that depended on: 1) determining a baseline; 2) on-site measuring of the angles of the triangles forming the triangulation network; 3) determining precisely the longitude and latitude of the two extremities of the arc; and 4) adjusting, as possible, for differences in longitude and altitude of the points in the network.

When the telescope of Galileo Galilei (1609) was added to angle-measuring instruments, heretofore furnished only with pinnules, sightings improved considerably; the addition of the vernier scale (1631; after Pierre Vernier) made angle readings more precise. From 1659, Huygens produced regulators that enabled clocks to keep the second on the hour for a month.

On 23 May 1688, Pierre de Carcavy reminded the Académie that Colbert "wanted work done to make geographic maps of France more exact than those made heretofore." He invited Guillaume Sanson, an "able geographer," to discuss the matter (Gallois 1901, 196). After hearing Sanson, the Académie decided to prepare a map of the environs of Paris in order to compare possible methods of triangulation and to select the best one. The task was given to David Vivier under the supervision of Gilles Personne de Roberval and abbé Jean Picard. In his report of 1669 Picard recommended replacing the alidade with pinnules with an alidade with a telescope. To further these operations, Colbert summoned the Italian Jean-Dominique Cassini (I) to Paris, where he arrived on 4 April 1669. Cassini I was to verify with Picard the position of the principal points on a map, which would serve as a foundation for the map of the environs of Paris (see fig. 4).

This map depended upon the measure of an arc of the meridian of the Paris Observatory between Sourdon, north of Paris (20 km south of Amiens), and Malvoisine, south of Paris (6 km from La Ferté-Allais). Picard constructed a chain of thirteen triangles along both sides of the Paris meridian according to Gemma Frisius's method. The vertices of these triangles were the "stations" chosen for their mutual visibility. The baseline ran along the road from Paris to Fontainebleau between

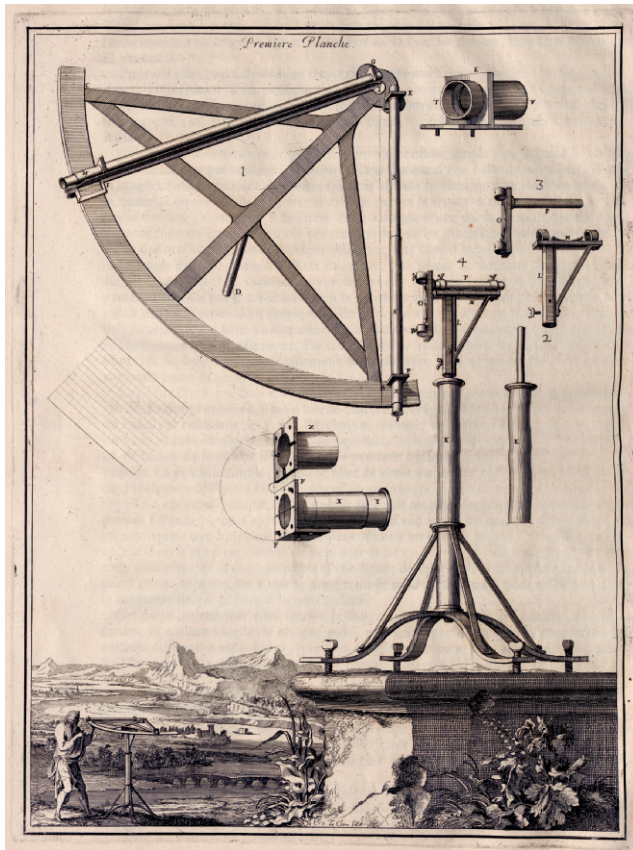


FIG. 265. QUADRANT WITH TWO TELESCOPES, 38 POUCES (1.03 M). From the first edition of Jean Picard's *Mesure de la Terre* (Paris: Imprimerie Royale, 1671), pl. 1, engraved by Sébastien Le Clerc. At bottom left, an observer has arranged the instrument horizontally and aims it along the arc. An enlarged detail of the arc's transversal scale is shown, rather faintly engraved, just below and left of the quadrant itself.

Size of the original: ca. 39×29 cm. Image courtesy of the Division of Rare and Manuscript Collections, Cornell University Library, Ithaca.

the mill of Villejuif and the pavillon of Juvisy, measured with two sets of poles. Each set comprised two poles of 2 toises (3.898 m), screwed together to make two measures of 4 toises (7.796 m); these sets, lined up straight, made one 8-toise unit.

Picard created three instruments for taking angular measurements. The angles of each triangle were measured with a quadrant of 38 pouces (1.03 m) (fig. 265), whose arc (limb) could be set at any angle, thanks to a central joint (*genou*), to sight each angle in the plane formed by the three vertices of the station and the two targets. The quadrant had two telescopes: one was fixed and pointed toward the origin of the angle; the other pivoted and was used like an alidade moving along the graduations of the arc. The eyepieces of the two sighting telescopes were on the arc end of each; they

were equipped with reticules that permitted measuring the difference in altitude for the apex of each triangle sighted in relation to that of the operator. A micrometer, which Picard constructed with Adrien Auzout in 1666, further refined the measurements. Its eyepiece had a focal reticule with cross hairs. Readings along the arc were taken to one minute with the help of an adjustable piece fixed to the telescope (Picard 1671, 11–15).

To learn the subtending angle along the meridian between Sourdon and Malvoisine, Picard had constructed a zenith sector 10 pieds (3.25 m) in radius whose arc was 38 pouces (1.03 m) (see fig. 396). Its astronomic telescope had a long focal length, allowing the viewer to relate terrestrial measurement to the heavens. With this instrument, Picard determined the zenith distance of the same star at the two extremes of his triangulation. By observing the star near its zenith, he limited the effects of refraction and could accurately determine the latitude of each place. At this middle latitude, he established the length of a degree of latitude along the meridian to be 57,060 toises (111.09 km). Picard published the result of this work, completed from 1669 to 1670, under the title *Mesure de la Terre* (1671).

It is fairly easy to determine latitude based upon the height of the terrestrial pole above the horizon, but longitude is more difficult to evaluate. Because the earth turns on the axis of its poles every twenty-four hours, in the absence of a directly accessible celestial reference point the measurement of longitude requires precise timepieces. Cassini I had perfected the calculation of longitude by a method based on observing the satellites of Jupiter; he determined the precise time of their eclipses with his own updated table. These eclipses occurred at the same time everywhere they were visible on earth and thus served as a reference clock. Observers noted the local time of a given eclipse and compared it to that of the meridian of origin. Thus the longitude of a location was the difference between the local time of the observation and that of the Paris meridian.

Picard and Philippe de La Hire planned to use this method to determine the coordinates of points on the coasts of France. They took measurements in Brest and Nantes in 1679, in Bayonne, Bordeaux, and La Rochelle in 1680, and on the northern coast of France in 1681. In 1682, La Hire went to Provence and to Lyon. They plotted the corrected data on a map of France, and then compared that outline to the map that Guillaume Sanson had provided in 1679. The result was astonishing: compared with Sanson's map, Brittany, the Cotentin Peninsula, and the Atlantic coast, whose longitudes were based upon the Paris meridian, retreated eastward by more than a degree (about 80 km), reducing the size of the realm by a fifth (see fig. 625). A draft of this map was



FIG. 266. SHEET 4 OF THE CARTE DES PROVINCES DE FRANCE TRAVERSÉES PAR LA MÉRIDIEN DE PARIS. From Jacques Cassini (II), *De la grandeur et de la figure de la Terre, Suite des Mémoires de l'Académie Royale des Sciences, année 1718* (Paris: Imprimerie Royale, 1720). Map shows the network of triangles up to Mont Ventoux.

Size of the original: ca. 37 × 46 cm. Image courtesy of the Division of Rare and Manuscript Collections, Cornell University Library, Ithaca.

presented to the Académie by La Hire on 12 February 1684 and engraved in 1693.

Even though in February 1681 Picard contemplated combining existing maps of provinces to make a general map of the realm, “it was still necessary to arrive at a general framework [of triangles]” (Gallois 1909, 293). Upon Picard’s death in 1682, Cassini I took over. In 1683, he continued the meridian south to Bourges, while La Hire continued north to Béthune. But Colbert died on 6 September 1683 and was replaced by François-Michel Le Tellier, marquis de Louvois, who

suspended operations. They only began again in August 1700. Cassini I, aided by his son Jacques (Cassini II) and his nephew, Giacomo Filippo Maraldi, continued the triangulation to Canigou, where a pyramid was erected in order to extend observations to the east into Roussillon. Operations concluded in 1701 with the measure of a base 1,583 toises (3.15 km) in length near Collioure (fig. 266).

In 1718 Cassini II, Maraldi, and Gabriel-Philippe de La Hire extended the Sourdou meridian to Dunkirk, where they measured a baseline. The length of a degree

of the meridian found by Cassini II differed according to latitude: 57,097 toises for the southern segment from Paris to Collioure, and only 56,960 toises for the northern length from Paris to Dunkirk. From this difference Cassini deduced a shrinkage as one moved north: the earth must be an elongated ellipsoid, squeezed at the equator (see fig. 255 bottom). Until this moment, the work of Huygens and Isaac Newton, supported by experimental results from Jean Richer, had suggested that the earth was a flattened spheroid, on which the length of a degree grew longer as one moved north (see fig. 255 middle). The dispute was not resolved until 1737 with the Lapland and Peru expeditions. Between 1739 and 1740 César François Cassini (III) de Thury and Nicolas-Louis de La Caille measured the meridian once again from Villejuif to Juvisy and found that previous measurements were faulty. They remeasured it five times in 1750, finding the section to be five toises longer. The earth was therefore indeed a flattened spheroid.

The effect of the geodetic work of the Académie on geographical mapmaking was not immediate, but it demonstrated strikingly the necessity of establishing maps with accurate coordinates, as also shown by comparison of the Académie's map with that of Guillaume Sanson. The geodetic network progressively completed by transversals (great circles cutting perpendicularly across the meridian at particular latitudes) and astronomical verification of the key points of Cassini's triangles henceforth allowed maps to be established on precise coordinates.

However, the cartography of the coasts of the realm did not immediately benefit. The maps of *Le Neptune françois* (1693) used the longitude measurements of the Académie, but the chains of triangles had yet to reach the coasts. The maps of the *Frontières de l'Océan*, surveyed by Claude Masse between 1688 and 1724 using a graphomètre, were based only on purely local geometrical foundations (Bousquet-Bressolier 2003, 64–67, 71–73).

Yet geodetic work influenced the compilation process of geographical mapping. Claude Delisle and his son Guillaume, both members of the Académie, renewed *géographie de cabinet* by gathering and compiling a wide variety of information (travel accounts, direct measurements, maps, and descriptions) and relying upon firsthand data obtained from local informants with whom they were in constant contact. The notes of Claude Delisle conserved in the Archives nationales de France show the care with which he transcribed distances as well as longitudes and latitudes, whether observed using methods of geodesy or estimated by informants (Lagarde 1995, 130–36; Pelletier 2002). All the maps from the Delisle workshop and from that of their heir, Philippe Buache, referred to these observations and demonstrated the increasing reliance by the *géographes*

de cabinet on the astronomic and triangulation work of the geodesists.

Ecclesiastical cartography also benefited from the progress of geodesy. From its appearance in 1678, the Académie map of the environs of Paris served as a model for the map of the *Diocèse de l'archevêché de Paris* (1675–80) by Albert Jouvin de Rochefort, which also employed the triangle network of the Académie map. Jouvin de Rochefort filled in watercourses and inhabited areas, though with little concern for topographical exactitude (Dainville 1956, 52–53). Attractive maps would follow, however, with the *Diocèse de Coutances* (4 sheets) by G. Mariette de la Pagerie (published by Nicolas Langlois, 1689) considered one of the most accomplished in terms of its precision, the quality of its relief representation, and the subtlety of the engraving. Similar precision permeates the map of the *Evesché de Meaux* (1698), prepared by François Chevalier, whose method of surveying terrain (*des châssis*) proposed in 1707 to the Académie, served as an example to others. Similar standards guided the map of the *Evesché du Mans* (1706), the *Carte particulière du Diocèse de Rouen* (6 sheets; 1:97,300) prepared by Frémont before 1707 and engraved by Claude-Auguste Berey, Académie des sciences engraver, as well as many others, including maps by Guillaume Delisle and later Jean-Baptiste Bourguignon d'Anville (Dainville 1956, 55–70).

Thus, geodesy continued to overlap with the geometric triangulation that accompanied large-scale projects. However, the military *ingénieurs géographes* who drew up the map of the coasts of Brittany in the years 1771–76 noted sizeable discrepancies in distances from the meridian and requested copies of the calculations from Cassini's general triangulation of France. Cassini III answered their requests by publishing the *Description géométrique de la France* in 1783 (Pelletier 2006, 172). Henceforth, military *ingénieurs géographes* would take up geodesy.

The geodesy of France extended beyond its frontiers. On his visit Europe in 1717, Peter the Great twice visited the Paris Observatory. He invited the astronomer Joseph-Nicolas Delisle to found an observatory in St. Petersburg, together with a school, in order to lay the foundation for a map of Russia. The project took shape in 1725. At the death of the czar, Catherine I confirmed the mission of Delisle, who would remain in Russia for twenty-two years. The observatory was constructed, but geodetic operations were limited to the measurement of a baseline near St. Petersburg in 1737 and 1738 (Archives de l'Observatoire de Paris, A7/7, 64–65).

During the War of the Austrian Succession (1740–48), Cassini III followed the army and received the order from Louis XV (17 April 1746) to continue the triangulation operations begun in France into Flanders and

Brabant. Cassini linked Paris to Bergen op Zoom and Maestricht with an “uninterrupted series of triangles” (Pelletier 2006, 164). These surveys served as a foundation for the military maps of Flanders surveyed by François Félix Masse at a scale of 1:14,400 and as a matrix for the map of Joseph Jean François de Ferraris, surveyed at a scale of 1:11,520 and reduced to 1:28,800 (Lemoine-Isabeau 1984, 46–73).

After completing the operations with his father from Brest to Strasburg for the perpendicular to the meridian of Paris, Cassini III continued to Vienna, where he began operations in 1761. He continued into Bavaria (base of 2,000 toises), to the Duchy of Württemberg, and to Duisburg (base of 1,000 toises). In 1762, he carried out a new expedition to construct triangles covering the Palatinate, Franconia, and Austria (Cassini [III] de Thury 1763).

Though the indifference of both Emperor Joseph I of Lorraine and the Grand Duke of Tuscany forced him to abandon these operations, Cassini III next worked to link England with the triangulation of France carried out between 1763 and 1784. His proposal, transmitted by the Royal Society, was well received by King George III. After the untimely death of his father, Jean-Dominique Cassini (IV) took over the project with Adrien-Marie Legendre and Pierre-François-André Méchain. Cassini IV compared the results from Jean-Charles Borda’s improved repeating circle with Méchain’s use of the quadrant. On the English side, William Roy worked under the authority of the Royal Society with the Ramsden theodolite. Dunkirk was joined to Greenwich by about thirty triangles.

The extension of triangulation allowed the spread throughout Europe of the “geometric description” of France completed by Cassini IV. French astronomers from Picard to Cassini IV had provided the methods and instruments for geodetically based mapping on a national scale. On 26 March 1791, the Assemblée Constituante adopted the report proposing a measure of an arc of the meridian between Dunkirk and Barcelona that would definitively establish the value of the meter and commissioned Jean-Baptiste-Joseph Delambre and Méchain for the task.

CATHERINE BOUSQUET-BRESSOLIER
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SEE ALSO: Academies of Science: Académie des sciences (Academy of Sciences; France); Bouguer, Pierre; *Carte de France*; Cassini Family; Ferraris Survey of the Austrian Netherlands; France; Greenwich-Paris Triangulation; La Caille, Nicolas-Louis de; La Condamine, Charles-Marie de; Lapland and Peru, Expeditions to; Meter, Survey for the; Paris Observatory (France); Picard, Jean

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Geodetic Surveying by the German States. See Topographical Surveying: Topographical and Geodetic Surveying in the German States

Geodetic Surveying by Great Britain. At the start of the last half of the seventeenth century, Britain had yet to make its particular contribution to the mapmaking sciences. The country had not lacked excellent mapmakers such as Christopher Saxton and John Speed. However, mapmakers, chartmakers, and surveyors still struggled to achieve a mutually acceptable standard (and definition) for the natural geographical mile. John Davis had published *The Seamans Secrets* in 1595, a treatise on navigation that remained influential for some sixty years, in which he recognized the commonly understood relationship between angular latitude and linear miles.

He stated that a degree of a great circle was “20 leagues, which is 60 mile,” therefore a minute of arc was a mile of “1000 paces, every pace 5 foote” (i.e., the Roman mile), and a degree was therefore 300,000 feet (91.44 km) (Davis 1595, B4). However, he acknowledged that the estimate for the length of a degree lacked any precision.

By the mid-seventeenth century, the 66-foot (22.12 m) chain devised by Edmund Gunter, professor of astronomy at Gresham College, provided English land surveyors with a reliable standard of length. Its measure of 66 feet, or 22 yards of 100 links, was chosen because it was a multiple of the standardized English 16½ foot perch (rod or pole). The same could not be said of the seaman’s nautical mile. Widely accepted as the linear equivalent of a minute of arc, the value for the nautical mile varied substantially. A contemporary of Davis, the mathematician Thomas Blundeville, calculated a nautical mile to be 4,166 feet (1.27 km) based on a degree of latitude being 2,500 fathoms of 5 feet. The mathematician William Oughtred proposed 5,830 feet (1.78 km) assuming a degree of 66¼ statute miles each of 5,280 feet (Glover 2001, 11). It was to answer these uncertainties that Richard Norwood undertook the first measurement of a degree of latitude in Britain.

Norwood, a surveyor and mathematician, began his career in the coastal trade, receiving a rudimentary education in mathematics and navigation. In 1613 he journeyed to Bermuda, where he surveyed and mapped the islands from 1614 to 1617. After a brief period as surveyor to the Virginia Company, Norwood exploited his knowledge of mathematics and navigation as a tutor and author of a number of influential mathematical text books including *Trigonometrie* (1631) and *The Seaman’s Practice* (1637). In the latter work he described his observations and calculations for determining the length of the contentious nautical mile.

For this first reliable measurement undertaken in Britain, Norwood used a five-foot-radius sextant to measure the meridian altitude of the sun observed near the Tower of London on 11 June 1633, finding an altitude of 62°01′, giving 51°30′ latitude. For the north end of his baseline, Norwood chose York, a city found to be some 170 miles distant from London through a combination of chaining with a Gunter’s chain and matched pacing. On 11 June 1635, Norwood observed the solar meridian altitude at York of 59°33′, giving 53°58′ latitude; the difference in latitude from London to York was therefore 2°28′. He divided the distance from London to York, adjusted for the terrain, by the difference in latitude from the solar altitudes, giving him a value for the nautical mile of 6,120 feet (1.87 km; the modern International Nautical Mile is 1,852 meters exactly, or 6,076 feet).

That his nautical mile was a mere 44 feet too great is

remarkable given the instruments of the period. However, the importance of Norwood’s determination is not that he achieved an apparently reliable result (York lay a degree west of London and a straight line route would have been impossible), but that he recognized the importance of an accurate value for the nautical mile and was the first Briton to measure it. Norwood’s determination, applied to the spherical earth, gave it radius of 21,037,635 feet. Despite these achievements, Norwood had to return to Bermuda in 1638 to escape persecution for his religious beliefs, dying there in 1675.

Similar work to determine the size of the (spherical) earth came in France in 1669 when the abbé Jean Picard measured a meridian arc near Paris by triangulation using a quadrant with a three-foot (1.03 m) radius and observed its terminal latitudes with a long (3.25 m) zenith sector fitted with a telescope and (probably) the first use of fine cross-wires at the focus point (see figs. 265 and 396). Picard’s length for a degree of latitude was 57,060 toises (365,184 feet; 111.21 km) (Danson 2006, 23–24) making the earth’s radius 20,890,809 feet and a nautical mile 6,086.4 feet; a result close to Norwood’s and remarkably similar to modern measures.

Worldwide trade by the maritime nations stimulated a demand for better navigation solutions, which, in turn, called for precise star charts for marine use. Apart from the Pole Star, few star positions were accurately known. To overcome this paucity of data, the Greenwich Royal Observatory was established in 1675. The shape of the earth was held by most scholars to be a sphere. In 1687, Isaac Newton reached his dramatic conclusion that the earth was in fact flattened at the poles because of the effects of its daily rotation and, importantly for geodesy, speculated that the gravity of a mountain’s mass might be sufficient to deflect a plummet, a theory that became known as the attraction of mountains.

Interest in measurements of angle and distance during the early seventeenth century was principally limited to land surveyors and the more mathematically sophisticated mapmakers. At sea, mariners had benefit of tables of latitude, a means of observation with Davis’s back staff (1594), and Norwood’s value for the nautical mile (1635). With the invention of the telescope and its adaptation to astronomy, practical astronomers were beginning to map the heavens. On land, surveyors had the benefit of Gunter’s chain (1620), the principal instrument in estate surveying for distance measurement, as well as the circumferentor and the first theodolites for angular measures. They also enjoyed the availability of many textbooks on surveying methods and rudimentary land law. The general increase in land rents toward the end of the century and the slow rise of the enclosure movement led to increases in land value and the consequent need for better instruments to measure field areas

more quickly and accurately. The combination of better instrumentation and mathematical training opened the way toward the radicalization of geodesy during the next century.

It was important for geodesy that secondary education for the sons of the more affluent artisans provided an improved and plentiful source of land surveyors to meet the hugely increased demand for accurate plats. Their practical education included mathematics, geometry, and trigonometry as well as instruction in the use of John Napier's logarithms for complex calculation. By the first decades of the eighteenth century, both Cambridge and Oxford had consolidated the teaching of mathematics and geometry in their curricula.

As education improved, so did the instruments of the surveyor and practical astronomer. Located along London's Strand and Fleet Streets, the chief instrument-makers included Jonathan Sisson, who advanced the art of circle division, improving the theodolite with the addition of a telescope, a graticule, and a horizontal bubble. In 1742, the Royal Society of London commissioned him to construct the first imperial standard yard. Made of brass and engraved by his young apprentice, John Bird, copies of the standard went to the Académie royale des sciences in France and to America in 1816 with Ferdinand Rudolf Hassler. For the Greenwich Observatory, George Graham constructed an 8-foot mural quadrant fitted with a vernier scale reading to 15' of arc, and a 12½-foot (3.81 m) zenith sector for observing latitude by transiting stars. Bird, perhaps the finest of this group of instrumentmakers, took handmade divisions on instruments to their zenith. Between 1749 and 1767, Bird constructed an 8-foot mural quadrant, fitted with his tangent screw micrometer, for the Greenwich Observatory, and furnished many of the quadrants and sectors employed during the transit of Venus campaigns. The introduction of the achromatic lens, patented in 1758 by John Dollond and Peter Dollond, led to a great improvement in telescopes and allowed short, practical telescopes to be fitted to land survey instruments. The most innovative were those of Jesse Ramsden, who pioneered mechanical division, creating a family of exquisite, precise measuring instruments. While London was the center of British instrumentmaking, the trade also flourished across the country, since for their basic income craftsmen relied on satisfying the growing demands for land surveyors mapping the new enclosures and for the engineers contributing to the Industrial Revolution.

Most learned commentators agreed that the earth was not round; it was either flattened, the Newtonian view, or elongated, a view held by some in France. Thanks to the work of Norwood and Picard, the all-important nautical mile had been established with an accuracy

commensurate with the needs of good navigation. The next challenge was to determine the true shape of the earth and its precise dimensions.

Britain took no major part in the early science of geodesy. The French Académie royale des sciences led the determination of the figure of the earth. In 1736–37 the expedition of Pierre Louis Moreau de Maupertuis to Lapland gave the length of a degree in the meridian of 57,437.9 toises (367,602.56 feet) at the latitude of the Arctic Circle (Danson 2006, 35). The expeditions of Charles-Marie de La Condamine and Pierre Bouguer to Peru in the years 1735–43 determined the length of a degree at the latitude of the equator as 56,753 toises (363,219 feet) (Danson 2006, 40). While in Peru, Bouguer attempted to detect and measure Newton's prediction for the attraction on mountains using the mass of Mount Chimborazo in the Andes. His value of 7.5 arc seconds seemed too small and Bouguer suspected the accuracy of his zenith sector. Nevertheless, he had demonstrated a practical method.

When incorporated with the work of Picard, and later the Cassini family in France, the arcs in Lapland and Peru firmly established the flattened shape of the earth and gave for the first time a reliable value for its principal dimensions. All this work was carefully followed in Britain, but it was not until the advent of the 1761 transit of Venus and its possibility for measuring the solar parallax that serious scientific attention was paid. Led by the fellows of the Royal Society and, in particular, Astronomer Royal James Bradley, two expeditions were sent abroad: one to Benkulen (Bengkulu) in Sumatra and another to the South Atlantic island of Saint Helena. The Benkulen team comprised astronomer Charles Mason and land surveyor Jeremiah Dixon. Forced to divert to Cape Town, they successfully observed the transit and spent a number of months observing southern stars. Their colleague on Saint Helena was Nevil Maskelyne. These three men represent the beginnings of Britain's geodetic work that culminated with the great surveys of India and Africa in the next century and the development of the first reference ellipsoids, or mathematically defined surfaces used to approximate and visualize a planetary body such as earth.

In 1769, Mason and Dixon joined the hundreds of astronomers from across Europe and North America to observe the second transit of Venus. The recent completion by John Harrison of a successful chronometer, H4, provided a quick and accurate mechanical solution to finding the longitude, surpassing even Maskelyne's lunar distance method.

The perplexing enigma of the attraction of mountains remained contentious. Any precise earthly measurement dependent on the vertical as an index was, according to Newton, a candidate for susceptibility. Evidence for the

existence of the attraction of mountains was mounting from the many gravity observations around the globe and the small inconsistencies apparent in some meridian arc measurements; all hinted toward the density of the earth, still unknown, not being completely consistent with a solid or even (as some contested) a hollow world. Maskelyne was firmly of the opinion that the aberrations were consistent with what might be expected from Newton's attraction of mountains and set out to prove it.

Under the auspices of the Royal Society, Maskelyne devised a simple but clever experiment, requiring either a deep valley or a moderate mountain oriented east-west and preferably isolated from its peers. Maskelyne postulated that if the effect were real, then the latitude observations either side of such a defile or hill would be influenced by the change in mass occasioned and that, when converted to distance using Bouguer's *La figure de la Terre* (1749), would differ from a directly measured distance. The difference between the two would be twice the value of any vertical deviation due to a discordance of gravity.

In August 1773, Charles Mason traveled to Scotland to find a suitable site for Maskelyne's experiment. By the end of October he reported finding a remarkable hill in the Scottish Highlands: Schiehallion. Mason declined the invitation to make the experiment because of ill health and inadequate recompense. The Royal Society turned instead to the mathematician Reuben Burrow to carry out the following instructions: first, to find by celestial observations the apparent difference of latitude between the two stations on the north and south sides of the hill; second, to find the distance between the parallels of latitude; and third, to determine the figure and dimensions of the hill (Maskelyne 1775, 508; Danson 2006, 119–20).

After many difficulties, the fieldwork was completed on 24 October 1774. Maskelyne delivered a paper to the Royal Society on 6 July 1775, in which he announced that the difference between the measured distance between the northern and southern observatories and that derived from the latitude observations amounted to 11.6 arc seconds and, therefore, Schiehallion's attraction, or the amount by which its mass deflected the plumb line, was 5.8 arc seconds (ca. 600 feet [182.9 m] over the ground). Maskelyne scarcely mentioned any of the many scientists and practitioners who assisted him, entirely dismissing Burrow "on account of his inferiority of education and situation in life" (quoted in Danson 2006, 195). For his experiment, Maskelyne was awarded the Society's 1774 Copley Medal.

Maskelyne had determined the deflection of the vertical; it only remained to calculate the volume and mass of the mountain and its gravitational attraction in order to derive a mean density of the earth itself. This task

was awarded by the Royal Society to the mathematical genius Charles Hutton, who took almost four years to solve the riddle. His paper was presented to the Society's fellows on 21 May 1778 (fig. 267).

Hutton's remarkable conclusions were that the ratio of Schiehallion's gravitation attraction to that of the whole earth was 1:9,933; that the theoretical attraction of the mountain was 20.8 seconds of arc which, given Maskelyne's observed 11.6 arc seconds, meant that the mountain was approximately 55 percent the density of the entire earth; and the mean density of the planet was approximately 4.5 times that of water. He acknowledged that the geological information he had at his disposal was limited in the extreme and that the world would have to wait for a more thorough examination of the density of the mountain's rock (Danson 2006, 154). Hutton described a large four-foot-square map (no longer extant) used to set down the data acquired during the expedition, and he employed contour lines of the thousands of elevations calculated by Burrow (Hutton 1778, 714–15, 756–57, 780).

In 1782, Burrow left England for a career in India. Between 1790 and 1791, with the encouragement of William Roy and the mathematician Isaac Dalby and with funds from the East India Company, he measured a degree of longitude and another of latitude in Bengal, the first arcs measured in India. In 1802, William Lambton began work on the Great Arc of India, a network of triangles extending from Bangalore south to Cape Comorin.

The early years of the eighteenth century saw a rapid improvement in the quality and quantity of land surveying instruments available to the surveyors servicing the agricultural community. That said, the majority of land surveyors throughout the century preferred to work with a chain only. Angle-measuring instruments were limited to the more affluent surveyors.

The invention of John Hadley's double reflecting octant (or quadrant) in 1730 and the sextant in the latter half of the century radically improved the measurement of latitude at sea. Combined with Tobias Mayer's and Maskelyne's lunar distance tables, determining longitude became ever more precise. Finally, Harrison's invention of the chronometer made the business of finding a reliable longitude simple and precise. Although an expensive piece of equipment (ca. £60 for a good "marine watch"), by the close of the century most foreign-going British vessels carried one.

The invention of the dividing engine and achromatic lenses in the second half of the century led to the construction of extremely precise instruments for both astronomical and geodetic observations. Baseline measurements improved significantly with the introduction of precisely calibrated rods and chains, and the process of

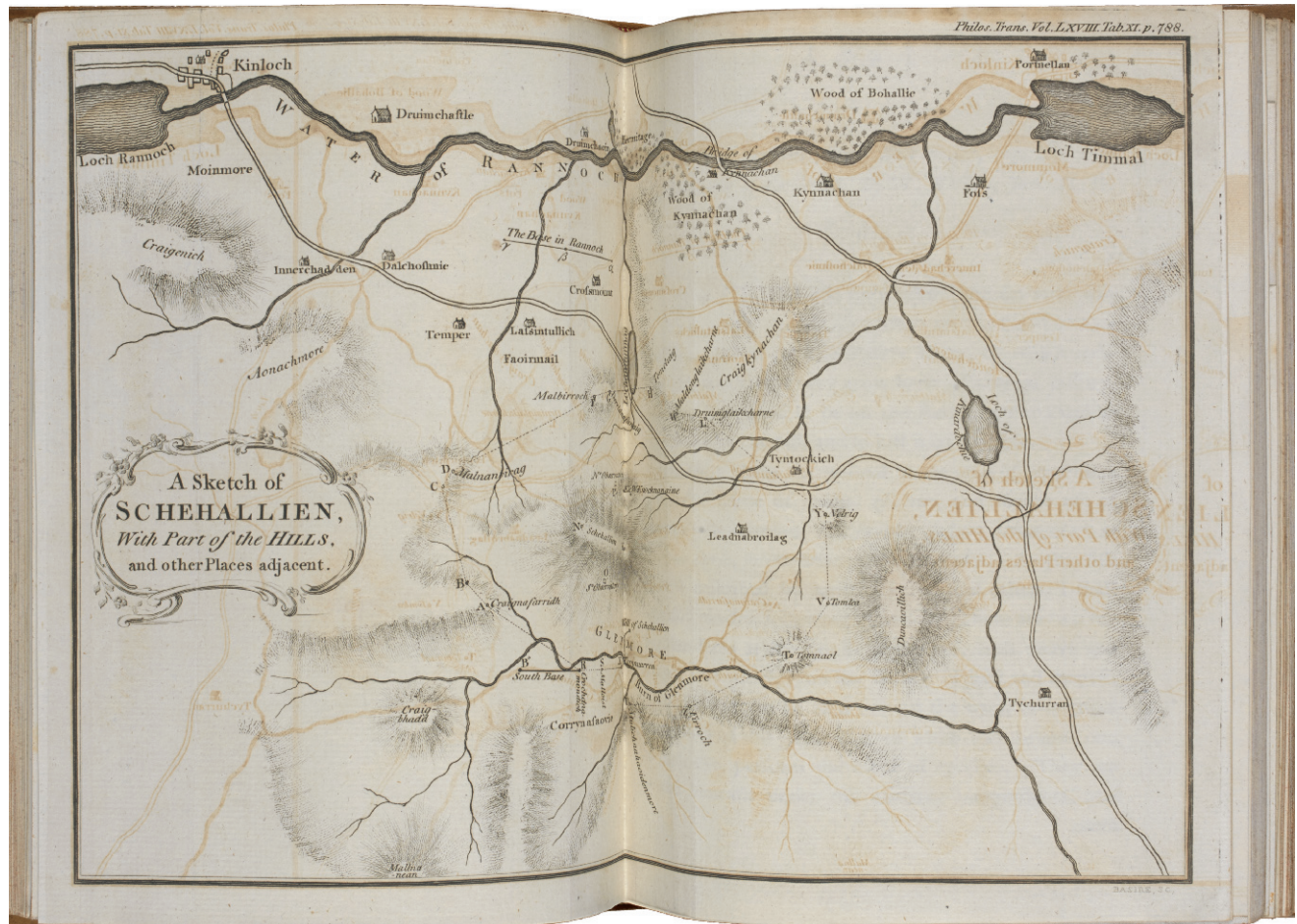


FIG. 267. A SKETCH OF SCHEHALLIEN, WITH PART OF THE HILLS, AND OTHER PLACES ADJACENT, 1778. From Hutton 1778, pl. XI.

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triangulation became widely accepted as the most precise and rapid means for establishing mapping control.

The work of Mason and Dixon in America, that of Burrow on Schiehallion, and Roy's great triangulation led to the development of advanced measuring methods and the disciplines necessary for precise determinations. The use of calibration techniques and the application of corrections for temperature, atmospheric pressure, and tension allowed these first geodetic surveyors to achieve remarkably accurate (standardized) measures of length. The certainty of the attraction of mountains, measured by Maskelyne, cautioned geodesists to be aware of the effect and encouraged the collection of data from around the world. By the close of the century, the basic principles and a growing awareness of the strange effects of natural phenomena on geodetic observations were in place for the geodesists of the nineteenth century to develop, explore, and understand the mechanics that make geodesy one of the most fascinating of the natural sciences.

EDWIN DANSON

SEE ALSO: Academies of Science: Great Britain; Great Britain; Greenwich Observatory (Great Britain); Greenwich-Paris Triangulation; Mason-Dixon Line; Roy, William

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Geodetic Surveying by the Italian States. In 1655 the Italian Jesuit Giovanni Battista Riccioli, with the help of his fellow Jesuit Francesco Maria Grimaldi, produced a calculated estimation of the earth's size, the first effort in Italy to do so. The century that followed opened with the work of Monsignor Francesco Bianchini, who produced a partial correction of the geodetic alignment of the Italian peninsula and, between 1717 and 1725, carried out astronomical and trigonometrical measurements in order to produce a map of the Duchy of Urbino.

Italy's more substantial contribution to both the practice and theory of geodesy developed from the middle of the century onward. As part of scientific research aimed at defining the terrestrial spheroid, geodesy formed a necessary basis for “protogeometric” cartography (Cantile 2004); as Elio Manzi (1987, 338) points out, it was one of the cultural products of what Giambattista Vico described as the recurring tension between “truth” and “certain knowledge.” Credit for the realization that “only precision greater than that actually necessary for the drawing of maps would provide material and data of high scientific interest” (Mori 1922, 4) lies almost exclusively with Jesuit and Piarist scientists (the Piarist order was founded in seventeenth century by Saint Joseph Calasanz and devoted to education and scientific research). Not only were they responsible for Italy's main achievements in geodesy during the eighteenth and nineteenth centuries, they also trained the ranks of scholars and technicians who would play a decisive role in nascent official cartography within the peninsula (Cantile 2007).

The first such work was carried out in the years 1750–53 within the Papal States, when the Jesuits Ruggiero Giuseppe Boscovich and Christopher Maire measured the arc of meridian between Rome and Rimini (Maire and Boscovich 1755). The two scientists prepared a trigonometric network of nine large triangles spanning about two degrees of latitude for an arc of $2^{\circ}9'46''$ (fig. 268). To measure the length of this arc, they established two geodetic baselines at the ends of the span: one in Rome (running along the Via Appia from the Tomb of Cecilia Metella to Frattocchie) and the other at Rimini (running from the mouth of the Ausa River to-

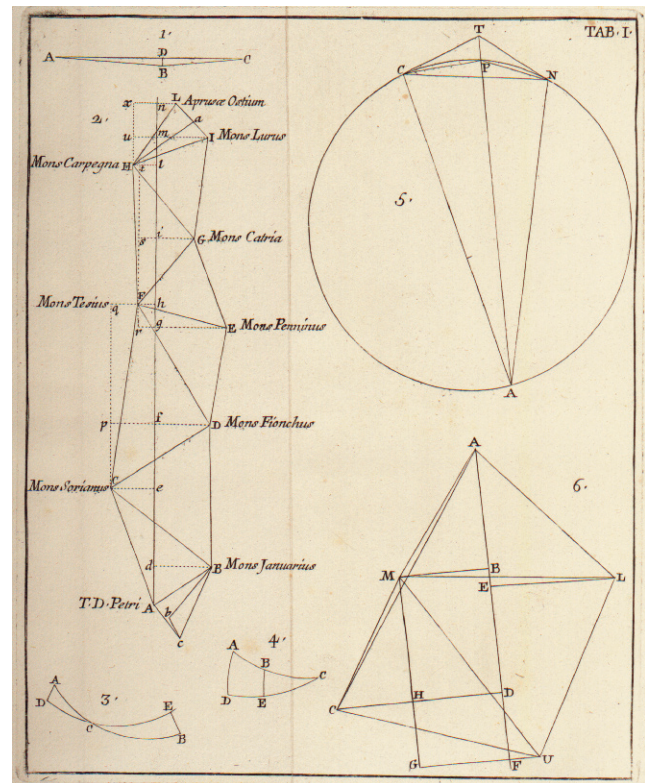


FIG. 268. THE TRIANGULATION OF THE ECCLESIASTICAL STATES. From Maire and Boscovich 1755, tab. 1.

Size of the original: 19.0×15.5 cm. Image courtesy of the Stephen S. Clark Library, University of Michigan, Ann Arbor (QB 296 P2 M2).

ward Pesaro). The baselines were measured using three rods of seasoned wood, each 27 palmi romani (6.03 m) long, which were calibrated against an iron toise copied from the toise de Pérou owned by Jean-Jacques Dortous de Mairan. Over the following decades, the measurement of the Via Appia baseline was rechecked several times, with a new measurement ultimately determined by the Jesuit Angelo Secchi (Borchi and Cantile 2000). The angles at the vertices of the network and the relative azimuths at Rome and Rimini were measured with a quadrant 3 piedi romani (0.89 m) in diameter; the absolute latitudes at the ends of the arc of meridian were determined using a circular sector 9 piedi in diameter (2.68 m). The results achieved—56,979 toises per degree—did not agree with the previous measurements for the length of a degree of arc obtained along the southern section of the French meridian. These differences led Boscovich to claim that their measurements confirmed Newton's theory; he explained the discrepancies between the experimental data as due to the effect of mountain masses on the plumb line. The work of these two “indefatigable gentlemen” (Pedley 1993) provided the geometric framework for Maire's *Nuova carta geo-*

grafica dello Stato Ecclesiastico (1755, ca. 1:375,000), the first geodetic map produced in Italy (see fig. 90).

Boscovich's conclusions required further testing to establish whether the Alps did indeed cause the plumb line to deviate from the vertical. In 1759, the king of Sardinia, Carlo Emanuele III, commissioned the Piarist cleric Giovanni Battista Beccaria to carry out further measurements. From 1760 to 1764 Beccaria measured a trigonometric network stretching from Mondovì (Monregalese) to Andrate, covering just over one degree of latitude (arc length $1^{\circ}7'54''$) and composed of seven triangles with its geodetic baseline stretching from Turin to Rivoli. He used iron bars of about 6 piedi parigini long (1.96 m) to measure the baseline and a quadrant with a 300 linee (0.68 m) radius to measure the angles at the vertices and to take astronomical measurements at the ends of the network. To test the hypothesis that the proximity of the Alps caused a deviation from the vertical, Beccaria divided the arc of meridian into two parts—to the north and south of Turin. This gave him two different readings of the average degree of latitude along the *meridiana Andratensis* and the *meridiana Monregalensis*; once again, both measurements differed from the French measurements. These results convinced Beccaria of the truth of Boscovich's theory ([Beccaria] 1774). However César-François Cassini (III) de Thury disagreed, claiming that the differences with respect to the French meridian were due solely to inaccuracies in the geodetic procedures, a view shared by Franz Xaver von Zach. It was only when the astronomers Giovanni Plana and Francesco Carlini made more accurate measurements that the conclusions from Beccaria's experiment were accepted in principle, despite all the objective limits to the accuracy of his network. Beccaria's work was furthered in 1788 by Father Salvatore Lirelli, who extended the network with fifty new triangles, although they were not measured with any great accuracy (Mori 1922, 9–12).

Within the Duchy of Milan, Boscovich was a rather isolated figure when he carried out his astronomical and geodetic measurement in 1762, but thanks to government commissions to the Jesuits Barnaba Oriani, Francesco Reggio, and Giovanni Angelo de Cesaris, geodetic work was carried forward. All members of the Brera Observatory, they measured an arc of meridian and prepared a topographical map of the duchy. From 1788 to 1791, they determined a trigonometric network stretching from the Alps to the area of Piacenza and across to the borders of the Veneto; the geodetic base was calculated near Somma Lombardo, on the left bank of the Ticino. Distances were measured using three sophisticated T-shaped iron rods (*longimetri*), twice the length of the standard toise of the Paris Observatory,

itself copied from the toise de Pérou (Reggio 1794). For their trigonometric procedures the astronomers used a mobile quadrant with a radius of 1.5 piedi (0.49 m) and three different Troughton theodolites, while the measurement of astronomical coordinates at the Brera Observatory was made with a mural quadrant with a radius of 8 English feet (2.44 m) specially built by Jesse Ramsden. Their work, inspired by the famous *Carte de France*, bore cartographic fruit, and a final image was drafted and engraving begun in 1792–93 (fig. 269); the ten-sheet *Carta topografica del Milanese e Mantovano* was finally printed in 1804–7 (ca. 1:86,400) (Combi 1930; see also fig. 306).

In the Venetian Republic, Giovanni Antonio Rizzi Zannoni in 1776 calculated a small trigonometric network for his map, *La gran carta del Padovano* (1780–81, ca. 1:20,000; see fig. 422). However, it was only during the Austrian occupation after 1797 that regular survey work began to cover the entire territory of the former Republic. Headed by General Anton von Zach—brother of the aforementioned Franz Xaver—the survey team calculated a trigonometric network from four geodetic baselines; the first one, the most famous of these, measured in the immediate vicinity of Padua (from the city's Porta Santa Croce to Pozzovigiano) and the other baselines measured respectively on the left bank of the Piave River, in Passariano, and in the land of Schwarzaneck in Carinthia. Measurements of the first baseline were obtained with four rods of seasoned wood, each measuring 4 Viennese klafter (7.59 m) and calibrated against a copy of the French toise; the angles at the vertices of the network were, however, calculated using quadrants of no great precision. War temporarily stopped the geodetic and topographic work, which was concluded in 1805; its results served the production of the unpublished “Topographisch-geometrische Kriegskarte von dem Herzogthum Venedig,” consisting of 120 sheets (*Sectionen*), at 1:28,800 scale, with military descriptions (*Militarische Beschreibungen*) (Rossi 2005), and the published map, *Das Herzogthum Venedig / Il Ducato di Venezia* (1806, ca. 1:234,000). The results of this survey were so uncertain from a scientific point of view that Franz Xaver von Zach intervened to correct the locations of various points.

In the Grand Duchy of Tuscany, 1750 marked the first of the three commissions given to the Jesuit scientist Leonardo Ximenes to create a map “founded on geometric bases” (Mori 1905, 373). However, even though numerous maps were prepared with each serving specific purposes, no solid geodetic work was ever carried out throughout the eighteenth century (Rombai 1987, 296). Repeated calls for such cartographic projects all came to nothing; neither the regency governments of



FIG. 269. GIOVANNI ANGELO DE CESARIS, FRANCESCO REGGIO, AND BARNABA ORIANI, *CARTA TOPOGRAFICA DEL MILANESE E MANTOVANO ESEGUITA DIETRO LE PIÙ ESATTE DIMENSIONI GEOGRAFICHE ED OSSERVAZIONI ASTRONOMICHE*, ENGRAVED (1792–93) AND PRINTED (1804–7), FOGLIO 1, SCALE 1:86,400. The three Jesuits measured an arc of meridian and prepared a

topographical map of the duchy after determining a trigonometric grid stretching from the Alps to the area of Piacenza and across to the borders with the Veneto from 1788 to 1791. (For a detail from another sheet of this map, see fig. 306.) Size of the original: 54 × 87 cm. Reproduced with permission of the Istituto geografico militare, Florence (authorization n. 6934 dated 03.15.2017).

1737–65 nor Grand Duke Leopold I of Tuscany (later Emperor Leopold II) showed the political will and determination necessary for such an undertaking. Failing to understand the social and scientific importance of such work, its leaders allowed Tuscany to trail behind in geodetic surveying (Cantile 2008).

In the Kingdom of Naples, on the other hand, thanks to the enlightened initiative of the abbé Ferdinando Galiani, Rizzi Zannoni set to work. From 1781 onward he became the first to undertake systematic geodetic surveys in southern Italy, laying the baselines for one of the most important cartographic projects in Europe (Valerio 1993). Rizzi Zannoni established the fortress of Sant’Elmo in Naples as the origin of his geodetic frame of reference. He then established the absolute latitudes of Lecce and Capo Santa Maria di Leuca and measured

two geodetic baselines (one in the plain between Caserta and Caivano, the other near Lecce). From these he proceeded to make a general triangulation of the kingdom (three volumes of manuscripts, his “*Observations astronomiques et géométriques*,” can be consulted in the Biblioteca Attilio Mori at the Istituto geografico militare, Florence). He determined the astronomical coordinates of the Sant’Elmo fortress with a Ramsden quadrant 2 feet (0.62 m) in radius but measured the baselines of Caserta and Lecce with walnut rods standardized against a special iron chain that had been compared “with a standard that was kept in the Customs House” (Firrao 1868, 6). Using a Ramsden graphomètre 1.5 feet (0.46 m) in diameter, he measured the angles of the vertices of the triangles, starting from the Orlando Tower in Gaeta. Finally he joined all these measurements to the



FIG. 270. GIOVANNI ANTONIO RIZZI ZANNONI, GULF OF NAPLES, 1794. From his *Atlante geografico del Regno di Napoli* (Naples, 1788–1812), foglio 14, scale ca. 1:114,000. From 1781 onward Rizzi Zannoni was the first to undertake systematic geodetic surveys in southern Italy.

Size of the original: ca. 53 × 78 cm. Reproduced with permission of the Istituto geografico militare, Florence (authorization n. 6934 dated 03.15.2017) (Archivio cartografico, Gruppo 11, n. 28 d'ordine, Cartella d'Archivio 85, Documento n. 6).

geodetic network of the Papal States. Thus, based on the assumption that the earth is a sphere, he obtained the length of the arc of meridian between Capo Santa Maria di Leuca and Naples and between Naples and Rome. All of Rizzi Zannoni's work in the geodetic field was designed purely for use in cartography, which means that on a scientific level it cannot be compared to work carried out with more rigorous standards. Nevertheless, it did result in the completion of the most wide-ranging cartographic project within Italy to date: the famous *Atlante geografico del Regno di Napoli* (1788–1812, ca. 1:114,500) (fig. 270).

Other Italian states made few original contributions to geodesy; in the Republic of Genoa there were no initiatives (Quaini 1986), while in the Duchy of Modena the topographical work of Domenico Vandelli included the *Stati del serenissimo signor duca di Modena in Italia* (1746, ca. 1:200,000). After the French occupation, the geodetic network already established for Lombardy was

also extended, covering the duchies of Modena, Parma, and Piacenza.

Finally, in the Kingdom of Sicily the baron Samuel von Schmettau, quartermaster general in the Austrian army, undertook a topographical survey on his own initiative but with the approval of Prince Eugene of Savoy, from 1719 to 1721, with a team of six military engineers including Lieutenant Michel (Miguel) Angelo de Blasco (Dufour 1995, 25–50). On his return to Vienna in 1721, Schmettau supervised Blasco in the preparation of two manuscript maps at 1:80,000. By 1723 a printed version ca. 1:321,000 appeared under the title *Nova et accurata Siciliae . . . Descriptio universalis* (see fig. 305). The printed map bore the claim that it was based on astronomical observations, and there is no evidence that it was based on a geodetic framework (Dufour 1995, 35–38).

ANDREA CANTILE

SEE ALSO: Boscovich, Ruggiero Giuseppe; Italian States; Rizzi Zannoni, Giovanni Antonio

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Geodetic Surveying by Portugal. In Portugal during the reign of João V (1706–50), the need to redefine the

borders of overseas territory with Spain stimulated the spread of new surveying methods. In 1720, the *engenheiro-mor* (principal engineer) of the kingdom, Manoel de Azevedo Fortes, began to reform teaching in the military academies to produce capable engineers skilled in surveying and large-scale mapmaking techniques. To achieve this, Azevedo Fortes published his *Tratado do modo o mais facil, e o mais exacto de fazer as cartas geograficas* (1722) and *O engenheiro portuguez* (1728–29), syntheses of French treatises available at the time (Bueno 2011, 101–2). Between 1722 and 1729, João V also established two astronomical observatories in Portugal (Bueno 2004, 232).

The first concern of the Crown was the geodetic surveying of overseas territory, such as the urgent project "Novo atlas da América portuguesa" (Almeida 2001, 100–142). Instead of waiting for results from Azevedo Fortes, João V decided to contract Giovanni Battista Carbone and Domenico Capassi, Jesuit astronomers by profession, living in Naples, to start making the first maps with latitudes and longitudes observed in loco. Carbone was replaced by another Jesuit, the Portuguese Diogo Soares. These *padres matemáticos* (mathematician priests) made the first general maps of Brazil.

After the Treaties of Madrid (1750) and San Ildefonso (1777), the Portuguese and Spanish sent expeditions to demarcate the new frontiers of their territory in South America. These expeditions integrated Portuguese and foreign military engineers and astronomers who were charged with the difficult task of surveying and also with making astronomical observations (Ferreira 2001, 91–114). Some of the astronomers contracted at that time by the Portuguese government, like the Italian Miguel António Ciera, later returned to Portugal, where they played an important role in beginning geodetic work there.

In Portugal, geodetic work effectively began only toward the end of the eighteenth century after the creation of the Academia Real das Ciências de Lisboa (1779). The subject of the "Carta geral do reino" was analyzed and discussed at the Academia by astronomers and mathematicians in the late 1780s. Portuguese astronomer Custódio Gomes de Vilas Boas presented his opinion to the secretary of the Academia, dated October 1789, in which he expressed the views of other members and demonstrated that their proposal was quite different from the way the work was to be carried out starting the following year (Dias 2003, 384–85).

In 1790, a government order placed the mathematician and astronomer Francisco António Ciera, a professor at the Academia Real da Marinha, in charge of the construction of the "Carta geral do reino" and the measurement of the meridian degree, following the example of other European models (Ciera was the son of



FIG. 271. FRANCISCO ANTÓNIO CIERA, MAP OF THE POINTS AND THE SERIES OF TRIANGLES FOR MEASURING THE DEGREE OF THE MERIDIAN BETWEEN 37° AND $43^{\circ}45'N$, 1791. Manuscript, ca. 1:2,000,000. The first geodetic network of Portugal, designed and signed by Ciera, based on the surveys of 1790–91 directed by him. Size of original: 49×40 cm. Image courtesy of Portugal/Gabinete de Estudos Arqueológicos da Engenharia Militar/Direção de Infraestruturas do Exército, Lisbon (4361/I-4-49-82).

the above-mentioned Miguel António Ciera, surveyor of South American boundaries). Two official engineers worked with Ciera: the Portuguese Carlos Frederico de Caula and the Catalan Pedro Folque. They traveled throughout Portugal during the first expeditions (1790–91), choosing the most appropriate high points from which to observe. Those travels were described in a manuscript report, “Viagem geografica & astronomica pelo Reino de Portugal p.^a a construsão da carta topografica e determinação do grão do meridiano” (Lisbon, Arquivo Histórico Militar). In the autumn of 1791, the observations were extended to Galiza (Galicia), in collaboration with Spanish officials. The result of these first expeditions was a map with the first geodetic network of Portugal (fig. 271).

In 1793 a short geodetic baseline was measured near Lisbon (Batel-Montijo), an operation repeated in the following year with measurements made by Ciera with

instruments developed by José Monteiro da Rocha, and, in 1796, another measurement in the central part of the country (Buarcos-Monte Redondo). From 1793 the team observed angles with a repeating circle made by George Adams Jr. and ordered from England. By the end of the eighteenth century, there was a network with a considerable number of points, but it did not extend beyond Serra da Estrela in the north. However, many points were established along the coast, and the triangulation of the harbor of Lisbon was completed. Ciera’s geodetic work was synthesized in the *Carta dos principais triangulos das operaçoens geodezicas de Portugal* (ca. 1:1,800,000, 1803), one of the rare maps printed by the Sociedade Real Marítima, Militar e Geográfica, under the direction of the French officer Louis André Dupuis. Brought to London, the map was surreptitiously translated and published by Aaron Arrowsmith in 1805. At the beginning of the nineteenth century the “Carta geral do reino” was finally begun, at 1:10,000, but work was suspended in 1804 by the political difficulties of the time. Not until 1835 were the geodetic works reinitiated by Pedro Folque and his son Filipe.

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SEE ALSO: Administrative Cartography in Portugal; Portugal

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Geodetic Surveying by Spain. Jorge Juan and Antonio de Ulloa, two renowned Spanish geodesists, participated in the French scientific expedition to Peru. This experience garnered numerous honors on their return to Madrid, and their detailed expedition report, *Relacion historica del viaje a la America Meridional* (1748), to secretary of state Zenón de Somodevilla y Bengoechea, marqués de la Ensenada, brought his patronage. Juan was familiar with the geodetic principles established by Jean Picard as a foundation for geodetic surveying in France; he incorporated these principles in his proposals for mapping Spain.

Ensenada was aware of the political importance of maps and the necessity of having a map of Spain prepared with geometric reliability that the administration could use to support its plans. In the memoir he presented to the king in 1753, he referred to geographic maps and affirmed: “The benefit that this provision will produce [is] not [only] for the knowledge of the exact position of each place; it will provide at a glance the extent of the territory, the exact boundaries of each province, the course of the rivers, the areas that they irrigate and their navigation, the use and exploitation of the lands. . . . and other important information leading to good government and the promotion of commerce” (quoted in Capel 1982, 150). Ensenada’s interest in cartography on a global level was complemented by his more local interest in the cadastre, set out in his “Proyecto de una única contribución en la Corona de Castilla” and elaborated in a royal decree of Fernando VI published in October 1749.

Juan described his first project in his “Instrucción de lo que se ha de observar . . . en la formación de los Mapas generales de España” (also attributed to Juan and Ulloa jointly). A manuscript of the “Instrucción” for this innovative cartographic project is preserved in the Real Academia de la Historia, Madrid, although its date of presentation is unknown. Juan recommended the construction of an accurate map of Spain based upon a geodetic network of triangles centered along one of the sides of a central triangle. The three chapters of the description of the project—geography, hydrography, and astronomy—detail all the geodetic measurements and type of geographic information to be recorded. One example of such an instruction refers to the error of closure of a triangle: “If the error exceeds six minutes it is mandatory to find out where this error comes from by observing again the three angles” (para. 24, p. 10). Juan also describes the angle-measuring instruments to be used: “A metal graduated quadrant, of nine inches radius and with all the pieces according to its usage, and a telescope of four lenses” (para. 30, p. 53) (Ruiz Morales and Ruiz Bustos 2005, 64, 66). Training survey works were carried out in Toledo, but unfortunately no written report is preserved.

Juan’s second project, “Método de levantar y dirigir el mapa ó plano general de España,” was presented to Ensenada in 1751 but not published until 1809. The technical considerations of the first project are included there, although generalized. Some aspects of this project are more precise than the first, such as the expected completion date. The geodetic foundations of the project included measuring a baseline in the center of Spain, although reduced by two or three leagues from the recommended length of Juan’s first project. Juan’s proposed configuration of the triangular network was unusual in an unexpected way. Instead of following the French

method of establishing chains of triangles along meridians and parallels, Juan proposed “eight series of triangles [to] be set up from the baseline, following the eight needle bearings to the end of the kingdom,” to follow the cardinal points of the compass (Juan 1809, 144).

These two geodetic proposals, large and all-encompassing for eighteenth-century Spain, were frustrated by Ensenada’s fall from power in 1754 due to political intrigues, which put an end to all the minister’s cartographic plans. Nonetheless, Juan’s projects served Vicente Tofiño de San Miguel in his instructions for the survey of the coast of the Iberian Peninsula. Tofiño established triangular chains along the coast, measuring several baselines, and making angular observations. Complementary astronomical observations helped to calculate the latitude and longitude of single points (fig. 272). The fieldwork, carried out between 1783 and 1788, led to the production of the *Atlas marítimo de España*, containing the first Spanish maps compiled using contemporary geodetic methods.

As part of their program of cartographic renewal, Juan and Ulloa proposed to Ensenada that Tomás López be sent to Paris to learn the art of engraving and geographic mapmaking. Although López stated later that the purpose of his sojourn was to learn how to make a map of Spain, his important compilation of cartographic information lacked geometric reliability because it wasn’t based on any geodetic network. Nevertheless, López played a major role in creating the Cuerpo de Ingenieros Cosmógrafos de Estado established by his good friend the prime minister, Manuel Godoy (Ruiz Morales 2003, 40–42). The ordinance of the Cuerpo, signed by King Carlos IV in August 1796, incorporated the need to create a geometric chart of the kingdom. The first surveys were carried out four years later in Catalonia and Galicia, but no documents are preserved. Unfortunately, the Cuerpo de Ingenieros Cosmógrafos was suppressed by a royal order of the government on 31 August 1804. It would take another fifty years before the creation of an institution, the Dirección de la Carta Geográfica de España, that could establish a geodetic network based on a central baseline at Madridejos (Toledo).

Nonetheless, at the end of the eighteenth century other geodetic work took place in Spain along the frontier, stemming from the prolongation of the meridian of France to south of Barcelona, performed in order to define the geodetic meter. Pierre-François-André Méchain was in charge of these operations up to the eastern coasts of Spain, and after his death his successors Jean-Baptiste Biot and François Arago expanded the triangulation network to include the Balearic Islands. Various Spanish geodesists collaborated with them, including José Rodríguez González. During the two years of the survey (1806–8), he supervised the triangulation of Majorca, uniting that network to those on Ibiza and



Formentera (Ten 1996, 163–80). Rodríguez González further enhanced his scientific prestige by critically analyzing the geodetic works of William Mudge and Isaac Dalby in England, Nicolas-Louis de La Caille in South Africa, and William Lambton in India. His study appeared in the 1812 *Philosophical Transactions of the Royal Society of London* as “Observations on the Measurement of Three Degrees of the Meridian Conducted in England by Lieut. Col. William Mudge.” Even though the results of this Balearic network helped to confirm the value of the meter, linking the triangles to the peninsula was not completed until well into the nineteenth century, with work supervised from 1865–85 by Carlos Ibáñez e Ibáñez de Ibero.

MARIO RUIZ MORALES

SEE ALSO: Lapland and Peru, Expeditions to; Spain; Ulloa, Antonio de, and Jorge Juan

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Geodetic Surveying by Sweden-Finland. In 1671, the French astronomer Jean Picard carried out measurements at Tycho Brahe’s old observatory Uranienborg together with Anders Spole, professor of astronomy at the University of Lund. It was then proposed that similar geodetic measurements be made on the ice between Stockholm and Torneå or another place in Norrland. In 1695, Spole joined an expedition from Uppsala to Torneå, although no measurements of the meridian arc were then carried out, due to lack of financial support.

In 1732 Spole’s grandson Anders Celsius had started

a European study tour to perfect his astronomical skills and bring back to Sweden the most recent techniques. In 1734, he was in Paris where he came into contact with Pierre Louis Moreau de Maupertuis. When the latter wanted to organize an expedition to test the theory of the flattening of the earth at the poles, Celsius suggested the Torne Valley as an ideal area, and in 1736 the French expedition got under way.

The previous year Celsius had been in London, where he purchased a quadrant and other instruments with a view to establishing more precisely the difference in longitude between Uppsala and Torneå, Göteborg and Stockholm, and Åbo (Turku) and Uppsala. In the wake of Celsius, Daniel Ekström, a commissioner from Uppsala observatory, went to London to study the making of precision instruments for astronomical and survey purposes; he was eventually appointed director of manufacture of mathematical instruments in Sweden.

Celsius became the Swedish specialist who accompanied the French expedition. His assistant was Anders Hellant, a native of Torneå and a student at Uppsala, later his pupil. When the measurements were done, the Frenchmen returned to Paris, while Celsius went back to Uppsala to complete work on his thermometer. As a result of the expedition, the first Swedish triangulation network was constructed between Torneå and Kittisvaara in 1736–37 and a map of the meridian and triangulation was published in 1738 (fig. 273).

After working with the Maupertuis expedition, Hellant continued his own work in Lapland, observing eclipses of Jupiter’s moons at Torneå simultaneously with observations made at Uppsala, instrumentally locating ten places in Lappmark, producing his own map of Torne and Kemi Lappmark, and in 1752 determining the longitude of Kemiträsk, Inari, Utsjoki, and Vadsö, near Varanger Fjord. Hellant raised some objections to Maupertuis’s results, but a remeasurement of the meridian arc was not realized until 1801–3, with the support of the Kungliga Vetenskapsakademien and the government. It was carried out by the mathematician Jöns Svanberg.

The land survey office, Lantmäterikontoret, in Stockholm had been suspicious of the French enterprise and delegated the land surveyor Nils Marelius to accompany the Frenchmen and at the same time learn as much as possible from them. During the 1740s Marelius continued to establish positions along the east coast between Karlskrona and Umeå. After 1752 his main achievement

(facing page)

FIG. 272. DETAIL OF THE CENTRAL PORTION OF THE *PLANO DEL PUERTO DE CADIZ* BY VICENTE TOFIÑO DE SAN MIGUEL. Approximately 1:30,000, two maritime miles divided into decimes (= 12.3 cm), Madrid, 1789. To establish the outline of the Iberian coast, Tofiño used methods similar to the techniques of the Académie des sciences in France by projecting chains of carefully measured triangles

along the coastline complemented by angular and astronomical observations. The letters next to the soundings represent the nature of the sea floor: A, sand (*arena*); C, gravel (*cascajo*); L, ooze (*lama*); P, rock (*piedra*); and F, mud (*fango*). Size of the entire original: 56 × 86 cm; size of detail: ca. 42 × 29 cm. Image courtesy of the Biblioteca Nacional, Madrid (MV/29, C. 01, n. 006).



FIG. 273. DETAIL FROM THE CARTE DE L'ARC DU MERIDIEN MESURE AU CERCLE POLAIRE, 1738. From Pierre Louis Moreau de Maupertuis, *La figure de la Terre, déterminée par les observations* (Paris: Imprimerie Royale, 1738), following p. 184. Detail showing the line of the meridian (“Meridien de Kittis”), the horizontal double line of the Arctic Circle (“Cercle Polaire”), the baseline measured across the frozen river (“Base de 7406 [toises] 5 [pieds] 2 [pouces]”), and the central portion of the geodetic triangulation. See figure 436 for a map of the entire triangulation. Size of the entire original: ca. 17 × 10 cm; size of detail: ca. 8.4 × 8.4 cm. Image courtesy of the Special Collections Library, University of Michigan, Ann Arbor (QB 283 .M45).

was the marking and mapping of the long boundary between Sweden and Norway. For this task Ekström constructed a plane table alidade that incorporated a spirit level like that invented by the London maker Jonathan Sisson in 1734. The instrument combined the plane table’s ease of recording horizontal angles directly on a map with the ability to determine vertical angles (and hence, altitudes) across long distances.

The Vetenskapsakademien encouraged the use of geodetic methods for surveying—triangulation and astronomical determination of position—particularly in border areas. The secretary of the academy Per Elvius (the younger) had in 1748 determined the longitude of Göteborg (Gothenburg) and emphasized the need for more accurate coordinates along Sweden’s west coast. In 1742–44 Jacob Faggot was secretary of the academy and urged the importance of mapping Finland. In Åbo (Turku) he enlisted the help of Jacob Gadolin, a professor of theology and a brilliant mathematician and astronomer. In 1748 Gadolin had established Åbo’s astronomical position and then provided the basis of triangulation measurements from the Swedish east coast to Helsingfors (Helsinki).

An important result of the mapping of Finland after 1747 was the manuscript atlas by Eric af Wetterstedt, which was later called “Chartor öfver Stor Furstendömet Finland,” dedicated in 1775 to King Gustav III (Krigsarkivet, Stockholm, SE/KrA/0410/A/001). In 1771 af Wetterstedt became the head of the land survey of Finland, Finska lantmäterikontoret, and continued in this position until his death. His general map and four county maps of Finland (1775) were the basis for Finnish military reconnaissance mapping and eventually for Carl Petter Hällström’s maps included in Samuel Gustaf Hermelin’s atlas of Sweden (*Geographiske chartor öfver Sverige*).

Beginning in the middle of the century, the measurement of altitude claimed growing attention. Barometers were being used for this purpose with increasing frequency, and a dissertation on the subject was written at the University of Lund in 1752 (Isaac Barck Larsson, “Dissertatio gradualis de altimetria geodætica”). In 1802 the botanist Göran Wahlenberg started his measurements of altitude in the Kemi Lappmark, culminating in his important book and map, *Berättelse om mätningar och observationer för att bestämma lappska fjällens höjd och temperatur vid 67 graders polhöjd* (1808).

ULLA EHRENSVÄRD

SEE ALSO: Lapland and Peru, Expeditions to; Sweden-Finland

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Geodetic Surveying by Switzerland. Due to the small size of the Old Confederation’s constituent polities, no countrywide geodetic survey was undertaken by the Swiss in the Enlightenment. There were individual regional maps, which were at least based on surveys made by a graphic triangulation, but the resulting maps, which were more or less of similar accuracy, remained limited to small surface areas. The correlation between the quality of the geodetic base and the system of government is well illustrated by a comparison with France. Around 1765 the Cassini *Carte de France* reached the western border of present-day Switzerland, whose standard map during the Enlightenment, *Nova Helvetiae tabula geographica* (by Johann Jakob Scheuchzer, 1712; see fig. 771), was then already five decades old (Rickenbacher 2007a, 25). Analyzing the accuracy of these two maps, it is apparent that the

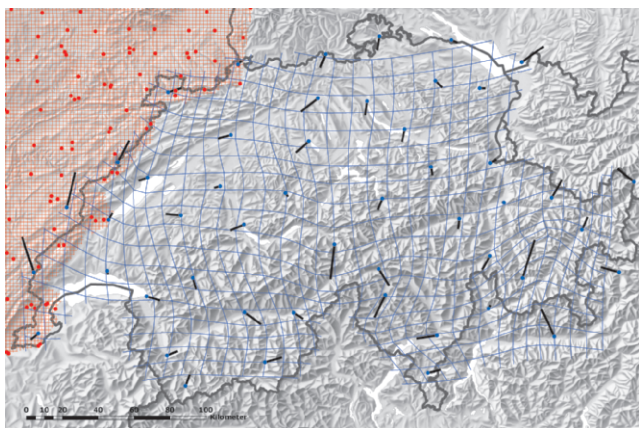


FIG. 274. CARTOGRAPHIC MODERNITY APPROACHED SWITZERLAND FROM THE WEST. Juxtaposition of the deformation grid of the *Nova Helvetiae tabula geographica* of 1712 (blue, mesh size 10 km) and the *Carte de France* from ca. 1765 (red, mesh size 2 km). The French achieved a homogeneous precision over large territories, while Swiss cartography reflected the political heterogeneity of the Confederation without internal coherence (Rickenbacher 2011, 253 [fig. 5-3]). Image courtesy of the author.

centrally organized kingdom of France achieved similar levels of exactitude over large distances, while the maps of the Confederation reflected the political heterogeneity of a Switzerland without internal coherence (fig. 274).

The *Carte de France* also comprised roughly 2,000 square kilometers of current-day Swiss territory. The coordinates of numerous church spires calculated from the triangulations made by Cassini's engineers are among the first geodetically determined values for Switzerland. Under the leadership of General Jean-Claude-Eléonor Le Michaud d'Arçon, the French expanded the "Carte géométrique des frontières de France" between 1779 and 1781 as far as the main crest of the Jura. Their military engineers (*officiers du Génie*) mapped approximately 2,560 square kilometers on a scale of 1:14,400. The triangulation for this map comprised 113 points in Swiss territory (Rickenbacher 2007a, 29).

A few astronomical coordinates, mainly latitudinal, had been calculated in Switzerland by the first half of the eighteenth century. Yet, in contrast to France, a central government entity was lacking that could have articulated and implemented a geodetic survey project. This meant that the visionary ideas of Jacques-Barthélemy Micheli du Crest, who in 1754 had proposed a similar methodology in Switzerland as that conceived in France, were simply shelved. In 1757, on the initiative of Johannes Gessner and with the aid of the Physikalische Gesellschaft, Zurich's first astronomical observatory was constructed on the roof of the Meise guildhall (moved to the Karlsturm of the Grossmünster in 1774). In 1772 Jacques-André Mallet founded the Geneva Observatory. There were also a few private astronomical observatories,

but the geodetic projects of individual scientists remained limited to local areas and were not linked to one another.

It was not until December 1785, when twenty-two-year-old Hamburg native Johann Georg Tralles was appointed professor at the Berner Hohe Schule, that concrete steps were taken with regard to a geodetic survey. In 1790 Tralles published his *Bestimmung der Höhen der bekanntern Berge des Canton Bern*, which argued that the calculation of heights of mountains was absolutely necessary for the improvement of Swiss mapping, and this became the first geodetic project in the country. Together with his most notable pupil, Ferdinand Rudolf Hassler of Aarau, Tralles measured a thirteen-kilometer-long baseline in 1791 and again in 1797 in the Grosses Moos west of Bern, which was measured in 1834 for the third time and thereby formed one of the geodetic foundations for the *Topographische Karte der Schweiz 1:100.000* (called the Dufour map) (Rickenbacher 2006). In 1792, Tralles's achievements persuaded the Oekonomische Gesellschaft Bern to encourage the government of Bern to purchase a theodolite from Jesse Ramsden of three feet in diameter. The instrument, however, was not delivered until 1797 and, due to its weight, was not practical for observing from high mountain peaks. Hassler's handwritten index of coordinates, the "Resultats principaux des mesures," comprises fifty-one points on a surface area of approximately 11,500 square kilometers and forms the prime geodetic achievement of that era (Rickenbacher 2007b, 15).

After the collapse of the Helvetic Republic (1798–1803), both Tralles and Hassler left the country. Between 1803 and 1818, the Bureau topographique français de l'Helvétie mapped approximately 5,800 square kilometers of Swiss territory based on modern geodetic principles (Rickenbacher 2011, 313). After the breakdown of Napoleon's empire, the countrywide geodetic survey of Switzerland was discontinued until the formation of the nation-state later in the nineteenth century under the leadership of Guillaume Henri Dufour.

MARTIN RICKENBACHER

SEE ALSO: Switzerland

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Geographical Atlas. See Atlas: Geographical Atlas

Geographical Mapping.

ENLIGHTENMENT
 DENMARK AND NORWAY, WITH TOPOGRAPHICAL
 SURVEYING
 FRANCE
 NEW FRANCE AND THE FRENCH WEST INDIES
 GERMAN STATES
 GREAT BRITAIN
 BRITISH AMERICA
 ITALIAN STATES
 NETHERLANDS
 PORTUGAL
 PORTUGUESE AFRICA
 PORTUGUESE AMERICA
 PORTUGUESE EAST INDIES, WITH TOPOGRAPHICAL
 SURVEYING
 RUSSIA
 SPAIN
 SPANISH AMERICA
 SWEDEN-FINLAND

Geographical Mapping in the Enlightenment. The Enlightenment inherited the four categories of spatial knowledge that Renaissance philosophers had defined in emulation of ancient Greek terminology: cosmography, the study of an ordered and integrated creation; geography, the study of the earth; chorography, the study of specific regions; and topography, the study of precise places. After 1650, two independent trends served to rationalize and simplify these four categories into just two. Working from the bottom up, as it were, military engineers (e.g., the French *ingénieurs géographes*) extended their detailed, large-scale topographical surveys to cover ever larger regions. This trend, apparent after 1740 in such regional surveys as the Austrian Josephinische Landesaufnahme, constitutes a major theme in much of this volume. In contrast, this entry addresses the opposite trend: geography's subsuming of both cosmography and chorography and the idealization of geographical map-

ping as a top-down practice for organizing and mapping all knowledge of the world at smaller scales. The entry explores the practices by which Enlightenment geographers, working in their studios (i.e., *géographes de cabinet*), compiled and updated geographical maps. It also considers how geographical mapping was presented to and accepted by the public as a process that attempted to discern truth from multiple reports, even though common practices continued to introduce and perpetuate error. Despite contemporary claims that geographical mapping integrated topographical mapping and marine charting, the practices whereby geographical maps of the world and its regions were produced, circulated, and consumed remained distinct and mark geographical mapping as a separate cartographic mode in the Enlightenment.

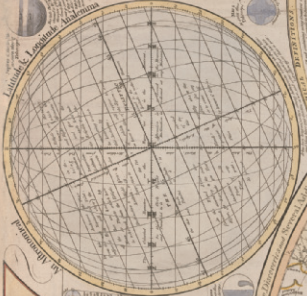
The redefinition of geography began when, in 1650, Bernhardus Varenius recast cosmography as “general geography” in his widely influential *Geographia generalis* (Schuchard 2007, 191–321). Varenius stripped Renaissance cosmography of its hermetic and micro-macrocosmic concepts and embraced its astronomical and geometrical core—the “doctrine of the sphere” (Dekker 2002), as enshrined in matching pairs of terrestrial and celestial globes and the many manuals explaining their use—and he wedded it to a new respect for empirical observation. For Varenius, all spatial knowledge was rooted in topography, which informed chorography, which in turn supplied material for what he now called “special geography” (the detailed description of the earth, region by region), which could finally be synthesized as general geography, the account of the earth as a whole (Varenius 1650, 2). That global synthesis depended in turn on cosmographic geometry: for example, the climatic zones, or latitudinal bands created by the earth's axial tilt, explained the distribution of flora and fauna (Varenius 1650, 491–616). Varenius repeatedly invoked the principles of what later scholars would call “mathematical” or “astronomical geography,” which is to say, the size and shape of the earth, the determination of latitude and longitude, the construction of global and regional map projections (albeit without explanatory diagrams), and the principles of marine navigation (Varenius 1650, 19–62, 437–91, 617–786). General geography thus deployed the geometry of cosmography to structure empirically derived information (fig. 275)

(facing page)

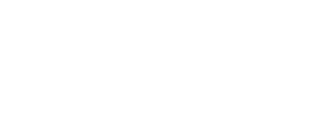
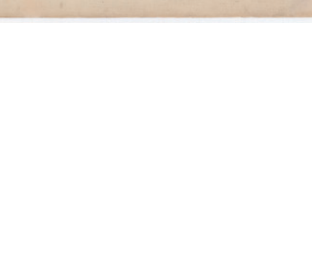
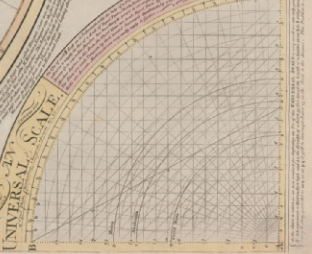
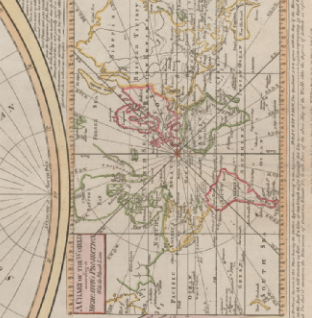
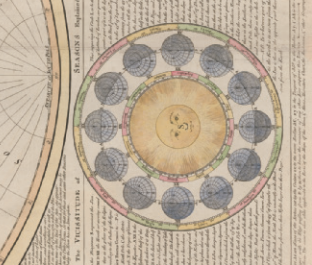
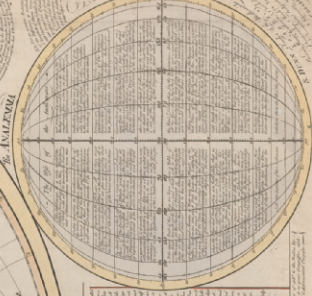
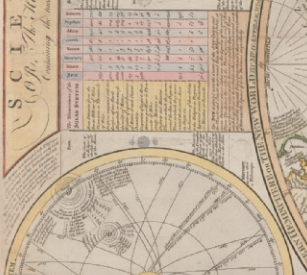
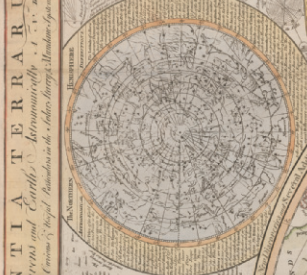
FIG. 275. WORLD MAP AS ORGANIZED, COMPREHENSIVE, COSMOGRAPHICAL KNOWLEDGE, OR SCIENTIA. Samuel Dunn, *Scientia terrarum et coelorum, or the Heavens and Earth Astronomically and Geographically Delineated and Display'd* (London, 1781; originally published in 1762). Close copies of this map were also published under the variant title *A General Map of the World or Terraqueous Globe, with All the New Discoveries and Marginal Delineations, Containing the Most Interesting Particulars in the Solar, Starry and Mun-*

dane Systems. This four-sheet map surrounded the standard double-hemisphere world map with a variety of astronomical diagrams and maps, including a diagram of the solar system (with comets), celestial hemispheres, an analemma (an orthographic projection of the celestial sphere, with instructions), and map of the moon. Each element was presented in a factual manner, but the overall effect was hardly plain. Size of the original: 104.7 × 124.5 cm. Image courtesy of Barry Lawrence Ruderman Antique Maps, La Jolla.

SCIENTIA TERRARUM ET COELO RUM
OPUS ASTRONOMICUM ET GEOGRAPHICUM
AUCTORITATE REGIAE SOCIETATIS REGIAE SOCIETATIS
PUBLISHED BY W. BENTLEY, ST. MARTIN'S LANE, 1734.



Latitude	Longitude	Distance
0	0	0
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10
11	11	11
12	12	12
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(see also, e.g., Lubin 1678, 5–8; Sturm 1705, 34, 52, 78; Gottschling 1711, 8, 16–18; Bruzen de la Martinière 1722, 50–51).

Geography's absorption of chorography took longer. In the early eighteenth century, definitions of "map" remained broadly inclusive and did not specify a required geometrical structure. For example, John Green (1717, 6) defined a map simply as the "Resemblance of the Heavens or the Earth on a plane Superficies." Yet by midcentury, "map" was accepted as necessarily the product of the projection of meridians and parallels onto the plane, as explicated in the *Encyclopédie*: "a plane figure that represents the surface of the earth, or one of its parts, according to the rules of perspective [i.e., projection]" (d'Alembert 1752, 706). The codification of any map or *carte géographique* as the product of the combination of cosmography with geography was matched by the codification of "chart" or *carte marine* or *carte hydrographique* as "representing only the sea, its islands, and its coasts" (d'Alembert 1752, 706) and also of "plan" as the product of surveys. The same distinctions are evident in Samuel Johnson's *Dictionary of the English Language* (1755).

Implicit in Varenus's intellectual schema was a distinction between "general" maps of the world and "particular" or "special" maps of smaller areas. As geography increasingly subsumed chorography, the distinction between general and particular maps became a sliding conceptual scale within which particular maps were understood as being assembled to form some general map, whether of the world, a continent, or a region. The distinction was relative. Geography and geographical mapping thus came to encompass the full range of scales of knowledge, from the provincial to the global. However, the label "universal" was applied only in an absolute manner, to indicate maps of the whole earth.

Geographical maps, whether particular or general, were thus a primary means for Europeans in the Enlightenment to learn about the wider world, organize it, and give it meaning. They were part and parcel of the broader mechanisms for creating and communicating knowledge. Indeed, geographical mapping consistently intertwined graphic maps with written accounts of the world. Geographical maps occurred within, or in conjunction with, a variety of texts, such as bibles, official memoirs, monthly periodicals, history books, atlases, and multivolume histories of travel and exploration (Verdier 2015, 21–79). Even when maps were apparently unaccompanied by written accounts—whether as globes, mounted on walls, or in atlases without text—they were nonetheless often read in conjunction with written works and manuals. Moreover, written accounts could constitute textual maps, expressing spatial rela-

tionships and hierarchies verbally (e.g., Edney and Cimburek 2004, 334–36).

The official, commercial, and scholarly networks interested in geographical mapping entailed both the practical use of maps as works of factual exposition and the intellectual reading of maps as works of scholarly imagination. Civil, military, and ecclesiastical officials all commissioned and used regional maps for a variety of purposes. While the range of participants in, and the objectives for, official mapping networks varied substantially, the maps produced tended to be instrumentally oriented, restricted in circulation and remaining in manuscript, focused on the territories of each particular state or colony, and made and used almost exclusively by men. By contrast, cultural and economic centers such as Amsterdam, Paris, London, Augsburg, and Venice sustained a dynamic commercial network based on the trade in geographical maps. This commercial network was supported by a broad desire for geographical knowledge in conjunction with history, religion, trade, politics, war, and current events generally (fig. 276). This commercial network tended to produce geographical maps that were more oriented to intellectual and pedagogic needs and were openly circulated (the maps were usually printed); its participants were broadly interested in the wider world and included women and literate members of the laboring classes. The commercial market embraced explicitly instrumental functions as well, especially in the form of road maps and other travel guides. Furthermore, in this era of still-nascent copyright protections, publishers made extensive use of the easiest and most cost-effective technique for making geographical maps in order to supply the marketplace: they simply copied existing works (Pedley 2005, 96–118, 200–203).

Scholarly networks, within which maps and other geographical texts were shared and circulated in pursuit of geographical knowledge, overlapped with and mediated between the official and commercial networks of geography. These scholarly networks featured a wide array of individuals, ranging from prolific, dedicated, and vocational scholars such as Jean-Baptiste Bourguignon d'Anville, to antiquarians and historians who consulted and made maps to aid their studies, to dabblers such as John Mitchell who made only one or two works. The ways in which official, commercial, and scholarly networks actually interacted and encouraged the circulation of geographical works remain little studied. In mid-eighteenth-century Britain, it appears that official maps and other geographical materials circulated in private and scholarly circles; from there, official and newly created maps entered the marketplace; published maps then formed a staple of official and private as well as public map consumption (Edney 2008, 69–70).



FIG. 276. A GEOGRAPHICAL MAP AS A POLITICAL STATEMENT. *Le triomphe des armées françaises* (Paris: Jean, [1797–98]). This cartographic celebration of French successes during the War of the First Coalition used a map apparently by Jean Baptiste Poirson of the political state of the Holy Roman Empire in April 1797 (Germinal V), after the Austrian Habsburgs had sued for peace. Napoleon is depicted at right, holding Italy. His fellow commanders slice up Poirson’s map

and strip away Habsburg territories. The untouched portion of the map, showing the remaining Habsburg territories, is grasped in the talons of an Austrian eagle who also wields a broken saber. A triumphal column, at left, names the victorious French generals.

Size of the original: 35 × 45 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge D 15324).

The relationships of scholarly geographical networks to other networks were undoubtedly different in other parts of Europe, given the various ways in which Europe’s states supported scholarship, and need to be clarified through detailed studies of how geographical materials traveled between networks. And those relationships were variously constituted, as geographers made their maps in response to personal, commercial, or official motivations (Haguet 2011). Overall, it seems clear that responsibility for the creation of new geographical maps rested with members of the scholarly networks, whether working on their own or at the behest of official or commercial paymasters.

COMPILATION AND UPDATING The task of geographical mapping was to integrate and present a wide range of knowledge, from detailed local studies, to regional and coastal surveys, to images of the entire earth. The steady flow of new geographical information—caused by the post-1650 growth of Europe’s economies, global trade networks, and colonies—engendered the constant augmentation of Europe’s maps and the creation of many new maps de novo. Despite the variety of occasions for geographical mapping, there were only two basic techniques by which geographical maps were produced and updated.

First, what we might call survey compilation featured

the combination, in an ad hoc manner, of detailed surveys within a locally measured framework (fig. 277). Second, geographical compilation assembled a wide variety of source materials within the cosmographical framework of projected parallels and meridians; this process could be as simple as reconfiguring an existing regional map within that framework (fig. 278) or as complex as re-drawing the map of the world from scratch. Over the course of the eighteenth century, geographical compilation steadily subsumed survey compilation to create a single, rational epistemology.

In survey compilation, particular surveys and accounts were incorporated into general maps through the creation or appropriation of an extensive geometrical framework. There was, however, no common practice for creating that larger framework, so that regional maps can appear to have been cobbled together in a pragmatic manner. For example, the geometrical structure of a large island is readily defined by a coastal traverse, whether surveyed anew, copied from existing charts, or assembled from information gathered from local mariners; the closure of the traverse gives the structure a degree of rigidity that can then control the assembly of particular terrestrial surveys. This was the procedure followed for the map reproduced in figure 277, which was created by fitting topographical maps within a coastline copied from a chart; most of the source materials had been acquired during France's intervention, in 1738–40, in the Corsican revolt against Genovese rule (Huguenin 1970, 124–25). An alternative method featured the construction of an internal framework from road or river surveys. In mapping Saxony in the 1730s, for example, Adam Friedrich Zürner surveyed the main roads to create a rigid framework within which to assemble detailed surveys (see fig. 954). Green (1717, 84–85, pl. 11) thought such processes were properly applicable to the “smallest portions of the Earth,” such as “a Town-Land, Territory, County, or Province,” but not to entire kingdoms or still more extensive areas.

In practice, each instance of survey compilation featured its own geometrical solution for combining and generalizing particular maps into a more general one. The relative ease of determining latitude also meant that a number of regional maps were compiled from

surveys with the help of observed latitudes (e.g., Edney and Cimburek 2004). By the 1780s, the adoption of the various techniques for determining longitude also meant that field surveys generally featured at least one position whose latitude and longitude had been determined, permitting the detailed survey to be readily incorporated into the geographer's cosmographical framework. Particular maps that lacked any reference to latitude and longitude (as fig. 277), unless included in an accompanying memoir, were largely a thing of the past by 1800.

By contrast, geographical compilation situated detailed maps within a cosmographical framework. Despite the importance of this framework, it received no specialized label from eighteenth-century geographers, who generally referred only to networks (*réseaux*) of lines of latitude and longitude; the use of “graticule” for a projected network of meridians and parallels is a mid-nineteenth century innovation and is used here only for convenience. So, the geographer first drew a graticule, as defined by a map projection, and then plotted key locations whose latitudes and longitudes were known. The epitome of such mapping was the map drawn by 1682 on a stone floor at the Paris Observatory under the direction of Jean-Dominique Cassini (I) to which new locations were added only when determined by reputable astronomical observations (see fig. 147). Itineraries or traverses along roads, rivers, political boundaries, and coasts were fitted in between these control points (fig. 279); their intermediate points could then be used to control the positioning of yet further detailed information, steadily building up the map in an iterative process.

Simple in principle, geographical compilation was difficult in practice: “nothing is more common and more easy than to make maps,” Jacques-Nicolas Bellin wrote in 1744, yet “nothing is so difficult as to make them tolerably well” (quoted by Dawson 2000, 95; see also Pedley 2005, 19, 248n1). In addition to the pragmatic issues of constructing the graticule and graphically interpolating source materials, Enlightenment geographers faced two interrelated problems. There were relatively few places whose geographical coordinates had been sufficiently well determined to serve as main control points, so geographers needed to use more detailed source materials

(facing page)

FIG. 277. A LARGE REGIONAL MAP COMPILED FROM SURVEYS. “Carte géographique et hydrographique de l'isle de Corse,” 1741. This anonymous manuscript map exemplifies the interconnection between topographical and chorographical work, compiling both within the coastline derived from a marine chart, all without any reference to latitude and longitude; the map lacks even the indication of the global coordinates of one key location and lacks the northward orientation encouraged by map projections, although its compass does

indicate both magnetic and true north. The map's different sources are reflected in the two scales, one for lieues and one for milles. The legend explains the locations of French encampments (A through Y) and the island's several jurisdictions (1 through 14), as per earlier maps (see fig. 13). The surrounding insets depict town and fortification plans.

Size of the original: 115 × 168 cm. Image courtesy of the Bibliothèque nationale de France, Paris (département Arsenal, MS-6434 [47]).

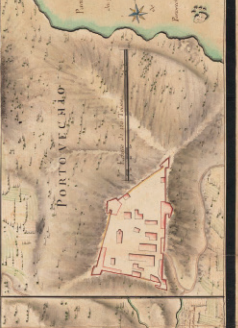
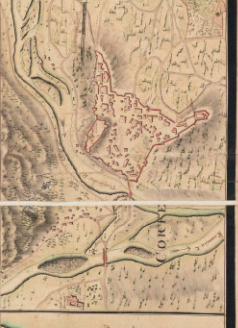
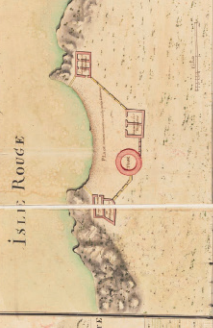
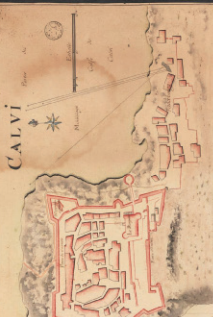


**CARTE GÉOGRAPHIQUE ET
HYDROGRAPHIQUE DE L'ISLE
DE CORSE**

sur cette île par le Capitaine de la Flotte et de la Marine
Monsieur de Choiseul, par le Capitaine de la Flotte et de la Marine
Monsieur de Choiseul, par le Capitaine de la Flotte et de la Marine
Monsieur de Choiseul, par le Capitaine de la Flotte et de la Marine

- A. Camp de Bastia, ou de S. Martin
- B. Camp de Bastia, ou de S. Martin
- C. Camp de Bastia, ou de S. Martin
- D. Camp de Bastia, ou de S. Martin
- E. Camp de Bastia, ou de S. Martin
- F. Camp de Bastia, ou de S. Martin
- G. Camp de Bastia, ou de S. Martin
- H. Camp de Bastia, ou de S. Martin
- I. Camp de Bastia, ou de S. Martin
- K. Camp de Bastia, ou de S. Martin
- L. Camp de Bastia, ou de S. Martin
- M. Camp de Bastia, ou de S. Martin
- N. Camp de Bastia, ou de S. Martin
- O. Camp de Bastia, ou de S. Martin
- P. Camp de Bastia, ou de S. Martin
- Q. Camp de Bastia, ou de S. Martin
- R. Camp de Bastia, ou de S. Martin
- S. Camp de Bastia, ou de S. Martin
- T. Camp de Bastia, ou de S. Martin
- X. Camp de Bastia, ou de S. Martin
- Y. Camp de Bastia, ou de S. Martin

Notes de CORSE
 Les notes de cette carte ont été recueillies par le Capitaine de la Flotte et de la Marine
 Monsieur de Choiseul, par le Capitaine de la Flotte et de la Marine
 Monsieur de Choiseul, par le Capitaine de la Flotte et de la Marine
 Monsieur de Choiseul, par le Capitaine de la Flotte et de la Marine



MER MEDITERRANÉE



**CARTE NOUVELLE
DE L'ISLE DE CORSE**
 dressée d'après une grande Carte manuscrite
levée sur les lieux
par ordre de M. le MARECHAL DE MALLEBOIS,
par le Sr Robert de Vaugondy
 Géographe ord. du Roi et de M. Pol-Denis de Lorraine et de Bar.
de l'Académie royale des Sciences et Belles Lettres de Nancy.
1758.

A PARIS
 chez le Sr ROBERT Geog. ord. du Roy.
 Quai de l'Horloge du Palais.
 avec Privilège.

- Legende**
des Camps et Attaques.
- A. Camp de S. Nicolas de S. Battolone en 1754 au point de vue.
 - B. Camp de S. Nicolas de S. Battolone vers le Balagna.
 - C. Camp de Balagna de S. Battolone.
 - D. Camp de Balagna de S. B.
 - E. Camp de Palasca de S. B.
 - F. Camp de Vicalano de S. B.
 - G. Camp de Pignone de S. B.
 - H. Camp de Lante de S. B.
 - I. Camp de Bastarochia de S. B.
 - K. Camp de Morsaglia de S. B.
 - L. Camp de Omessa de S. B. (à 13 lieues de la capitale).
 - M. Camp de Corte de S. B.
 - N. Camp de Loretto de S. B.
 - O. Camp de M. de L'Arce de S. B.
 - P. Camp de Bastia de S. B.
 - Q. Camp de Bastia de S. B. (à 13 lieues de la capitale).
 - R. Camp de Bastia de S. B. (à 13 lieues de la capitale).
 - S. Poste Française près de Plana-Caldone de 20 hommes et un Lieutenant.
 - T. Poste de la Croix de S. Pierre de 20 hommes.
 - V. Poste de S. Pierre.
 - X. Poste de S. Pierre de 20 hommes de Bastia.
 - Y. Poste de S. Pierre de 20 hommes de Bastia.
 - Z. Poste de S. Pierre de 20 hommes de Bastia.
 - 1. Marche par les Corses le 10 Mars 1753.
 - 2. Marche en Balagna de S. Pierre vers le Camp de S. Pierre le 10 Mars 1753.
 - 3. Marche de S. Pierre.
 - 4. Marche des Français le 5 Juin.
 - 5. Marche des Français le 10 Juin.
 - 6. Bataille donnée à S. Pierre de S. Pierre et le C. Diacceto.
 - 7. Marche de S. Pierre de S. Pierre.
 - 8. Marche de S. Pierre.
 - 9. Marche de S. Pierre.
 - 10. Marche des Corses contre M. de Lamoignon le 10 Septembre.
 - 11. Marche de M. de Lamoignon.
 - 12. Marche de M. de Lamoignon.
 - 13. Marche de M. de Lamoignon.

ECHELLE
 Lignes de S. Pierre par géométrique.
 Milles de S. Pierre de 625 toises à pied chacun.



G. 22987

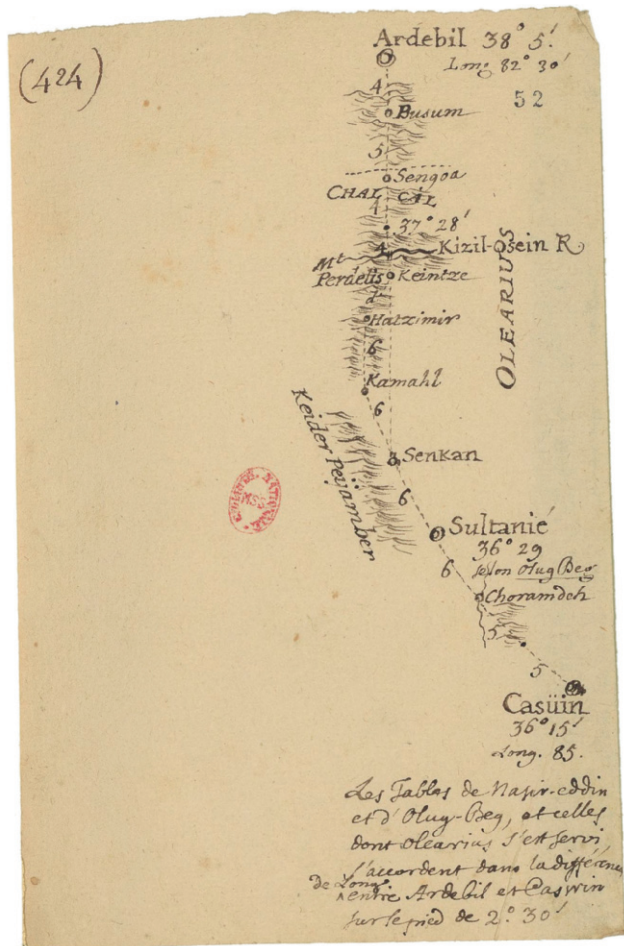


FIG. 279. A ROUTE SURVEY CONTROLLED BY GEOGRAPHICAL COORDINATES. From Jean-Baptiste Bourguignon d'Anville's "Œuvres diverses: I Mémoires relatifs à la géographie." D'Anville kept this undated diagram of the route from Casuïn (modern Qasvin, the ancient capital of Persia) to Ardebil (Ardabil), derived from the travels of Adam Olearius in 1635–39, within a collection of notes about Azerbaijan, northern Persia, and the seventh-century campaigns of the Byzantine emperor, Heraclius. D'Anville controlled the route with latitudes and longitudes taken from the tables of the thirteenth-century astronomer Naṣīr al-Dīn al-Ṭūsī and the fifteenth-century astronomer Ulugh Beg. D'Anville incorporated this information into a small map of Persia that would eventually be printed in Venice by Paolo Santini (1779). Size of the original: ca. 17 × 11 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Département des manuscrits, Nouv. acq. fr. 17381, fol. 52r).

(facing page)

FIG. 278. REGIONAL MAP WITHIN A GLOBAL FRAMEWORK. Didier Robert de Vaugondy, *Carte nouvelle de l'isle de Corse* (Paris, 1756). The island is presented within a geographical framework of latitude and longitude, indicated in the marginal gradations, and with its mountains depicted in a more conventionally geographical manner. The first state of a printed map, this work bears a legend at lower left indicating the camps of the French battalions and attacks by the Corsican

rebels. The map's subtitle claims that this map was derived from "a large manuscript map surveyed on the ground," but as figure 277 indicates, such a source map would *not* have been from a single survey but would have been compiled from multiple surveys.

to calculate coordinates for new control points. Moreover, those detailed sources varied widely in quality and were often ambiguous or even contradictory. Enlightenment astronomers made substantial improvements in the observation of terrestrial latitudes and longitudes. In particular, Cassini I's technique of timing the eclipses of Jupiter's moons to determine longitude, using his improved tables first published in the *Connoissance des temps* for 1690, would eventually prove especially significant in refining geographical coordinates. The *Connoissance des temps* provided long lists of observed positions, giving some measure of how their number slowly increased through the eighteenth century before accelerating rapidly after 1770 with the intensification of Europe's global enterprise: 90 positions in 1699; 220 in 1753, 390 in 1777, and 870 in 1785 (Chapuis 1999, 26–27).

Geographers defined the locations of most of their control points by calculation. If the distance and direction between two places are known, together with the size of the earth, then their latitudinal and longitudinal difference can be calculated with simple spherical trigonometry. (These calculations can be made from distances alone if the data are sufficiently redundant.) For small enough differences, plane trigonometry could suffice, as Franz Xaver von Zach demonstrated in 1790 (see fig. 952). Over time, astronomers and geographers had created extensive lists of geographical positions. Varenius (1650, 658–65) listed the latitudes and longitudes of some 225 places, Giovanni Battista Riccioli (1661, 402–25) no fewer than 2,200.

The process was rarely as straightforward as simply undertaking repeated calculations: different sources gave different distances between places; distances were expressed in various units of measure; calculating the location of one point via different routes gave inconsistent results; more fundamentally, different observers would produce variant values for the latitude and longitude of the same place. Geographers therefore carefully weighed their sources and the reliability of the geographers or travelers who made them and accordingly rejected some sources outright or took simple or weighted means of conflicting results.

The most extensive recalculation of geographical co-

ordinates was the work of the French astronomer and geographer Cassini de Thury, who, in 1744, published a new edition of the *Connoissance des temps*. The map's subtitle claims that this map was derived from "a large manuscript map surveyed on the ground," but as figure 277 indicates, such a source map would *not* have been from a single survey but would have been compiled from multiple surveys. Size of the original: 65 × 49 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge DD 2987 [5799]).

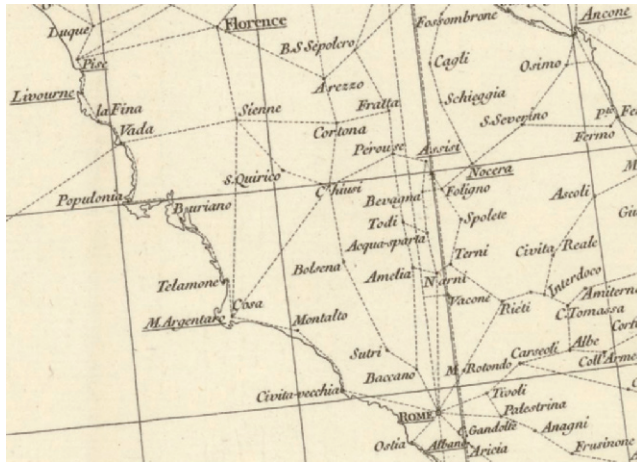


FIG. 280. A NETWORK OF KNOWN DISTANCES FOR RECALCULATING POSITIONS. Detail from Jean-Baptiste Bourguignon d'Anville, *Position des points discutés dans l'analyse géographique de l'Italie* in d'Anville 1744, 277, showing a portion of d'Anville's graphic presentation of the routes and other distances that he used to determine the latitudes and longitudes of numerous places across Italy. The map's scale bars (not shown) reflected his mix of ancient and modern sources, with scales for ancient Roman miles (each 755.5 toises), common miles (60 to one degree), Lombard miles (each 849 toises), and French leagues (each 2,500 toises). The thirty-one places with their names underlined—such as Florence, Rome, and Ancona—indicate that latitudes had been observed; only the longitude of Rome had also been determined (with respect to Paris). The network includes another 245 places. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge D 10822[A]).

ordinates was undertaken by Guillaume Delisle. Riccioli had used ancient itineraries and geographies to define distances across Eurasia, but he had not accounted for how the various stadia and other ancient itinerary measures related to modern measures. Delisle therefore set out to reconfigure the world's coastlines by comparing the available astronomical observations for latitude, and for a few longitudes, with the distances between ports, islands, and capes that he either measured from sea charts or took directly from mariners' pilot books. For example, he reduced the length of the Mediterranean Sea from the 56° of longitude or 1,160 leagues recorded in existing geographical maps (each league being equivalent to 3 nautical miles, or 5.6 km) to just $41^\circ 30'$ of longitude or 860 leagues; the width of northern Africa, from Cape Verde to the Horn, accordingly shrank from 80° to 70° of longitude. This global reconfiguration is evident in his many maps, from his 1700 map of Africa (see fig. 289) to his large maps of the Eastern and Western Hemispheres (1720). Delisle had great confidence in the quality of his source data because they had been communally created and implicitly tested and corrected by "an infinity of pilots" (Delisle 1722, 365,



FIG. 281. CORRECTED VERSUS UNCORRECTED OUTLINES. A detail from Jean-Baptiste Bourguignon d'Anville, *Parallele du contour de l'Italie*, in d'Anville 1744, 29, which covers the same portion of central Italy as figure 280. This outline map shows the results of his recalculations of latitudes and longitudes around the peninsula and compares his new outline (shaded solid line and capital letters for place-names) to previous maps by Delisle (solid line, Roman lettering) and Sanson (dotted line, italic lettering), with Rome defining their common longitude. D'Anville's commentary on the map indicated that his corrected outline revealed that Italy was much smaller than previously thought, only 10,650 square leagues (a league here being 2,500 toises; i.e., 252,831 km²) compared to Delisle's 13,200 square leagues (313,368 km²) and Sanson's 14,100 square leagues (334,734 km²). Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge D 10821[A]).

366, 368). All told, Delisle accomplished the remarkable act of completely reconfiguring global geography (see Dawson 2000, 245–52).

Other geographers recalculated geographical coordinates within particular regions. In the 1740s, for example, d'Anville and Tobias Mayer both used Roman itineraries to recalculate the latitudes and longitudes of places in Italy and Germany. To construct a new map of Italy, which he published in 1743 (see fig. 64), d'Anville first carefully studied Roman measures, concluding inter alia that the ancient Roman mile of eight ordinary stadia was equivalent to 755 toises 3 pieds, whereas the mile used in Roman Britain was longer, at 826 toises (d'Anville 1743, 1–164, esp. 162). Armed with these and other equivalents, d'Anville could establish a network of ancient roads across Italy (fig. 280) connecting thirty-one places with observed latitudes and just one observed longitude, from which he calculated the latitudes and longitudes of almost three hundred towns and other places (d'Anville 1744). He provided a graphic summary of the results that contrasted Italy's uncorrected and corrected outlines (fig. 281). In this he followed the example set by Jean Picard and Philippe de La Hire in their famous 1693 map of France's coasts before and after correction by new longitude observations (see fig. 625). In Germany, Mayer worked from thirty-three known latitudes and no observed longitudes to recalcu-

late some two hundred positions across the Holy Roman Empire. Like d’Anville, he presented the results in a map, his *Germaniae . . . mappa critica* of 1750, which contrasted his new geographical outline with those of Johann Baptist Homann and Delisle (Meurer 1995) (see fig. 532). John Cowley similarly corrected the coastline of Scotland in a 1734 map (see fig. 11).

For regions beyond Europe, geographers drew on a variety of ancient, indigenous, and colonial sources—whatever was available, whether textual or cartographic—to create new control points. For central Asia, d’Anville used the work of medieval and early modern Islamic astronomers to establish latitudes and longitudes of places along routes (see fig. 279). Geographers in St. Petersburg and Paris used information about China sent to them by the Jesuit missionaries who had worked with Chinese astronomers and surveyors under the Kangxi and Yongzheng emperors (Cams 2017, 177–242). For his enlarged, 1788 map of South Asia, James Rennell used a mix of ancient, local, and British sources. Like Delisle and d’Anville before him, Rennell carefully assessed the various itinerary measures used in the region, and he estimated the proper factors to correct the inevitable overmeasurement in the road distances surveyed by British army columns. Rennell tied all of these routes to the known locations of Bombay and Madras through a complex series of calculations and adjustments (Edney 1997, 84, 94, 98–102; Verdier 2015, 160–68).

Once a sufficiently detailed collection of control points had been defined and plotted on an otherwise empty graticule, the geographer could draw in the other source materials. The process of generalization—of reducing the information in particular maps and other sources so as to fit smaller-scale, general maps—was an implicit part of the art of the geographer. The general assumption was that if the particular sources were good enough, they would fit easily into the overarching geometrical framework. The actual process of fitting information was graphic in nature, as mapmakers sketched details within the geographical framework. For example, for the interior of New France, Delisle first constructed a series of geographical sketches derived from information and routes published in the *Lettres édifiantes* (the Jesuit Relations) and from personal correspondence and conversations with travelers. He then combined the sketches within a framework of latitude and longitude, finally integrating the results with an existing map (Dawson 2000, esp. 185–230; Pelletier 2002). Fitting the source material together in just the right way could be a laborious process: the perfectionist d’Anville, for example, made twenty drafts of a map of ancient Egypt before completing a fair copy (Haguet 2011, 90).

The variable quality and availability of particular source materials remained a significant issue. D’Anville

had intended his new map of Italy to be the first of a new set of large maps of European countries, but each posed a particular challenge. For France, d’Anville thought that the triangulation undertaken by the Académie des sciences would, when combined with detailed road surveys, produce “a consistent framework . . . markedly superior to all that have ever existed in this genre,” but many of the particular, provincial maps were so geometrically defective as to be useless even when fitted to this more perfect trigonometrical framework. Germany had the road network to create an adequate framework, but the final map itself “inevitably surpasses all other maps in difficulty, because of the prodigious number of states.” Spain’s political standing required it to be mapped anew, but d’Anville lamented the almost complete lack of good provincial maps that he might use as source materials. The British Isles presented the opposite situation: England’s wealth ensured that it was well covered with updated regional maps and road itineraries, although Scotland still lacked good coverage. The list continued (d’Anville 1744, i–xxxix, esp. xx, xxii). D’Anville was constantly aware of the shortcomings, or simple lack, of detailed information for areas remote from Western Europe. He would later admit, for example, that he would not have undertaken his four-sheet *Carte de l’Inde* (1752) had he not been specifically commissioned to do so by the Compagnie des Indes (Haguet 2011, 99); in the event, he filled the large white space in the center of South Asia with a set of scale bars and an admission: “A great expanse of country of which we have no particular knowledge.” Other geographers were, however, far less scrupulous in their use of existing maps and other source materials.

The fitting of source materials into the geographical framework was not without problems. Without good latitudes and longitudes to guide the act of compilation, detailed surveys might be misunderstood. An egregious instance was the creation in 1729–30 by Gaspard-Joseph Chaussegros de Léry of the “River of the West” that apparently reached from Lake Superior all the way across the uncertain continental interior of North America to the Pacific Ocean or to the putative “Sea of the West.” The origins of this mythic river lie in a map of a river from Lake Winnipeg to Lake Superior drawn by a Cree informant, Ochagach, for a French trader, Pierre Gaultier de Varennes de La Vérendrye in 1728–29 (see fig. 393). Lacking any indication of global coordinates or scale, and accompanied by an obscure narrative, geographers ended up drastically reconfiguring the map in accordance with the European desire for a water route through North America (Lewis 1991).

The addition of new information and the correction of existing data were constant and continual. Incremental changes could never be as concerted as the wholesale re-



FIG. 282. AN EXAMPLE OF INCREMENTAL GEOGRAPHICAL CHANGE. Details of Nova Scotia on John Mitchell's *A Map of the British and French Dominions in North America*: (left) the first variant (1755); (right) the fourth variant ([1756]), which Mitchell called the "second edition" of his map. The differences stemmed from Mitchell's incorporation of astronomical observations for latitude and longitude published in *Voyage fait par ordre du roi en 1750 et 1751, dans*

l'Amérique septentrionale (1753) by Joseph-Bernard, marquis de Chabert. Mitchell added a long explanation of both the original compilation and the corrections to the modified map, which he indexed by newly added Roman numerals. Size of the original maps: 136 × 195 cm; size of each detail: ca. 17.5 × 24.5 cm. Images courtesy of the Geography and Map Division, Library of Congress, Washington, D.C. (G3300 1755.M5 and G3300 1755.M523 respectively).

configurations effected by Delisle, d'Anville, and others. If anything, they were haphazard and opportunistic, being determined by individual geographers' ability to access and assess new information. And that ability was never perfect, even in those rare instances when a geographer had unprecedented access to private and official archives. When Mitchell was commissioned by the Board of Trade and Plantations to construct his large *Map of the British and French Dominions in North America* (1755), his access to the Admiralty's archives permitted him to assess and reject some potential sources, such as the 1715 manuscript chart of Nova Scotia by Nathaniel Blackmore (see fig. 862). Even so, Mitchell remained unaware that Joseph-Bernard, marquis de Chabert, had in 1753 published his astronomical determination of positions throughout maritime New France; once apprised of his failing, Mitchell soon made the necessary corrections to his map (fig. 282) (Edney 2008, 71–72). Bruno Latour's concept of "centres of calculation" (1987, 215–57) provides a useful model for understanding the concentration of geographical maps and reports in certain places, yet we must remember that even within the imperial capitals of Paris and London, circulation was always circumscribed by temporal, institutional, economic, and social constraints and was generally inefficient.

Overall, the construction of geographical knowledge was a process of combining and reconciling sometimes divergent reports. Geographers used the projected graticule as a logical scaffold on which to hang new and existing information and to identify and correct flawed information. With hindsight, the progressiveness of this

incremental process appears ineluctable. If Delisle had not used Spanish sources for his *L'Amérique septentrionale* (1700) to reattach California to North America and to correctly situate the mouth of the Mississippi River (Pelletier 2002), some other geographer would eventually have done so. Yet intellectually honest geographers admitted to being uncertain about their changes, knowing that new and better information might overturn their conclusions. With respect to his treatment of California, for example, Delisle actually only moved the island to be very close to the mainland to make California appear to be connected, but he did not completely eliminate the gap. Other geographers explicitly titled their cartographic hypotheses as attempts or trial designs, such as d'Anville's *Essai d'une nouvelle carte de la Mer Caspienne* (1754) and Didier Robert de Vauquondy's *Essai d'une carte polaire arctique* (1774). Some geographers were, however, more sanguine about how, working in their studios, they had "discovered" new features at the margins of certain geographical knowledge. Delisle himself remained uncertain whether indigenous sources did indeed indicate the existence of a great Sea of the West in the midst of North America, and so left it off his published maps, but his son-in-law Philippe Buache included it in a 1752 map of discoveries in the north Pacific (see fig. 390). At the very end of the century, Rennell construed a long chain of mountains—the "Mountains of Kong"—as running across Africa in the map he prepared for the 1799 edition of Mungo Park's journal (Bassett and Porter 1991). Modern hindsight should not deny the fact that geographical maps in the

Enlightenment were accepted as works of conjecture whose delineations might yet be overturned by new or reinterpreted data.

CRITICISMS AND IDEALIZATIONS The practice of geographical compilation entailed myriad decisions on the part of the geographer that were likely opaque to readers of the final maps. How could readers assess the quality of a geographer's work? The anxiety was highlighted when, in about 1690, the Dutch diplomat Nicolaas

Witsen sent a copy of his large map of northeastern Asia to the Royal Society (fig. 283). Sir Robert Southwell, the Society's president, promptly requested information from Witsen about his sources and methods. The map, he wrote, is "Columbus like" in its "Discovery of a New World" or "at least" in its giving "Tydings of those Parts, which from the beginning have layn in the Dark. But the Enterprise being so vast, and the success so unexpected; the Publick are very impatient to be told by what Magick you have been able to master this Work. For it



FIG. 283. A WORK OF UNKNOWN AND UNCERTAIN QUALITY. Nicolaas Witsen, *Nieuwe Lantkaarte van het noorder en ooster deel van Asia en Europa strekkende van Nova Zemla tot China* ([Amsterdam], 1687), in six sheets, dedicated to Peter I of Russia.

Size of the original: 118 × 127 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge D 11961 [RÉS]).

looks in one Part no less difficult then a Geographical Description of the Bottom of the Sea” (Southwell in Witsen 1691, 492).

It was to answer such concerns and to demonstrate the quality of their work that geographers shared information about their sources and techniques with others within the networks of scholarly geographers. We know of Witsen’s account because Southwell published it in the Royal Society’s proceedings, and Witsen later included a longer statement in his geographical description of the region, *Noord en Oost Tartarye* (1692). By 1700, geographers added explanatory comments to the maps themselves and increasingly published their accounts either as short articles in learned journals, as addenda to related geographical studies, or as stand-alone memoirs (Haguet 2011, 97–99). The production of stand-alone memoirs was especially a French practice but by the 1730s was being emulated by British geographers and, by the 1780s, by German geographers as well.

In addition to explaining the critical apparatus used to create specific maps—in which respect they constitute absolutely crucial source materials for historians of cartography interested in the maps and in the development of geographical methods more generally—the memoirs and other commentaries were integral to the formation of the public sphere and of the disinterested pursuit of knowledge during the Enlightenment. The royal prerogatives that had limited debate over political and cultural matters to royal courts and parliaments were steadily eroded by the increasing participation of the lesser gentry and middling sort in discussions and debates over policy within new social settings and in new forms of print. A good geographical education—which included knowledge of how to make maps and featured much geographical map work, from games to map copying—was crucial if one was to participate, or claim a right to participate, in open discussions of political, military, economic, religious, or cultural affairs (Withers 2001, 114–42). Renaissance justifications of geography either as the science of princes or as a balm for intellectual curiosity gave way after 1650 to the new expectation that geographical maps would be actively read by the developing public as a source of politically important information. The consumption of printed geographical maps, and of information about geographical maps, became a hallmark of membership within the still socially privileged circles of the public and was actively pursued by those seeking entry into those circles.

Public political debates depended on at least the façade of disinterestedness: opinion was not to be determined by personal or party-political gain, but was ideally to be structured by the rational evaluation of information and addressed to a generic community, the public per se. The debates accordingly promoted a concern with measured facts (data) presented in a plain

manner without rhetorical adornment, although the results could still be decorative. In addition to providing useful and essential information to the growing public, geographical mapping exemplified the rational creation of new knowledge. In several satires in the London newspapers, for example, Benjamin Franklin used the study of geography as a model of rational and systematic thought that elicits truth (Dean 2004, 104–5). The common metaphorical usages of “map”—whether as a guide to truth, salvation, or an organized life, or as a comprehensive statement of organized knowledge (i.e., *scientia*)—all depended on this understanding of geographical mapping as an inherently rational and coherent endeavor. The memoirs and commentaries sustained this understanding through three interrelated strategies.

First, the published accounts of geographical mapping extended invitations to the public to assess geographical maps, to engage critically with maps, and to be active participants in geographical mapping. For example, Herman Moll often asked his readers to compare and evaluate the maps of his competitors and to conclude that he was correct to disparage them. One comment on his ca. 1710 map of South America claimed that “every body may easily judge” how “false” and “dangerous” were other maps; his final, emphatic statement that those other maps were “notoriously false” implied a degree of public conversation about geographical maps (fig. 284). Sixty years later, Robert de Vaugondy’s facsimiles of early maps in the 1777 supplement to the *Encyclopédie*, which demonstrated the changing depiction of the Bering Straits and of California (see fig. 138), encouraged readers to compare the depictions and to see how debate and the geographical process could progressively extirpate error. More generally, in explaining their sources and methods geographers subordinated themselves to the public’s supervision and judgment. Each geographer “passed his observations down to posterity in a medium available to every reader. He had an obligation to tell the truth and ran the ‘risk’ of ruining his reputation and of sinning against mankind when he made a mistake” (Novak 2001, 220–21). It did not matter if memoirs were large or small, expensive or cheap, or even little read; they still had the potential to be read by anyone who was sufficiently interested.

Geographers opened up their work to the public by debating even fine points of geographical mapping in scientific journals, as when d’Anville and Bellin argued in print over the representation of the Kamchatka Peninsula as derived from their respective interpretations of distances and times and whether the resultant maps should be labeled as “probable” or “true” (Verdier 2015, 118–30). Geographers also argued at length during the 1750s over the truthfulness of the reported discoveries of the fictitious Spanish admiral Bartholomew de Fonte, and in the 1760s Robert de Vaugondy

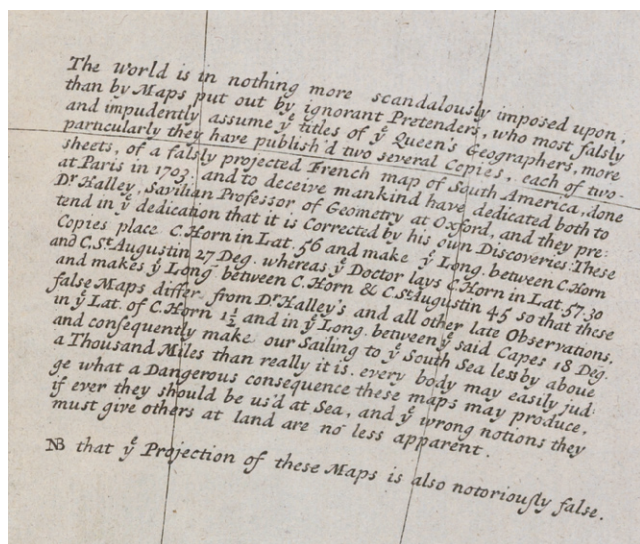


FIG. 284. AN APPEAL TO THE PUBLIC EVALUATION OF MAPS. Detail from Herman Moll's *To the Right Honourable, Charles Earl of Sunderland . . . This Map of South America, According to the Newest and Most Exact Observations is Most Humbly Dedicated*, in his *The World Described: Or, a New and Correct Sett of Maps* (London, [1727–28]), but originally published ca. 1710. Moll routinely added comments to his maps that puffed his own work and derided those of his competitors and, in doing so, asked his readers to critique the respective maps and to assess their worth. In this comment, Moll used “projection” to refer to the design and execution of the map (the project) and not just the construction of the framework of parallels and meridians.

Size of the entire original: ca. 62 × 99 cm; size of detail: ca. 9.5 × 11.5 cm. Image courtesy of the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland (SM-1719-11).

and Rigobert Bonne debated the value of taking into account the earth's flattened shape at the small scales of geographical mapping (Pedley 1992, 60–61, 74–78, 109–12).

There was indeed widespread public interest in assessing the quality of geographical maps and texts, fed in part by reviews of maps published in more popular journals, such as the *Mercure Galant* or the *Journal des Sçavans* in Paris (Verdier 2015, 87–89), the *Gentleman's Magazine* in London (beginning in 1731), and Zach's *Allgemeine Geographische Ephemeriden* (published beginning in 1798), and by books that offered long lists of the “best” maps (e.g., Gregorii 1713; Lenglet du Fresnoy 1716). The extent to which members of the public might have had the skills to assess geographical works is suggested by an April 1777 letter from British politician Henry Strachey, then in New York as secretary to Lord Richard Howe, head of the commission sent to negotiate peace with the American colonies, to his wife, Jane, in London, asking after recently published maps and books about North America: “If you can

hear a good Character of these, I should be glad to have them, but not if they are meer Catchpenny's—Nothing here is so scarce as Maps of the Colonies—I wish I had a good one of *each* Province separately but I doubt if there any *good ones* even in London—and I don't desire Trumpery” (Ann Arbor, University of Michigan, William L. Clements Library, Henry Strachey Papers). Implicit in this complaint is the expectation that Jane Strachey would have been able to determine, if not by herself then through consultation with others, that specific maps were indeed of good quality and worth their price, and not “catchpennies” made only to capture the hard-earned money of the unsuspecting.

The second strategy pursued within the published memoirs and commentaries was the self-conscious promotion of critical geography, or *géographie positive* (Robert de Vaugondy 1755, 159), and its distinction from the simple practice of copying existing works. The issue was clearly laid out by Green when he argued that a few critical geographers, such as Claudius Ptolemy, Gerardus Mercator, and most recently Guillaume Delisle, had periodically advanced geography by actively seeking accurate, coherent, and comprehensive geographical coverage. Yet the economics of publishing meant that it was cheaper to copy an existing map than to create a new one, so that “every one that can copy or engrave a MAP . . . sets up for a Geographer.” The result, Green declared, was that almost all published maps were only degraded copies of the critically produced few, “to the Dishonour, as well as Prejudice of Geography” (Green 1717, 132–34). Green's views were favorably reported in the *Mercure* in 1721 (Verdier 2015, 95), and similar sentiments were repeated by others who claimed critical standing (e.g., Delisle 1727, 120–21). The pursuit of an ostensibly critical geography permitted geographers to rise in social status through their intellectual achievements (Haguet 2011, 89, 99; Edney 1994b), a not inconsiderable point when social and cultural status was as important as that of the quality of one's techniques in the public assessment of map quality (Withers 1999).

In the third strategy, published commentaries established critical geography as an all-encompassing and innately progressive science. Some scholars have referred to this idealized and potentially perfect practice as “mathematical cosmography” because of the manner in which it unified geographical and astronomical work (Edney 1994b). The graticule, formed from the mapping of celestial circles onto the terrestrial globe, provided a means of readily translating and naturalizing any and all information from European and non-European sources within an apparently universal framework that could accommodate any degree of precision (Edney 1994a, 386–87; Edney 1997, 97). From this perspective, geographical practice was positioned as a universal map-

ping practice that properly encompassed all other kinds of mapping. Indeed, in addition to remarking on the ability of the graticule to integrate information drawn from mariners' charts and logbooks, some critical geographers even asserted that marine charts were properly geographical works. Varenius (1650, *Epistola dedicatoria*, unpaginated) argued that geography was crucial to mariners and that mariners themselves "acknowledge the enormous . . . aid that geography can give when they undertake to cross distant seas and a raging ocean, when they rely on the accuracy of the maps and on the principles which geography has bestowed on them for their use." Moll's disparagement of other maps of South America included the claim that mariners would be led astray by geographical maps, even though no mariner would ever have used such maps for actual navigation (see fig. 284). A number of geographers made works that they called "charts," such as Green, who in 1753 made a *Chart of North and South America* that indicated the discoveries of recent explorers and the routes of Pacific voyagers (Green 1717, 136–37; see fig. 342). Regardless of these claims by land-bound geographers, mariners generally went on following their own distinct practices for making and using sea charts. Overall, critical geographers argued not that their maps were statements of truth and perfect knowledge, but that geographical mapping was a process that leads to truth. Done right, critical geography was the proper methodology for knowing the world. In this respect, geographers were acutely aware of their place in a historical progression of geographical improvement (e.g., Robert de Vaugondy 1755) and held out the prospect of future perfection, especially in the face of contemporary degradation of geography by hack copyists.

The idealization of geographical practice within public debate depended on the drawing of a bright line between critical geographers and mercenary copyists. Yet it is hard, in hindsight, to discern a sharp distinction between, on the one hand, the small coterie of critical geographers, conceptually clustered around the exemplary and exceptional Delisle and d'Anville, and, on the other, an undistinguished mass of copyists. After all, many critical practitioners provided public explanations only when pressed to do so (as Witsen and Mitchell), or when prompted by public criticism (e.g., Robert de Vaugondy 1755, esp. xi–xii, 232–44), and many others had both critical and uncritical moments. It is possible to point to the way in which outmoded concepts persist on geographical maps, such as the continued depiction of California as an island, as evidence of the persistence of uncritical copying, while the common claim made in the titles of copyists' maps that they had been made from the "latest" or "best" sources seems to represent an attempt by the copyists to partake in the standing of critical geography and so enhance their reputation and

sales (Edney 1999, 188). Yet in practice, much of the critical work of geographical editing took place not in the concerted reconstructions of entire continents and countries but in the piecemeal and unremarked correction and editing of existing maps. The bright line soon fades and blurs.

Moreover, the claim that geographical mapping was a process leading ineluctably to truth was limited. Critical geographers and the public idealized geographical mapping as creating "a comprehensive *archive* constructed through the geographic practices of *reconnaissance* [*sic*] and *mapping*," but it proved incapable of digesting the products of the detailed, large-scale chorographical surveys increasingly pursued after 1740 (Edney 1999, 165–66). The last and grandest product of eighteenth-century geographical compilation was the forty-seven-sheet French topographical map of Egypt and Syria, as well as its three-sheet geographical reduction, produced in 1818 from a wide variety of materials that had been collected during the Napoleonic conquest of Egypt in 1799–1802 (Godlewska 1988). After 1800, the idealization of the geographical archive gave way to a new idealization of a spatial archive based on state territorial surveys (Edney 1997, 96–118).

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SEE ALSO: Atlas; Economy, Cartography and the; Education and Cartography; Geography and Cartography; Globe; Green, John; Hase, Johann Matthias; History and Cartography; Imaginary Geographies and Apocryphal Voyages; Indigenous Peoples and European Cartography; Map Trade; Measures, Linear; Itinerary and Geographical Measures; Memoirs, Cartographic; Mikoviny, Samuel; Modes of Cartographic Practice; Ottoman Empire, Geographical Mapping and the Visualization of Space in the; Projections: Geographical Maps; Public Sphere, Cartography and the; Religion and Cartography; Rennell, James; Transportation and Cartography: Road Map; Travel and Cartography; Vischer, Georg Matthäus; World Map

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Geographical Mapping and Topographical Surveying in Denmark and Norway. The small size and economy of Denmark, the still poorer economy of Norway, and the financial problems caused by recurrent wars in the seventeenth century, especially those with Sweden, all contributed to the distinctive character of topographical and geographical mapping in Denmark and Norway. To begin with, topographical and chorographical efforts were closely interrelated, and so are combined within this entry (Dahl 1993 reproduces examples of most of the projects). Moreover, until the middle of the eighteenth century, mapping projects were not well anchored institutionally: individuals often performed the work, and the projects ceased when they died or changed jobs; the results were often regarded as military secrets and the maps were not printed. The sporadic results of the early work informed ambitious projects after 1750, even as a series of official and semiofficial efforts engaged in new mapping.

Hans Willumsen Lauremberg, who had secured the professorship of mathematics at Sorø Akademi in 1623 on the strength of a proposal to survey Denmark, was appointed in 1631 to be royal mathematician by Christian IV. In that capacity Lauremberg was to survey the country. He produced many maps and the first land surveying text published in Denmark, *Gromaticæ libri tres* (1640), but he failed to have the maps printed and in



FIG. 285. JOHANNES MEJER'S ORIGINAL MANUSCRIPT MAP OF SLESVIG. Mejer prepared this untitled map in about 1650.

Size of the original: 66 × 72 cm. Image courtesy of Det Kgl. Bibliotek; The Royal Danish Library, Copenhagen (KBK 1111, 155-0-1650/1).

1645 lost the king's favor. Lauremberg was succeeded as royal mathematician, in 1647, by Johannes Mejer, a prolific surveyor from Husum, in Slesvig, who had studied astronomy at Copenhagen University. Mejer's extensive work in Slesvig and Holstein had produced an atlas of forty maps that would be published, together with an expansive text by Caspar Danckwerth, as *Neue Landesbeschreibung der zweij Hertzogthümer Schleswich und Holstein* (1652). Mejer added that work to Lauremberg's to create a large manuscript map of Denmark that he presented in 1650 to Frederik III, who hung it on his study wall (fig. 285). Thereafter, Mejer contin-

ued to map Denmark—Jutland, 1654–55 and Skåne (now in Sweden), 1655–58—and also prepared a number of fanciful maps, full of forests and towns, of Greenland and other Arctic territories claimed by Denmark. In 1658–60, Mejer collected eighty-two maps for a putative “Nordic atlas,” however the work remained unfinished (Dreyer-Eimbcke 2006; Ehrensvärd 2006, 125, 170–80).

Although no official successor to Mejer was appointed, his efforts to create a comprehensive and detailed atlas of Denmark were continued by the mayor of Copenhagen, Peder Hansen Resen. Resen sought to create a great *Atlas Danicus* covering not only the ge-

ography of Denmark but also local history, antiquities, monuments, and natural history. He worked with Mejer's maps, with the large corpus of local topographical materials collected pursuant to a 1622 decree by Christian IV, and with further information gleaned from fellow antiquaries. Resen and the copper engraver at Copenhagen University, Johan Huusman, prepared and engraved 115 maps—mostly urban plans (see fig. 890) but including twenty-six regional maps—as well as numerous topographical and architectural views. Resen included these in an exemplar volume, printed in 1677, of which only five copies are known, none complete. The whole project grew to no fewer than thirty-nine volumes in manuscript. Resen eventually reduced them to seven volumes, and then to a three-volume precis that was finally published in 1774. Resen's source materials were destroyed, along with the rest of the university library, by the great fire of 1728; transcripts of the seven-volume precis did survive, with a few views of estates and landscapes, and have been variously edited and published in the twentieth century (Resen 1974; Ehrensvärd 2006, 180–81).

Further surveys were undertaken. From 1691 to 1697, a carriage designed by the astronomer Ole Rømer with a waywiser fitted to a wheel to count its revolutions was used to measure itinerary distances along Denmark's principal roads (Pedersen 1992, 92). In 1720–23, Captain Abraham Christian Willars surveyed *rytterdistrikter* or “reuter districts” (cavalry districts), areas from which the king could demand supplies of horses and other commodities to support the military. Seven beautiful maps are known from this work, in various scales from 1:30,000 to 1:70,000 (Nørlund 1943, 56–57) (see fig. 16).

The early mapping of Norway was equally fragmentary and sporadic. A Dutch military engineer, Isaac van Geelkerck, surveyed and mapped several parts of Norway between 1644 and 1657, although with an emphasis on fortresses and urban places. In 1650, the Crown also requested that Van Geelkerck produce a regional map of Norway; probably completed, this map is now lost. However, in 1658–60, the engineer Gottfried Hoffman compiled Van Geelkerck's and Mejer's maps into a general map of both Denmark and Norway, presented to the Crown prince, later Christian V (see fig. 203). After 1688, Melchior Ramus of Trondheim worked with royal support to turn his own itineraries and other records into a large map of Norway at 1:320,000, which he presented to Christian V in 1692; Ramus died before the map could be published. A map of all of Norway, *Delineatio Norwegiæ novissima*, drawn by Joachim Frederik Ramus, nephew to Melchior Ramus, was appended to a history of the Norse kings, *Norriges Kongers Historie* (1719) by Jonas Ramus. Melchior Ramus's work seems

also to have been used, at least in part, by Ulric Frideric Aagaard for a series of maps of *fogderier* (counties) by 1705; nine are known to survive, but more research is still needed to clarify their relationship to earlier maps (Hoem 1986, 97). The maps by Aagaard and the Ramus family seem to have been the primary source for maps of Norway by Ove Andreas Wangenstein (*Kongeriget Norge*, 1761) and Erich Johan Jessen-Schardebøll (*Det Kongerige Norge*, 1763) (Nissen 1938–39, 1963–64; Hoem 1986; Ginsberg 2009, 94–96, 100–105).

A more concerted interest in topography and geography was fostered within the Kongelige Danske Videnskabernes Selskab, founded in 1742 by Christian VI. Almost immediately, Christian VI tasked the academy with several topographical projects. Least successful was the publication of the lavish manuscript that commemorated, with sixty-eight landscape views and detailed maps, Christian VI's grand progress through Norway in 1733; the task proved beyond the capacity of the academy and local publishers (*Norske reise* 1992 is a modern facsimile). More successful was the academy's publication of the results of Frederik Ludvig Norden's expedition to Egypt in 1737–38, which Christian VI had funded; Norden had traced and mapped the course of the Nile from Alexandria to the second cataract (fig. 286). Norden's work eventually appeared in print, with many maps, plans, and views, in two volumes, as *Voyage d'Égypte et de Nubie* (1755). Then, in 1751, Frederik V ordered the academy to organize an expedition in 1752–57 to survey the geography, natural history, and economy of the still little-known Norwegian territory of Iceland; the academy also published a study of Iceland, with map, by Niels Horrebow, previously funded by Frederik V: *Tilforladelige efterretninger om Island med et nyt landkort* (1752) (Pedersen 1992, 65–71).

Members of the academy, influenced by these diverse projects, began to ponder a comprehensive topographical survey of Denmark. They were also motivated by the example set by the regional mapping of Sweden, published by the Vetenskapsakademien in Stockholm, and perhaps by some jealousy of royal plans for an expedition to Arabia and Persia in 1761–67, whose sole surviving member was the geographer Carsten Niebuhr. As Norden's work was being prepared for press, an anonymous proposal wondered at the cost involved and whether the funds would be better spent on a good map of Denmark, like that of Sweden; such a map would be made by the academy's members selecting the best of all the existing maps, correcting them as necessary, and then compiling them into a single map (Pedersen 1992, 93–94). While there is no evidence that the academy ever formally considered this proposal, it did pay heed to another that was submitted to the king in 1757



FIG. 286. FREDERIK LUDVIG NORDEN'S MAP OF THE NILE. The manuscript "Carte de l'Egip-te. & de Nubie," [1738], would inform the overview map, in two sheets, of the course of the Nile in Norden's posthumously published *Voyage d'Egypte et de Nubie*, trans. J.-B. Desroches de Parthe-

nay, 2 vols. (Copenhagen: Imprimerie de la Maison Royale des Orphelins, 1755).

Size of the original: 34.0 × 22.5 cm. Image courtesy of the Royal Danish Academy of Sciences and Letters, Copenhagen, and reproduced with their permission.



FIG. 287. MAP OF DENMARK. Theodor Gliemann, "Kongeriget Danmark," 1815, compiled with assistance from the sheets of the Videnskabernes Selskab kort, manuscript maps of Slesvig and Holstein by military officers, and Samuel Gustaf Hermelin's printed map of Sweden (1810).

Size of the original: 91 × 63 cm. Image courtesy of Det Kgl. Bibliotek; The Royal Danish Library, Copenhagen (KBK 1111-0-1815/1).

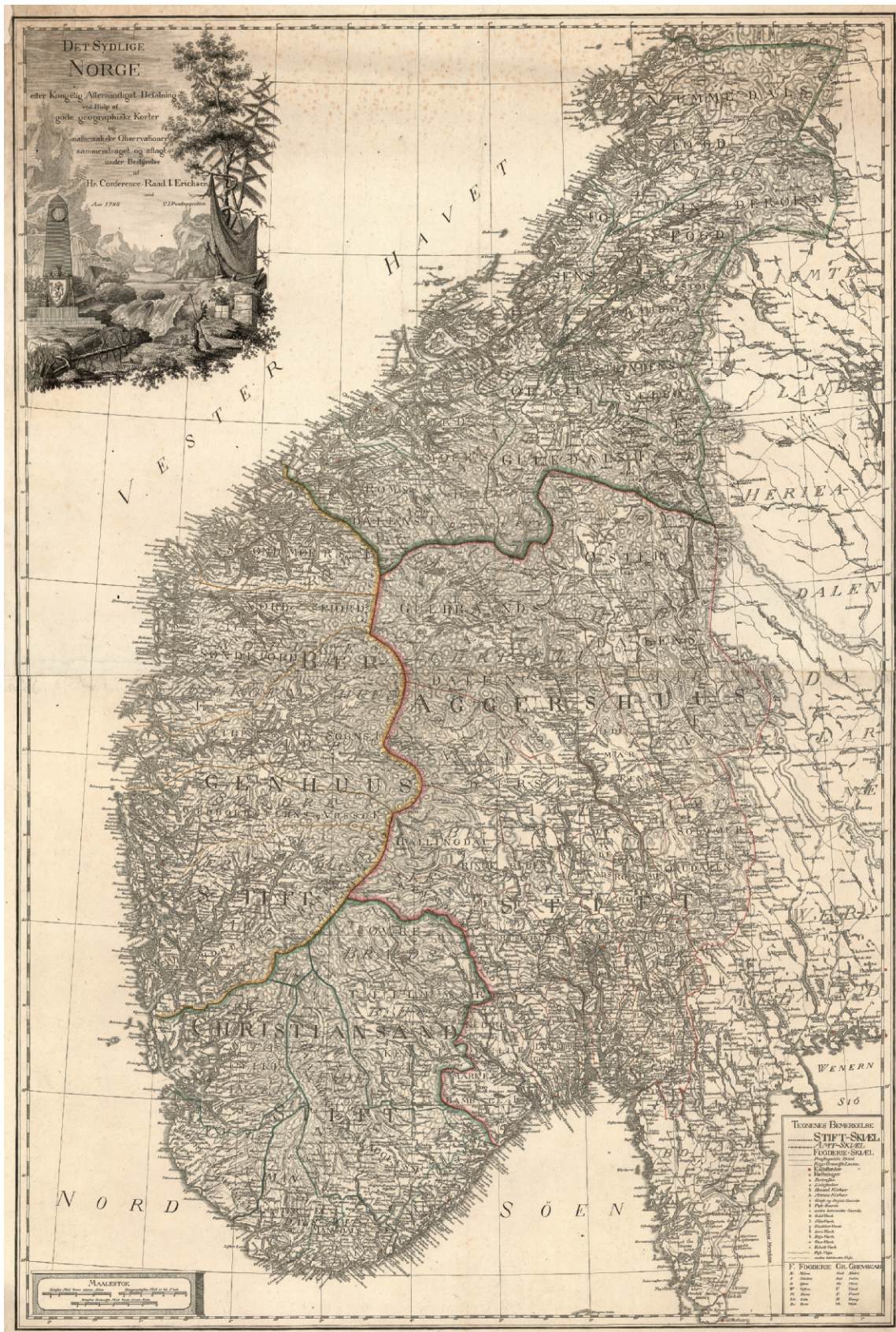


FIG. 288. CHRISTIAN JOCHUM PONTOPPIDAN, *DET SYDLIGE NORGE*, 1785. Pontoppidan followed this work by the smaller-scale *Det nordlige Norge* (1795). Copper engraving on two sheets, ca. 1:840,000.

Size of the original: 100.5 × 68.0 cm. Image courtesy of Det Kgl. Bibliotek; The Royal Danish Library, Copenhagen (KBK 1112-0-1785/5).

via the royal architect, Laurids de Thurah, by a young scholar Peder Koefoed, on the condition that he be appointed professor of mathematics at the gymnasium in Odense. Koefoed proposed a completely new survey, using plane tables equipped with a telescopic alidade of his own design. Unfortunately, he completed only one map, of Copenhagen, before his death. The academy soon pushed ahead with a plan for the mapping of Denmark along the same lines as César François Cassini (III) de Thury's survey for the *Carte de France*, to be undertaken by Koefoed's assistant, Thomas Bugge (Pedersen 1992, 89–97). In 1761, the academy secured royal support for the triangulation-based survey; by 1805, Bugge and his assistants had completed and published sixteen regional maps at 1:120,000 (see fig. 944) and some larger-scale maps of some of the islands. The academy eventually used these as a basis for mapping the country as a whole (fig. 287).

As the book trade grew in Denmark and Norway, it featured the commercial production of a few geographical works. The essayist and playwright Ludvig Holberg, who became professor of geography at Copenhagen University in 1730, prepared a short *Compendium geographicum in usum studiosæ juventutis* (1733), but without maps. Nicolai Jonge would use Holberg's name for his much larger seven-volume geography—*Baron Ludvig Holbergs Geographie eller Jordbeskrivelse* (1759–91), with several maps—although there was little connection between the two works; Jonge also produced other geography books with regional maps, as well as a small *Skole-Atlas* (1772) with maps derived from those of Johann Baptist Homann (Erslev 1884).

The geographical and topographical tradition of Resen's *Atlas Danicus* was perpetuated by the bishop Erik Pontoppidan, who produced a small map of Denmark in 1729 and then a small topography of the country published in Bremen: *Theatrum Daniæ veteris et modernæ* (1730). The royal architect, Thurah, published a topographical account of Copenhagen, *Hafnia Hodierna*, in 1748 and would have published more had he not died. Pontoppidan continued his own work, to create *Den Danske Atlas eller Konge-Riget Dannemark* (1763–81). Pontoppidan prepared two volumes before his own death; another five were prepared by his sister's husband, Hans Hofman. All told, the seven volumes contained more than two hundred city plans and fifteen maps by Diderich Christian Fester; with the academy's survey barely begun, Fester compiled the maps from Mejer's manuscripts, corrected by the later works of Willars, Resen, and maybe also by the coastal charts of Jens Sørensen (Ehrensward 2006, 300–301, 305).

A similar project was undertaken by the theologian Gerhard Schøning for Norway: his three-volume *Norges Riiges Historie* (1771–81) combined topographical and geographical imagery. The latter drew in particular

on Melchior Ramus's maps but also other manuscript works. Many of the maps collected by Schøning were later used by other geographers in their work on Norway. Thus, the teacher of drawing at the Landkadetakademi (founded 1713) in Copenhagen, Christian Jochum Pontoppidan, used a variety of sources for his two detailed maps of Norway in 1785 (southern; fig. 288) and 1795 (northern), whose construction and sources were explained in brief memoirs (Hoem 1986; Ehrensward 2006, 333; Ginsberg 2009, 114–17, 122–27).

HENRIK DUPONT

SEE ALSO: Bugge, Thomas; Denmark and Norway; Niebuhr, Carsten; Videnskabernes Selskab kort (Academy of Sciences and Letters map series; Denmark)

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Geographical Mapping in France. From the middle of the seventeenth century to the end of the eighteenth, geographical maps enjoyed commercial success in France and in continental Europe, and they played a fundamental role in the development of the discipline of geography. During the Renaissance, interest had focused on maps of the realm, a trend that the publication of the first national atlas of France in 1594 confirmed (Maurice Bouguereau's *Le theatre francoys*). Yet it was only in 1658 that the first important French world atlas appeared: *Les cartes générales de toutes les parties du monde*, produced by Nicolas Sanson and issued in seven editions until 1676. For the Sanson family—Nicolas and his son Guillaume—the map was the essential element



FIG. 289. GUILLAUME DELISLE, *CARTE D'AFRIQUE DRESSÉE POUR L'USAGE DU ROY* (PARIS: CHEZ L'AUTEUR, 1722). A new edition of the 1700 map by the same author, which had already corrected the Mediterranean shoreline of Africa. This map was dedicated to the king and was therefore a political map; yet it also reflects the progress

in geography, which could be studied in three different ways: with globes and maps; with tables incorporating the divisions and subdivisions of empires, monarchies, realms, republics, and other sovereign states; and finally with textual descriptions (Sanson 1681, 6). Thanks to Nicolas Sanson, whose geographic tables so “marvelously” aided the memory that “only eyes and maps were necessary,” geography became accessible to users as various as poets, philosophers and historians, sovereigns and politicians, churchmen and financiers, magistrates, businessmen, and travelers, as well as readers of historical works and travel narratives (Sanson 1681, 6, [IV], [II–III]).

By the early eighteenth century, geographic maps benefited from new data gathered and transmitted by the Académie royale des sciences, which allowed precise lo-

made by Delisle in understanding the continent, for example in his separation of the courses of the Senegal River from that of the Niger.

Size of the original: 50.0 × 64.5 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge DD 2987 [7771]).

calization of an ever-increasing number of points whose latitudes and (less easily determined) longitudes were becoming known. These new data allowed geographers to modify the map of the world by presenting “a nearly new earth” (Fontenelle 1728, 78), as demonstrated by the *Mappe-monde* (1700) of Guillaume Delisle (see fig. 201), which shortened the length of the Mediterranean Sea by 300 leagues and the length of Asia by 500 leagues, thus changing the breadth of Africa as well (fig. 289). Soon, *géographes de cabinet* were immersed in increasingly numerous sources, especially travel narratives. They had to synthesize an immense amount of material, a task too formidable for many, who found it simpler to copy from a colleague. Understanding these imperatives and undoubtedly with Delisle in mind, Didier Robert de Vaugondy wrote: “The astronomer and

the geometer each has his own sphere of knowledge; but the geographer should possess knowledge of both [subjects] and be able to discuss [each] in order to reconcile and to utilize appropriately the support that he draws from each" (Robert de Vaugondy 1757, 613).

Philippe Buache followed in Delisle's footsteps, using the latter's collection before it was transmitted in 1773 to Buache's nephew, Jean-Nicolas Buache, who sold it in 1780 to Jean-Claude Dezauche. In fact, the contract of this sale shows that, in the course of their long life, the plates of the geographic maps (the world and the continents), undoubtedly much in demand, had been frequently brought up to date by several successive engravings, thus explaining the variety of dates given for the same map; other plates that had become unusable were "to be remade" ("Vente" 1780). For the purpose of selling maps, the names of Guillaume Delisle and Philippe Buache assuredly attracted buyers.

Another concern for geographic mapping was the question of projection, which was debated alongside that of the flattening of the earth. Rigobert Bonne revived the projection used by the Italian Bernardo Silvano in the 1511 edition of Ptolemy's *Geography* (Silvano's projection was itself a variant of Ptolemy's second projection). It represented parallels with concentric circles and all the meridians with curves except for the central one, which is straight, something that distinguished his projection from truly conic projections. Bonne's projection, reconfigured for the ellipsoid, was later used for the nineteenth-century map of France at a scale of 1:80,000, called the *carte de l'État-Major*.

In November 1752, Philippe Buache presented to the Académie royale des sciences an "Essai de géographie physique" in which he distinguished physical or natural geography from historical geography and from mathematical or theoretical geography, which concerned itself with methods for producing maps. Buache considered that "the most general" part of physical geography was "the type of frame," which appeared to him to be "the support for different parts of the terrestrial globe and which is formed by chains of high mountains that encircle it and traverse it" (Buache 1756, 400–401). He demonstrated his theory of the "framework of the earth" with the *Cartes et tables de la géographie physique ou naturelle* (1754–56), presented to the king in 1757, and still published as late as the end of the century by Dezauche. Buache termed another aspect of physical geography as the *intérieure* (interior), concerning minerals, the sources of fountains, the various layers "that are found in mountains," as well as the interior of the sea, the direction of currents, and the observation of the magnetized needle, important subjects for navigation (Buache 1756, 400). Buache's essay was well received by the Académie des sciences: "This way of viewing our globe opens a new avenue for geography. It is perhaps

more interesting to know the directions of these mountain chains which serve as a frame for the earth and, in some sense, a restraint on the fury of the waters of the sea, which supply and direct the waters of rivers and of fountains, and which are perhaps linked to many other physical phenomena, than it is to know the ancient boundaries of a realm or of an empire that no longer exists" ("Sur les chaînes" 1756, 124) (see fig. 5).

This favorable response from the Académie did not stop other critics. In the first volume of the *Géographie-physique*, Nicolas Desmarest accused Buache of never having been in the field, which would have allowed him to observe "that the supposed catenation of these [mountainous] ridges does not exist as Buache represents it on his maps" (Desmarest 1795, 69). Desmarest argued that new science should be based upon dependable observations and should offer tools for explaining the form and causes of the heights of mountains. Desmarest (1795, 151–88) was similarly critical of the geological labors of Jean-Étienne Guettard. Nevertheless, the geographical theories of Buache were adopted by his nephew Jean-Nicolas Buache. In the diplomatic context of the Franco-Spanish boundaries, the younger Buache, writing in 1791, favored a natural frontier constituted by the "crest or the summit of the Pyrenees Mountains," "determined along their whole length by the innumerable sources of rivers that emerge from them to water the lands of France and those of Spain." He claimed that this type of "simple and natural" division "had been adopted by the United States of America when they determined the limits of their possessions" (cited by Nordman 1984, 105). Thanks to such an approach, nations "would more efficaciously assure and defend the limits of their possessions by adopting the constant and invariable boundaries that are established by nature," as Buache said in his lectures to the École normale (Nordman 1984, 107). His views contrasted with the less utopian outlook expressed forty years earlier by the politician and economist Anne Robert Jacques Turgot. His *Plan d'un ouvrage sur la géographie politique* recognized that states had used natural boundaries, but he placed them once again within a historical context, as he reflected on the great moments of history (Nordman 1984, 107).

Throughout this long period, geographers continued to publish historical maps as part of their standard repertoire. All the great *géographes de cabinet* of the eighteenth century, such as Guillaume Delisle, Jean-Baptiste Bourguignon d'Anville, Gilles Robert Vaugondy, and Didier Robert de Vaugondy, produced historical maps on which they tried to locate exactly places cited by ancient authors or in sacred history. D'Anville justified his work with accompanying *mémoires*. Delisle focused on the Middle Ages and planned to draw up five series of historical maps (Hofmann 2000, 106). Michel Picaud presented thirty maps to illustrate *Les révolutions de*

l'univers (1763) by Étienne-André Philippe de Prétot, using the same map, repeated with varied coloration, to follow the evolution of world history from the dispersion of the sons of Noah up to the eighteenth century.

Increased production and demand created a promising climate for the trade in geographical maps. In 1752 the publisher and mapseller Roch-Joseph Julien opened what was probably the first map store in Paris, offering a large selection of European maps. In his 1763 catalog, he remarked that Europe was inundated with a “prodigious number” of available maps, obliging him to make a considered selection for his customers (Pedley 2005, 160); in his choices for France, the names of Guillaume Delisle, Jean-Baptiste Bourguignon d’Anville, and Didier Robert de Vaugondy stand out. The maps of d’Anville were the most costly: 5 livres for his *mappemonde* in two hemispheres of 1761 (fig. 290), while that of Delisle cost only 2 livres 10 sols. Moreover, observing that “a good atlas is put together according the use one wishes to make of it and how much one wishes to spend,” Julien offered his services to counsel any client who wished to create his or her own *atlas factice* (Pedley 2005, 160, 282n7). Nevertheless, large coherent atlases continued to be produced by single cartographers. For their *Atlas universel*, Gilles Robert Vaugondy and Didier Robert de Vaugondy chose a format compatible with the folio volumes of libraries, identical symbols for all maps in order to facilitate comprehension, and demanded a high quality of engraving that sometimes seemed excessive to the engravers. Their editor, Antoine-Chrétien Boudet, protected himself from financial risk by proposing a subscription in 1752, which was well-received and gave purchasers significant savings. In the tradition of the cartographic memoir, Didier Robert de Vaugondy cited the sources for his large atlas: he had used classic models like Nicolas Sanson, whose plates his family had inherited, and Guillaume Delisle, but also numerous geographers of the eighteenth century whose work he had examined with care (Robert de Vaugondy 1755). Gilles and Didier preferred to correct existing documents that they had selected as the bases of their work, rather than creating completely new ones (Pedley 1992, 51–68). Buache and Dezauche followed the same method of correction in reediting the maps of Delisle.

Geographical maps played an important role in teaching geography. By the end of the eighteenth century, professors had at their disposal a whole arsenal of maps and atlases, from which they could carefully select in order to protect their students from bad documents and faulty counterfeits. The *Institutions géographiques* (1766) by Didier Robert de Vaugondy, published in the tradition of the *Introduction a la géographie* of Guillaume Sanson, recommended the maps of his *Nouvel atlas portatif* of 1762. That same year Jean Lattré and Jean-Thomas

Hérissant published the *Atlas moderne*, which targeted a similar scholastic audience and, with fewer maps, was slightly less expensive (Pedley 1992, 100–102). The best pedagogue appears to have been Edme Mentelle, who took geography outside the walls of his *cabinet*: beginning from the geographic position of his students and progressing outward in concentric circles, he had his pupils travel metaphorically to the ends of the earth (Nordman 1994, 146). Mentelle’s *Géographie comparée; ou Analyse de la géographie ancienne et moderne des peuples de tous les pays et de tous les âges* (1778–84) returned to a tradition of linking ancient and modern geography using maps and tables. An atlas of great quality complemented this work containing simplified, clearly engraved and color accented maps that were easily comprehended and even included the *Mappe-monde physique* of Buache (fig. 291).

The most capable geographers were sought to illustrate books in which a map seemed to be indispensable. This work was not negligible, for it both provided complementary revenue to the geographers and expanded map appreciation to a wider reading public. Jacques-Nicolas Bellin, in addition to his duties at the Dépôt des cartes et plans de la Marine, illustrated the voyage of Pierre-François-Xavier de Charlevoix to Canada (1744) and the *Histoire générale des voyages* (1746–1802 [an X]), edited until 1761 by the abbé Antoine François Prévost. D’Anville prepared the maps for the description of China by Jean-Baptiste Du Halde, published in 1735. Didier Robert de Vaugondy illustrated different texts including the first volume of the *Histoire naturelle* (1749) by Georges-Louis Leclerc, comte de Buffon, and the *Histoire des navigations aux terres australes* (1756) by Charles de Brosses; he also prepared two maps for the posthumous edition of the *Esprit des loix* (1758) by Charles-Louis de Secondat, baron de Montesquieu.

In general, the most well regarded geographical maps produced in France were the work of practicing geographers who taught mathematics and geography and who were active contributors to scientific debate in the learned academies. The work of these *géographes de cabinet* dominated until the last quarter of the century, when scientists and scholars in the field drew attention to the important work of synthesis that could be performed by leaving the office for direct observation of nature.

MONIQUE PELLETIER

SEE ALSO: Anville, Jean-Baptiste Bourguignon d’; Atlas: School Atlas; Buache, Jean-Nicolas; Buache, Philippe; Delisle Family; France; Historical Map; Robert de Vaugondy Family; Sanson Family

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FIG. 290. JEAN-BAPTISTE BOURGUIGNON D'ANVILLE, *HÉMISPHERE ORIENTAL OU DE L'ANCIEN MONDE* (PARIS: CHEZ L'AUTEUR, 1761). This map of the Eastern Hemisphere is one half of the first edition of d'Anville's double-hemisphere world map. As he had already done in his map of Africa of 1749, d'Anville emptied the interior of this conti-

ment of any contents that did not appear to him to be verified and based on reliable information.

Size of the original: 65 × 59 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge DD 2987 [96 B]).



FIG. 291. MAPPE-MONDE PHYSIQUE D'APRÈS DES VUES DE M^R. PALLAS, 1779. Mentelle was one of the first to include maps of physical geography in his school atlases, beginning with the *Atlas nouveau* (1784). Here the views of Peter Simon Pallas replicate the global chain of mountains initially proposed by Philippe Buache, and the map includes the heights of particular mountains as well as asterisks marking

volcanoes. From Edme Mentelle and Pierre-Grégoire Chailaire, *Atlas universel de géographie physique et politique, ancienne et moderne* (Paris: chez les Auteurs, An XIV [1806]). Size of the original: 26 × 42 cm. Image courtesy of the William L. Clements Library, University of Michigan, Ann Arbor (Atl 1806 Me).

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Geographical Mapping in New France and the French West Indies. Geographical mapping in French colonial possessions of North America, the islands of the Caribbean, and French Guiana was organized in various ways and produced varied results, but differences arose not so much from geographic variations as from differences in chronological development and the way in which maps were ordered and used. Moreover, this particular historical period witnessed important developments in modes of spatial representation as well as the extension of the domains covered by cartographic documents. Finally, this type of mapping was rarely the fruit of isolated labor or of self-taught mapmakers.

The purpose of medium- to small-scale geographical maps was to function as political tools, which allowed the king to see the extent of his holdings and could serve as foundations for diplomatic negotiations (fig. 292). Such maps also had a military objective: identifying enemy forts and the location of enemy troops, information on which the defense of colonies and attacks on enemy

positions depended. The scale of geographical maps allowed them to be useful for other purposes. Marine maps indicated passable waters and provided bathymetric information. Thematic maps noted the locations of indigenous tribes. Route maps displayed the network of roads and trails connecting commercial posts and religious establishments. A general map of Saint-Domingue (1784) even showed the network of mail distribution in the colony (fig. 293). This sizable cartographic production originally remained in manuscript form, but by the mid-eighteenth century it was beginning to be synthesized and printed by the *Dépôt des cartes et plans de la Marine* under the supervision of Jacques-Nicolas Bellin.

After the initial work of French navigators who described the coastline of North America from direct observation in the sixteenth century, cartographers also began to incorporate data from astronomic observations. In 1601 Guillaume Levasseur drew a chart of the Atlantic Ocean using the Mercator projection, which represented shipping routes as straight lines and cor-



FIG. 292. NICOLAS DE FER, *LES ISLES DE L'AMERIQUE CONNUES SOUS LE NOM D'ANTILLES* (PARIS, 1702). Ca. 1:10,900,000. This map of the Antilles and the Gulf of Mexico, compiled and published in Paris, depicts the claims of the French, Spanish, and English Crowns.

Size of the original: 33 × 22 cm. Image courtesy of the Bibliothèque nationale de France, Paris (*Cartes et plans*, GeD 13302).



FIG. 293. ANONYMOUS, CARTE DES POSTES AUX LETTRES DE L'ÎLE DE SAINT DOMINGUE, 1784. This printed map shows the postal routes and post houses in the French part of Saint-Domingue.

© Archives nationales (France) (N III Saint-Domingue, pièce 3).

rected the alignments of the Mediterranean and North American coastline by taking into account magnetic declination. Such information was digested by a new type of geographer, the *géographe du roi*, a title created by Armand Jean du Plessis, Cardinal Richelieu. One of the first *géographes*, Nicolas Sanson, published a map of New France in 1656 that incorporated information provided by Jesuit missionaries, especially for Canada and the St. Lawrence River valley.

Accounts by travelers and explorers provided critical information to cartographers: topographical indications,

the number of days required to walk between places, information on orientation, as well as botanical and ethnographic data. However, these sources were not always reliable. At the end of the seventeenth century, following the twenty-year-old path of the Recollect father Louis Hennepin along the Mississippi, the naval officer Pierre Le Moyne d'Iberville had many occasions to curse the imprecisions of his predecessor. When a colony was established, the inhabitants themselves, concessionaires and scholars, administrators, surveyors, and engineers, helped to produce maps and plans and endeavored to

make them more accurate. However, in the absence of strong copyright laws, commercial geographers copied one another to boost their own production, not always aware of the most recent works, even though these maps were not always evaluated and verified. Thus documents with obsolete information circulated alongside works with the most recent data.

The creation of the Académie des sciences along with the improvement of timekeepers and angle measuring instruments pushed cartographers toward overseas expeditions for astronomical observations to determine exact latitudes and longitudes in order to establish better maps. While earlier geographers like Sanson drew on literary accounts and the works of others, the new geographers working in Paris relied on astronomers by asking them specific and precise questions with a desire to produce maps on the scientific basis of consistent inquiry, observation, and measurement. The loci of these observations were often in French possessions in the Western Hemisphere. Between 1672 and 1673 Jean Richer observed Mercury from Cayenne, and in 1685 Jean Deshayes determined the longitude of Quebec in Canada. Nonetheless, even these observations were subject to scrutiny by geographers such as Guillaume Delisle in Paris, who queried results such as the information provided by René Robert Cavalier de La Salle, who found the mouth of the Mississippi by land rather than by sea. Further data were required in order to check earlier work. Antoine François Laval crossed the Atlantic

in 1720 (fig. 294), noting the variations of the compass during his voyage and comparing these measurements to those on Edmond Halley's map, first published in 1701 (see fig. 348). From 1729 to 1733 the astronomer Pierre Baron made observations in New Orleans in French Louisiana, the results of which he reported to the Paris Académie des sciences (Langlois 2003, 152–53). In 1750 and 1751 Joseph-Bernard, marquis de Chabert, used a quadrant for his geometric operations in Canada, which resulted in maps of the environs of Louisbourg, the Scatari Island, and the Strait of Fronsac. His astronomic observations also included the eclipses of the satellites of Jupiter at Louisbourg (previously observed by Laval from Dauphin Island in 1720). Chabert's results were remarkably precise: the measures differed from modern measures by only three minutes in longitude and one in latitude. The tasks required of these learned field observers were sometimes arduous. In 1749 Father Joseph-Pierre de Bonnécamps was sent to map the Ohio River Valley near the Great Lakes as a member of the expedition directed by Pierre-Joseph Céloron de Blainville, but he was unable to fulfill his mission because of harsh conditions, bad weather, and the limitation of the itineraries chosen by his military escort, who had other concerns.

Many early observers sent their findings to Paris, where Claude Delisle and his son Guillaume established a cartographic workshop in the first third of the eighteenth century (Dawson 2000). They prepared documents for engraving, synthesizing all the accounts and

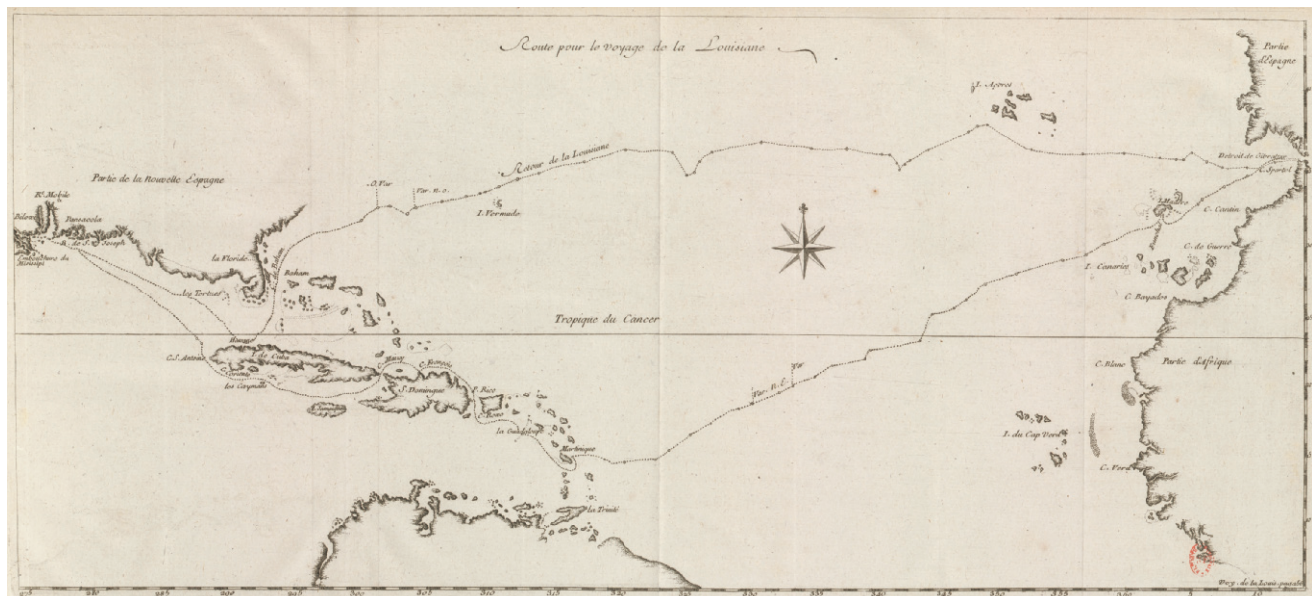


FIG. 294. ANTOINE FRANÇOIS LAVAL, *ROUTE POUR LE VOYAGE DE LA LOUISIANE*, 1720. The Jesuit Laval was a mathematician and hydrographer, *professeur royal* for the Marine officers in Toulon after he opened an observatory in Marseille in 1702. The printed map, included in Laval's *Voyage de*

la Louisiane (Paris: Jean Mariette, 1728), between 256 and 257, shows the plan of the Atlantic route followed by French ships sailing to Louisiana and includes notations of magnetic variation along the route.

Image courtesy of the Bibliothèque nationale de France, Paris.

observations available and working in connection with the new Paris Observatory and the Cassini family. Bellin and Jean-Baptiste Bourguignon d'Anville continued the compilation method of the Delisles. For the encyclopedic compilation of the *Histoire générale des voyages* by the abbé Antoine François Prévost (15 volumes, 1746–59), Bellin compiled the majority of maps of America.

The first manuscript maps to describe with great precision the colonized territories in New France were the work of geographers residing there, including Jean Baptiste Louis Franquelin in Canada (1688) and François Le Maire in Louisiana (1716). Military engineers also played a part in this exhaustive cartographic labor, including Gaspard-Joseph Chaussegros de Léry in Canada, Ignace-François Broutin in Louisiana, Amédée-François Frézier in Saint-Domingue, and François Blondel in the Antilles. Their precise and nearly unimpeachable research brought the best sources of information to geographers in the metropole (fig. 295). Broutin,

for example, lived more than thirty years in Louisiana, where he arrived in 1720 as an officer charged to defend two concessions in the Natchez region. Although he never obtained the title of engineer, Broutin served in turn as surveyor (map of Chapitoulas, ca. 1726), architect (plan of an Ursuline convent in New Orleans, 1745), and hydrographer (a large map of the course of the Mississippi, 1731). Thanks to the protection of Jean-Baptiste Le Moyne de Bienville, Broutin played the role of engineer-in-chief without the title, and in this capacity he produced plans, sections, and elevations of fortifications and buildings in most of the outposts and cities in the colony (Langlois 2003, 82, 192, 251, 287; Dujardin 2008).

For a generation earlier Franquelin provides a notable example of a resident geographer, living twenty years in Quebec (New France), whose story strikingly demonstrates the king's interest in his North American colony. As a young merchant, Franquelin crossed the Atlantic in



FIG. 295. BARON DE CRENAY, "CARTE DE PARTIE DE LA LOUISIANNE," 1733. De Crenay was one of the French officers to lead the punitive expedition against the Natchez. He designed this manuscript map to trace land routes across colonial Louisiana between Native American settlements and

French establishments. It is the only map of its type known for the region.

Size of the original: 77.5 × 113.5 cm. Image courtesy of the Archives nationales d'outre-mer, Aix-en-Provence (DFC Louisiane 6A, pièce 1).

1671 or 1672 to Canada, where he studied geography at a small seminary in Quebec. Called upon to depict the expedition of Louis Jolliet and Jacques Marquette on the Mississippi, Franquelin furnished the *intendant* Jacques Duchesneau in 1678 with two maps remarkable for their aesthetic qualities: one showed the expedition itself and the other, the Gulf of St. Lawrence to Lake Huron. Sent to Jean-Baptiste Colbert, these documents assured the standing of the new geographer, who was summoned to perfect his scientific knowledge in Paris. There, with La Salle, Franquelin prepared maps of La Salle's discovery of Louisiana. Returning to Quebec in 1684, Franquelin dedicated himself to the cartography of the St. Lawrence and Acadia. He was named royal hydrographer in 1687, and in this capacity he produced a map of the boundaries of English and French possessions (see fig. 244). Between 1689 and 1692, in the face of war with the English, he took up engineering, producing plans for the defense of Quebec. Franquelin was asked to complete all types of tasks, and he defined his own work as follows: "to draw accurate lines and to divide this great land into provinces, to which will be assigned both boundaries and French names" (Franquelin 1694, 294).

Similar representations of the French West Indies found in small-scale geographical maps outlined claims against those of the English such as the *Carte de l'isle de Saint Christophe* (ca. 1650) by Abraham Peyrounin showing French positions at both extremities of the island and British positions in the center. Others were propaganda documents designed to encourage settlement, such as the *L'Isle de Cayenne* by Étienne Vouillemont (1667), praising the attractiveness of Cayenne and the other islands and describing their resources through the inset of illustrations around the map (for example, "Représentation des moulins à sucres desdites isles"). Vincenzo Coronelli's map of Marie-Galante (*Isola di Maria Galante nelle Antilli*, 1671), at a larger scale (ca. 1:60,000), details coastline, footpaths, land parcels, ponds, gullies, and noteworthy trees, suggesting that the Venetian geographer had access to cartographic sources not employed by other French mapmakers.

In the eighteenth century, parallel with serious administrative efforts in mapmaking, commercial geographers in Paris benefited from access to manuscript sources such as the "Carte des Antilles françoises," by the colonial engineer Jean-Baptiste-Pierre Le Romain (see fig. 21). Philippe Buache (*Carte de l'isle de la Martinique*, 1732), Gilles Robert de Vaugondy (*Isles de Saint-Domingue ou Hispaniola et de la Martinique*, 1750), and Jacques-Nicolas Bellin (*Carte réduite des isles de la Guadeloupe, Marie Galante et les Saintes*, 1759) produced maps attesting to increased development of the islands.

Geographical mapping of the French colonial world combined the on-site observation and measurement by engineers, officers, and self-taught geographers resident in

the colonies with the compilation effort of *géographes de cabinet* resident in France. The work of the colonial geographers tended to remain in manuscript and circulate only in a small circle unless it was sent to the capital, where the geographers of the metropole had access to the wider resources of commercial printing and distribution centers.

GILLES-ANTOINE LANGLOIS, WITH ADDITIONAL
INFORMATION ON THE FRENCH WEST INDIES
PROVIDED BY JEAN-LOUIS GLÉNISON

SEE ALSO: Franquelin, Jean Baptiste Louis; French West Indies; New France

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Geographical Mapping in the German States. There were few motives for geographical mapping in the German states during the Enlightenment. The Thirty Years' War (1618–48) had depopulated large parts of Germany and devastated its economy; the political settlement had fractured the Holy Roman Empire and led to the increasing independence of the many, mostly small *Reichsstände* (imperial estates). The rise to military and political power of Brandenburg-Prussia was not accompanied by much regional mapping because of concerns for secrecy. Yet there were two exceptions to the generally discour-

aging socioeconomic conditions: the continued commercial trade of maps, focused in some trading towns and southern Germany's free imperial cities; and the pursuit of mapmaking on mathematical and astronomical principles at some of the smaller universities and the academies that started to emerge in the eighteenth century.

Nuremberg had cultivated the arts and sciences since the Middle Ages as well as the art of copper engraving since its invention. Cartography had long been an element of its cultural life, from the terrestrial globe by Martin Behaim and the several cartographic projects by Albrecht Dürer to Philip Eckebrecht's world map (dated 1630) for the *Tabula Rudolphina* of Johannes Kepler during the Thirty Years' War; this last work stands as perhaps the first critical attempt at an overall improvement in the representation of the world (Meurer 2007, 1193–98, 1239–40). After the war, engraving flourished again in Nuremberg and soon map engraving as well. In the eighteenth century, Johann Baptist Homann's publishing house (founded in 1702) became a major map producer for central and northern Europe; after his death in 1724, the business continued as Homann Heirs until 1813 and then, under the name of the last owner, Christoph Fembo, until 1852, albeit with diminished significance. The Homann maps were in wide circulation at home and abroad because they were well made, attractive, and inexpensive. Through them the results of eighteenth-century explorations were quickly disseminated across central Europe.

Homann commissioned a number of original maps, mostly of German territories (fig. 296). Most of the Homann maps of foreign countries were largely based on French or Dutch maps; however, they were not simply copied, but critiqued and enhanced, drawing extensively on the work of scientists such as Johann Caspar Eisenschmidt, Johann Hübner, Eberhard David Hauber, August Gottlieb Boehme, Johann Michael Franz, Georg Moritz Lowitz, and Tobias Mayer. Franz (one of Homann Heirs), Lowitz, and Mayer briefly ran a cosmographical society in Nuremberg between 1746 and 1754 through which they sought to emulate the geographical and astronomical achievements of the Académie des sciences in Paris (Forbes 1980, 427–28); all three were later recruited to Göttingen University, where Lowitz offered the first cartographic course at a university on the drawing of maps in 1757.

Homann Heirs also published the *Atlas coelestis* (also known as *Atlas novus coelestis*) by Johann Gabriel Doppelmayr in 1742, which popularized the Copernican view of the world; in addition to several maps of the cosmos and heavens, this astronomical atlas included a world map with 142 sites with astronomically determined geographical coordinates (fig. 297). Doppelmayr was also one of the most successful globe producers of the eighteenth century. In the last decades of that century, the renowned cartographer Franz Ludwig Güsse-

feld of Weimar produced many maps for Johann Christoph Weigel, an offshoot of the Nuremberg publishing house Schneider and Weigel.

Another cartographically productive imperial city was Augsburg, called the *Bilderfabrik Europas* (picture factory of Europe) in the eighteenth century due to its many active engravers. Its engraving was not based on a rich cartographic tradition, as in Nuremberg, but instead blossomed with the advent of etching techniques (*Vedutenstich*). The most prominent map publisher was Matthäus Seutter; he founded his company in 1707, and it was kept up by his heirs, particularly Tobias Conrad Lotter, until the end of the century. Based on the quantity of maps and commercial success, Seutter was the second most important publisher in the German states, but the quality of his maps could not measure up to Homann's. The vast majority of maps were copies, many of Homann's maps, and were adorned with splendid baroque cartouches and ornamentations. Only about forty maps were original, primarily of the southern German territories.

The imperial city of Frankfurt with its fair was, until the seventeenth century, the center of the German book trade. Matthäus Merian the Elder had taken over the business of his father-in-law Johann Theodor de Bry there in 1623, which existed until 1734 under his heirs. Its major works were the *Theatrum Europæum* (21 vols., 1633–1738) and *Topographia Germaniae* (16 vols., 1641–54) with bird's-eye views and small-scale maps. Heinrich Ludwig Brönner founded his publishing house in 1727. Johann Wilhelm Abraham Jäger founded Jägersche Buchhandlung and from 1778 to 1789 dealt particularly with the manufacture and distribution of an eighty-one-sheet topographic map series of Germany, the *Grand Atlas d'Allemagne*, which for the first time featured quadrangle map sheets. The Saxon trade and fair city of Leipzig surpassed Frankfurt as the predominant book city in the seventeenth century. Johann George Schreiber founded an important cartographic publishing house there, and his heirs carried on the business until the nineteenth century. Its map production was mainly focused on Germany.

The Akademie der Wissenschaften, founded in 1700 in Berlin (as the Kurfürstliche-Brandenburgische Societät der Wissenschaften), proved of particular importance to geographical mapping in the German states. It had mapping privileges in Prussia but did not excel in this enterprise because King Friedrich II prevented the mapping of his kingdom to maintain military secrecy. However, Leonhard Euler published his school atlas there in 1753. The particular achievements of the academy related to the theoretical foundations of geography. Friedrich II had invited leading mathematicians to Berlin. Pierre Louis Moreau de Maupertuis visited Berlin in 1740, returned in 1745, and became the academy's president in

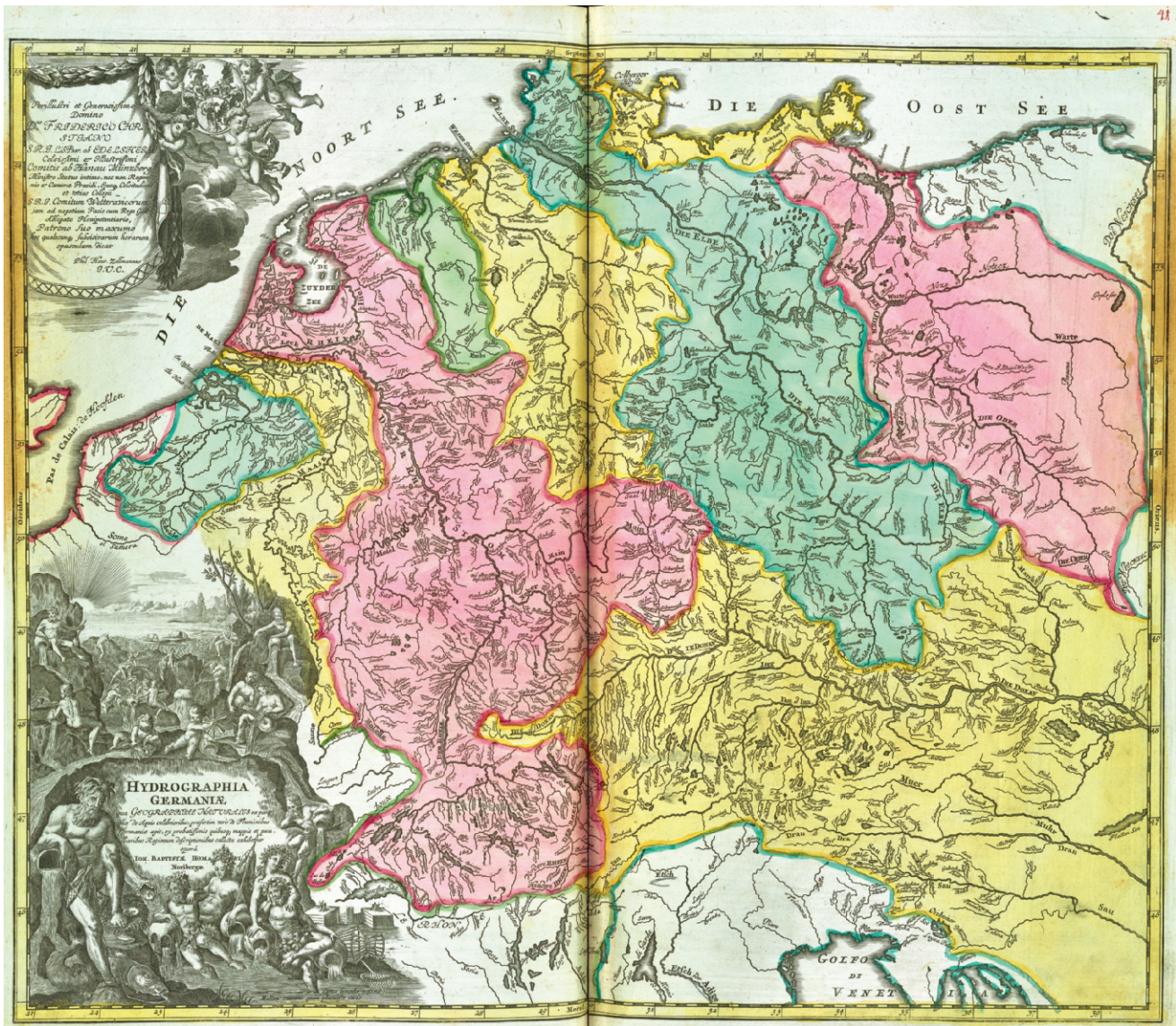


FIG. 296. PHILIPP HEINRICH ZOLLMANN, *HYDROGRAPHIA GERMANIÆ*, FIRST PUBLISHED BY 1712. From *Grosser Atlas* (Nuremberg: Johann Baptist Homann, 1716), map 41. The map celebrates the bounty and riches of the hydrographic network of the area of the German states

and beyond. It is colored according to the watersheds of the major rivers.

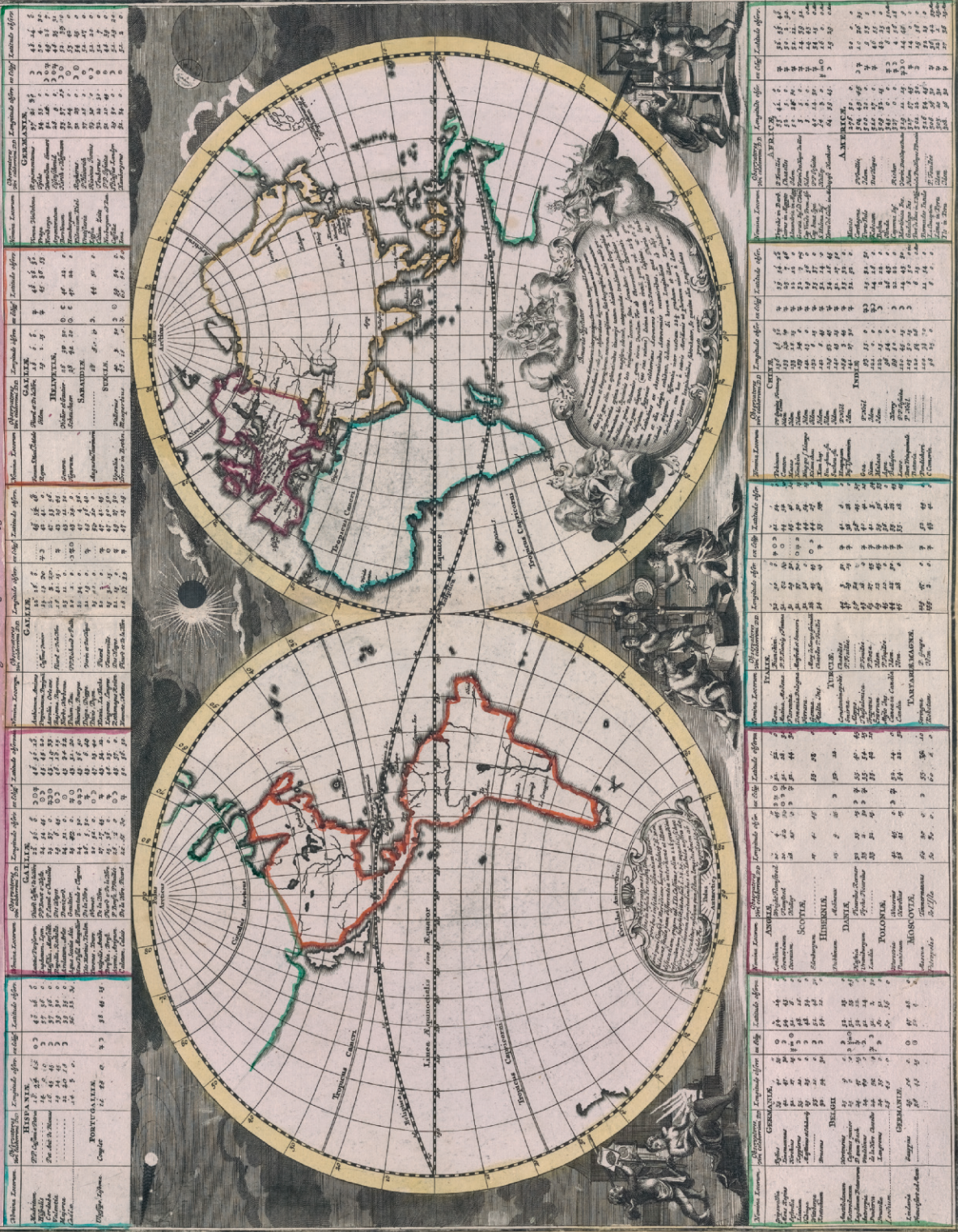
Image courtesy of the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland (SM-1716-2).

1746. Euler, who had also been in Berlin since 1741, led the academy after Maupertuis's death and through the Seven Years' War; disappointed on not receiving a formal appointment to the presidency, he returned to St. Petersburg in 1766. In 1764 mathematician and physicist Johann Heinrich Lambert joined the academy, and in 1766 mathematician and astronomer Joseph-Louis Lagrange arrived and remained in Berlin until the king's death in 1786. In their research, these scholars touched on questions about map projections and Lambert published his "Anmerkungen und Zusätze zur Entwerfung der Land- und Himmelscharten" in the third volume

of his *Beyträge zum Gebrauche der Mathematik und deren Anwendung* (1772). In 1783 the astronomer Johann Elert Bode prepared an oblique-aspect map of the world on the stereographic projection. The map was in two sheets with one hemisphere centered on Berlin (*Die obere oder nordliche Halbkugel der Erde*) and the other on Berlin's antipodes (*Die untere oder südliche Halbkugel der Erde*) (see fig. 639). After the death of Friedrich II in 1786, Prussian cartography was set free. The academy's cartographer, Daniel Friedrich Sotzmann, who lost his sight in the last decades of his life, designed excellent maps of Germany and other countries.

BASIS GEOGRAPHIAE RECENTIORIS ASTRONOMICA

in qua finis locorum indiguarum geographicis et exactitudine qua celeberrimi Astronomi eisdem per observationes planetarum luminarium et circumjovialium Eclipsis nobis haecenus suppliciarunt
pro certiori Geographiae stabilimento potius designantur
A. IOHANNES GABRIEL DOPPELMAYER MATH. PP. AUSTRIAE IOH. BAPT. HOKANYI S. C.M. GHOOR.
Civ. Pragensis (Pragae Bergensis) Vis. Cae. Aegyptiacae.



Regio	Caput	Latitudo	Longitudo
HISPANIA	Castellae	41 45'	3 00'
FRANCIA	Paris	48 28'	21 53'
ITALIA	Roma	41 54'	12 27'
GRAECIA	Athenae	37 58'	23 41'
ASIA	Constantinopolis	41 04'	28 55'
AMERICA	Medietas	39 54'	84 30'



Regio	Caput	Latitudo	Longitudo
GERMANIA	Frankfurt	50 05'	10 55'
BRITANNIA	Londra	51 30'	0 07'
DANIA	Copenhaga	55 42'	12 04'
SCOTIA	Edinburga	55 55'	0 07'
HOLLANDIA	Amstelredamum	52 12'	0 55'
RUSSIA	Mosca	55 45'	37 35'
AFRICA	Cairo	30 04'	31 05'
ASIA	Peking	39 55'	116 27'
AMERICA	Medietas	39 54'	84 30'

Changes in Germany triggered by the French Revolution and Napoleon's accession to power also affected geographical mapping. The Holy Roman Empire ceased to exist in 1806 and most imperial estates and cities lost their special status and the many privileges accorded to nobility. Vienna, Berlin, and the capitals of two remaining small duchies, Weimar and Gotha, became the centers of German cartography.

JOACHIM NEUMANN

SEE ALSO: Büsching, Anton Friedrich; German States; Homann Family; Mayer, Tobias; Seutter, Probst, and Lotter Families

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Geographical Mapping in Great Britain. Between 1650 and 1800, Great Britain developed from being a fledgling producer of geographical maps to being a leader in the genre in terms of quantity, diversity, and sophistication of production. Following the English Civil Wars (1642–51), English cartography was at its nadir. However, a series of mutually reinforcing developments following the Restoration of Charles II in 1660 laid the basis for the ascendancy of British cartography after 1750. First, Britain attained a degree of political stability and growing economic prosperity, fueled in part by its ever-expanding overseas empire and revenues generated from global trade and in part by agricultural and industrial reforms. Increasing prosperity, combined with growing literacy and public interest in global events, eventually resulted in the development of a large and sophisticated domestic map market, fostering the rise of a thriving and versatile commercial map-publishing industry. Another factor was the emergence of both private and public institutions that provided source material for printed maps but also acted as both commercial clients for maps and outlets for cartographic production in their own right. Eventually, geographical maps became integral elements of periodicals and travel books and ubiquitous aspects of popular visual culture in Britain.

(facing page)

FIG. 297. JOHANN GABRIEL DOPPELMAYR, *BASIS GEOGRAPHIÆ RECENTIORIS ASTRONOMICA*. From his *Atlas [novus] coelestis* (Nuremberg: Homann Heirs, 1742), pl. 15.

In the heady days of the Restoration, London's commercial mapsellers advanced grand proposals to create large atlases and folio-sized maps to rival those being produced in Amsterdam and Paris. Their ambitions were, however, restricted by high costs, a shortage of skilled labor (notably engravers), limited access to original cartographic sources, a lack of official, institutional, and private funding, and underdeveloped markets. John Seller, whose title of "Hydrographer in Ordinary" to Charles II did not come with any significant financial support, undertook a series of fine atlases mostly based on already-published Dutch sources, in particular the *Atlas terrestris* (1665), followed by the miniature *Atlas minimus* (1670). However, Seller's global sea atlas, *The English Pilot* (1671–1701), was only partially completed, as production costs drove him to financial ruin. Likewise, Moses Pitt's *The English Atlas* (1680–83), an attempt at a grand multivolume work in the Dutch baroque style, was never finished and landed Pitt in debtor's prison. Britain's still small economy meant that only a handful of the world atlases produced in this period turned a profit, and none of these were based on original cartographic sources. London mapsellers pursued several strategies to balance high cost and low demand: outright piracy; the use of subscriptions to raise capital; reissuing older works as if new; buying plates or already printed maps from Dutch publishers; and, after 1700, issuing atlases serially, map-by-map, to allow the nascent public to acquire large works over time. Despite these strategies, the roster of early mapmakers and mapsellers is littered with failure and bankruptcy (Tyacke 1978; Wallis 1978).

The primary geographical interest of the English public always lay in the constitution of England itself, such that the county atlas—generally showing each county on one small-scale sheet—became the staple product of the map trade. Mapsellers generally reprinted older county atlases, ultimately derived from the surveys by Christopher Saxton in the 1570s, although they occasionally employed local sources to add modest updates to their maps. In the early eighteenth century, agricultural reforms led to widespread interest in further improvements—from reclaiming marshes and wastes to building canals and turnpikes—all of which prompted the undertaking after 1700 of a series of commercial topographical surveys of England's counties that would revolutionize the geographical maps of England. The critical transitional work was Emanuel Bowen and Thomas Kitchin's *The Large English Atlas* (1749–60), which reduced many of the new county surveys to geographical scales (see fig. 475). By century's end, the county atlas

Image courtesy of the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland (SM-1742-3).



FIG. 298. JOHN CARY'S DEVONSHIRE, IN CARY'S NEW AND CORRECT ENGLISH ATLAS (LONDON, 1787). The map exemplifies late eighteenth-century small-scale English county maps. It shows Devon in high detail, including all settlements, roads (with mileages between points), forests, and major topographical features. It was based, albeit with some

updated modifications, on Benjamin Donn's award-winning large-scale survey, published in 1765.

Size of the original: 21 × 26 cm. Image courtesy of the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland (SM-1787-9).

had grown in order to accommodate the wealth of new information (fig. 298) (Skelton 1978; Hodson 1984–97; Delano-Smith and Kain 1999, 49–111; Fox 2010).

The growth of the overseas empire led to institutional and public demands for geographical maps. Indeed, maps played an important role in the public debates to define the emerging concept of the English and, later, British Empire (Harley 1997). For example, A *New Map of the Most Considerable Plantations of the English in America* by Edward Wells, in his successful *A New Sett of Maps both of Antient and Present Geography* (1700), provided a powerful and early notion of a coherent transcontinental English empire. Likewise, Herman Moll's *A Map of*

the East-Indies and the Adjacent Countries (1710) was an enthusiastic overview of the East India Company's activities in Asia. Britain's ascendancy as a global power led it to be involved in a series of wide-ranging conflicts, and to satisfy intense public interest, commercial publishers issued maps that featured the theaters of conflict. A fine example is Henry Overton's *A New & Correct Map of the Trading Part of the West Indies, Including the Seat of War between G^r. Britain and Spain* (1741), which was produced during the War of Jenkins' Ear (1739–48). Intense public interest in the period leading up to and during the Seven Years' War (1756–63) helped expand the large domestic map market, as ex-

citing new maps were sent from the regions of conflict back to London for publication, and the public devoured maps that advanced Britain's territorial claims, such as *A New and Accurate Map of the English Empire in North America* published under the auspices of the Society of Anti-Gallicans (1755) (Pedley 2007) (see fig. 179). By the end of the eighteenth century, British geographers and mapsellers supplied large atlases and maps about different parts of the globe to a flourishing domestic market stimulated by war and territorial growth. These works ranged from Robert Sayer and John Bennett's lavish *The West-India Atlas* (1775) and *The American Atlas* (1775), which both collected maps first published by Thomas Jefferys in the 1750s, to William Faden's sequence of maps of *The United States of North America with the British & Spanish Territories According to the Treaty of 1784* (1783 to 1796), to James Rennell's maps and atlases of India and Bengal in the 1780s (see fig. 588).

The information for these maps came originally from Dutch and French sources but were increasingly supplied by Britain's own imperial agents. The Board of Trade, the Crown committee that had oversight over the colonies in America and the West Indies, developed an important map collection under the guidance of its secretary, Wil-

liam Blathwayt, late in the seventeenth century. The committee eventually both commissioned and received new cartography, much of which was eventually disseminated to commercial printmakers (Edney 2008). The Royal Society (founded 1660), an organization of academic inquiry, issued a regular journal, the *Philosophical Transactions*, which included some important original geographical maps, such as Edmond Halley's world map employing a series of arrows traversing the oceans to depict the directions of the trade winds (1686), considered to be the first published meteorological map (see fig. 776).

Various colonial trading companies both produced and inspired important geographical cartography. The English East India Company, founded in 1600, was responsible for key maps of India and Southeast Asia. The Royal Africa Company, founded in 1660, produced many important maps of coastal West Africa, inspiring Samuel Thornton's *A Draught of the Coast of Africa from the Streights Mouth to Cape Bona Esprance* (1702–7), which employed flags to identify the forts belonging to the companies owned by various nations. Likewise, Overton's separately issued folio map of Africa (ca. 1730), dedicated to Queen Caroline, celebrates the Company's activities (fig. 299). Many maps of Canada



FIG. 299. HENRY OVERTON'S SEPARATELY ISSUED FOLIO MAP OF AFRICA. Dedicated to Queen Caroline, ca. 1730. The surrounding insets show local customs (left) and British establishments (right).

Size of the original: 57 × 99 cm. Image courtesy of Barry Lawrence Ruderman Antique Maps, La Jolla.

resulted from the voyages conducted for the Hudson's Bay Company (founded 1670), such as Jefferys's *A Map of Canada and the North Part of Louisiana with the Adjacent Countries* of 1760 (Winearls 1996).

More generally, the British public turned increasingly to geographical books to learn about the broader world. Their maps, whether bound into the books or as separate atlases, performed a major educational service throughout the eighteenth century (McCorkle 2009). As British explorers and adventurers played an increasingly consequential role in global discovery, the public's interest in their exploits led to the publication of many travel books and collected travel accounts illustrated with maps. Best-selling early examples were the pirate-writer William Dampier's *A New Voyage Round the World* (1697) and *A Voyage to New Holland* (1703); the latter contained the map *Capt. Dampiers New Voyage to New Holland &c. in 1699 &c.* Likewise, George Anson's *A Voyage round the World* (1748) featured many popular maps. Most significantly, the explorations of Captain James Cook produced many books containing maps based on new discoveries, notably *A General Chart: Exhibiting the Discoveries made by Capt. James Cook in His First, Second and Third Voyages* (1784).

The continued growth of Britain's economy and its military and colonial engagements thus drove a significant increase in geographical mapping through the eighteenth century. London's mapsellers produced large atlases, such as Bowen's *A Complete System of Geography* (1744–47), which contained maps of places such as the East Indies and Georgia (the colony in America); some, like Moll, devoted themselves solely to geographical publishing (Reinhartz 1997). Large world maps also became popular (Armitage and Baynton-Williams 2012), and geographical mapping was increasingly deployed to metaphorical effect (Reitinger 1999). Moreover, geographical maps proliferated in the monthly periodicals that flourished after 1730, especially the *Gentleman's Magazine* (founded 1731), *London Magazine* (1732), *Universal Magazine* (1747), and *Scots Magazine* (1739) (Jolly 1990–91). These publications were cheap, readily available, and did much to democratize cartography for the middling and even laboring classes. The largest single category of maps in these magazines were of the English counties, but they included many maps of other parts of the world (fig. 300).

The growth in consumption of geographical maps was paralleled through the eighteenth century by a growing technical appreciation of the processes of geographical mapping. It was, however, an appreciation tinged with nationalism, as British authors increasingly sought to compete with the great geographers of France, notably Guillaume Delisle and Jean-Baptiste Bourguignon d'Anville. The Irish-born John Green set the tone with his *The Construction of Maps and Globes* (1717); in his

appendix he advocated for the reform of British geography by treating geographical maps with the same critical care as systematic texts in which authors carefully evaluate and sift their source materials. From the 1730s, British geographers increasingly took care to identify their sources. Most geographers with any pretension to be "scientific" displayed their sources on their maps, but a few prepared pamphlets about their sources. John Cowley, for example, accompanied his several maps of Scotland, including one comparing six different coastal outlines (see fig. 11), with a pamphlet, *An Explanation of Four Several Maps Just Published* (1734); other examples include Green, who prepared *Remarks in Support of the New Chart of North and South America in Six Sheets* (1753) and an *Explanation for the New Map of Nova Scotia and Cape Britain* (1755), Rennell, who prepared *Memoir of a Map of Hindoostan* explaining his two- and four-sheet maps of India (1783 and 1788), and Aaron Arrowsmith, who wrote *A Companion to a Map of the World* (1794) and *Memoir Relative to the Construction of the Map of Scotland* (1809).

ALEXANDER JAMES COOK JOHNSON

SEE ALSO: Great Britain; Green, John; Jefferys, Thomas; Sibbald, Robert

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FIG. 300. THOMAS KITCHIN, A NEW AND ACCURATE MAP OF BENGAL DRAWN FROM THE BEST AUTHORITIES (LONDON, 1760). A good example of the maps that appeared in popular periodicals in Britain from the 1730s onward. In this case, it informed the British public about the ex-

tent of the new territories acquired by the East India Company. From the *London Magazine* 29 (February 1760), opp. 64. Size of the original: 18.3 × 25.4 cm. Image courtesy of the Department of Special Collections, Memorial Library, University of Wisconsin–Madison.

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Geographical Mapping in British America. The explorers and settlers who first arrived in British America faced the challenge of recording the locations of waterways, topographical features, coasts, and settlements. As land

changed ownership and frontiers shifted, the task of mapping property and boundaries expanded. Conflict led to additional mapping. Maps such as those made of the upper Ohio Valley by George Washington and Christopher Gist at the outset of the French and Indian War (1754–63) provided essential strategic intelligence (Brown 1959, 90–91, 101–2). Measuring and delineating lands, whether for military or civil purposes, typically resulted in manuscript plans. For political or commercial reasons, some surveys were engraved and printed and thereby found a larger audience. Many of those transformed into print can be classified as medium-scale maps that depict transcolonial regions such as coasts and waterways or individual colonies and urban areas.

Regardless of their content, the vast majority of published maps of eighteenth-century British America were engraved and printed in London or elsewhere in Europe.

In contrast to European efforts, American mapmakers generated relatively few printed maps. Early in the century, many colonial American cities supported printing presses, but the capacity to produce engravings lagged far behind the ability to print. While a handful of American artisans generated currency, bookplates, portraits, and the like, cartographic engraving formed an insignificant portion of their work. William Hubbard's map of New England, printed as a woodcut by John Foster of Boston in 1677, marks the beginning of published cartography in British America (Edney and Cimburek 2004). The engraving and printing of a copperplate map did not occur until 1717 when Cyprian Southack, a Boston merchant and ship pilot, issued a map of eastern North America (see fig. 129).

In addition to a dearth of engravers, the high cost of local labor and imported paper made map publishing a financially risky enterprise that relatively few American mapmakers attempted (Bosse 2007, 5–6). Those who

did had their works published in a number of ways. Virginians Joshua Fry and Peter Jefferson created a map at the request of a British colonial official, and its publication as *A Map of the Most Inhabited Part of Virginia* (ca. 1753) occurred through no direct involvement of their own (Cumming 1998, 266–69). Some mapmakers, such as John Henry of Virginia, put their manuscript into the hands of an English cartographic publisher after securing funds to pay for engraving and printing. Henry, who drew on his own surveys and those of others, contracted with Thomas Jefferys of London to engrave and print *A New and Accurate Map of Virginia* in 1770.

American mapmakers also made arrangements with local engraver-printers to produce their works, often financing publication by subscription. *A Plan of the City of New York* (1731) by James Lyne, *A Prospective Plan of the Battle Fought near Lake George* (1755) by Samuel Blodget, and the map of West and East Florida (1774) by Bernard Romans (fig. 301) resulted from such col-

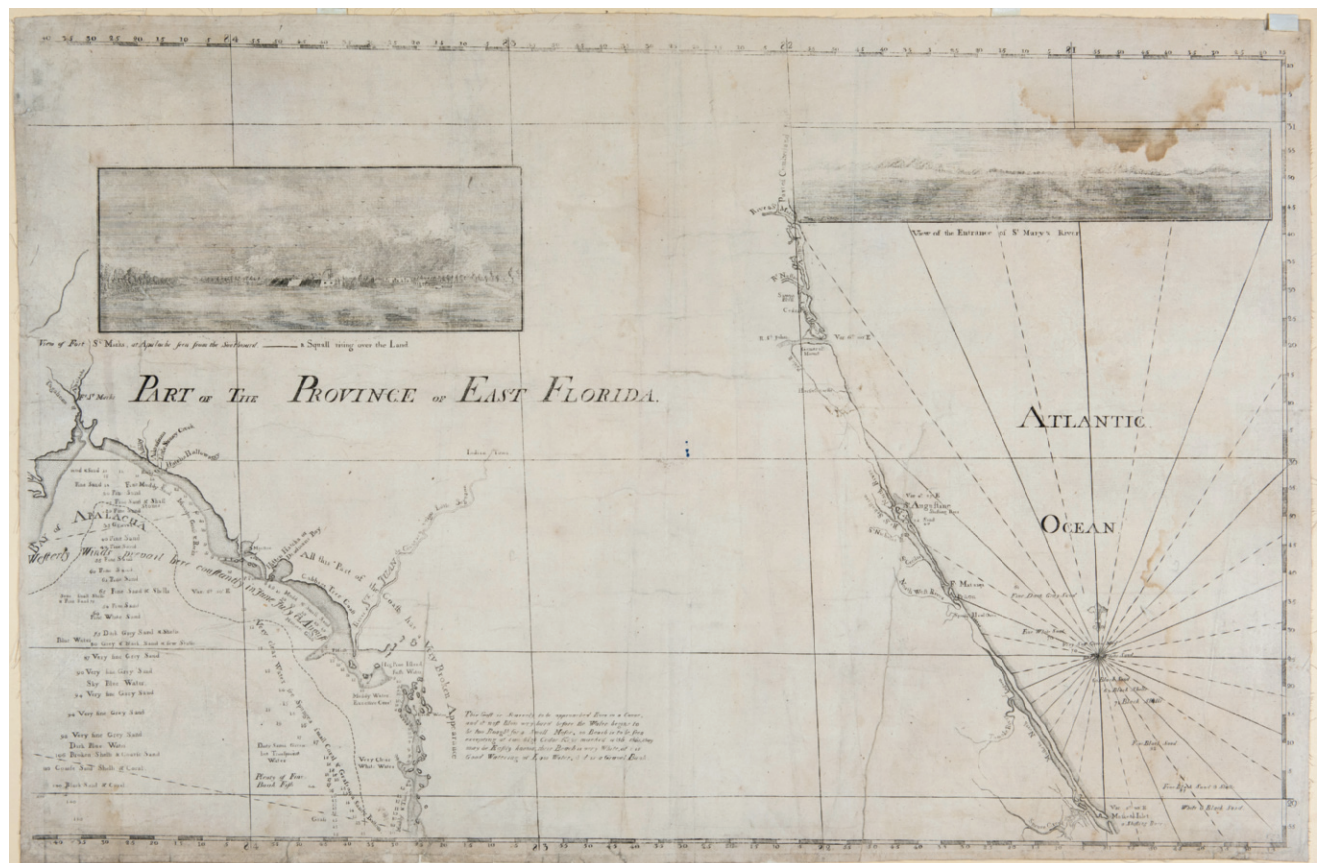


FIG. 301. EASTERN SHEET OF BERNARD ROMANS'S MAP OF EAST AND WEST FLORIDA, 1774. A map on three sheets, ca. 1:490,000, showing the coastal outline, with soundings, compass variation, and extensive notes about the sea bottom. A Dutch-born surveyor trained as an engineer, Romans worked for William Gerard De Brahm as a draftsman and mathematician in the Southern District of British America. He

surveyed East and West Florida independently for various employers. Romans compiled his survey work with data collected by others and published the flora and fauna of the region in his *A Concise Natural History of East and West Florida* (1775). Size of the sheet: 55.5 × 86.0 cm. Image courtesy of the William L. Clements Library, University of Michigan, Ann Arbor (Maps 5-J-1774 Ro).

laborations. In some cases the mapmaker, engraver, and printer were one and the same person, Thomas Johnston of Boston being a prime example. These enterprising but poorly capitalized Americans produced maps that addressed needs not met by available British or European commercial mapping: charts of waterways, city plans, and cartographic records of events, usually of a military nature.

Geographical mapmakers in British America came from no single milieu in terms of their social or educational backgrounds. Whether physicians, soldiers, traders, or adventurers, they were all drawn by the opportunity to compile new medium- and small-scale maps to describe and communicate images of newly visited lands and expanding landscapes. A few of these geographers adhered to the developing expectations for critical mapping by preparing written accounts of their cartographic and literary sources and of the compilation process. While most such accounts remained in manuscript, or were expressed on the maps themselves, some were published as cartographic memoirs, as for example Lewis Evans's *An Analysis of a General Map of the Middle British Colonies in America* (1755) (see fig. 235) and Thomas Hutchins's *A Topographical Description of Virginia, Pennsylvania, Maryland, and North Carolina* (1778) accompanying his large map of the frontier (fig. 302). In his *Summary, Historical and Political, . . . of the British Settlements in North-America* (1747–52), William Douglass also provided an example of cartographic criticism in his assessment of the qualities of earlier outmoded maps (Edney 2003, 167–68). Ezra Stiles at Yale College created manuscript maps as memory devices, as illustrations of his political thought, and as images to support his historical research (fig. 303). All these authors reflected the desire for more support for mapping on the ground; indeed, Hutchins was himself a military engineer and surveyor who was appointed first geographer of the United States by Congress in 1781.

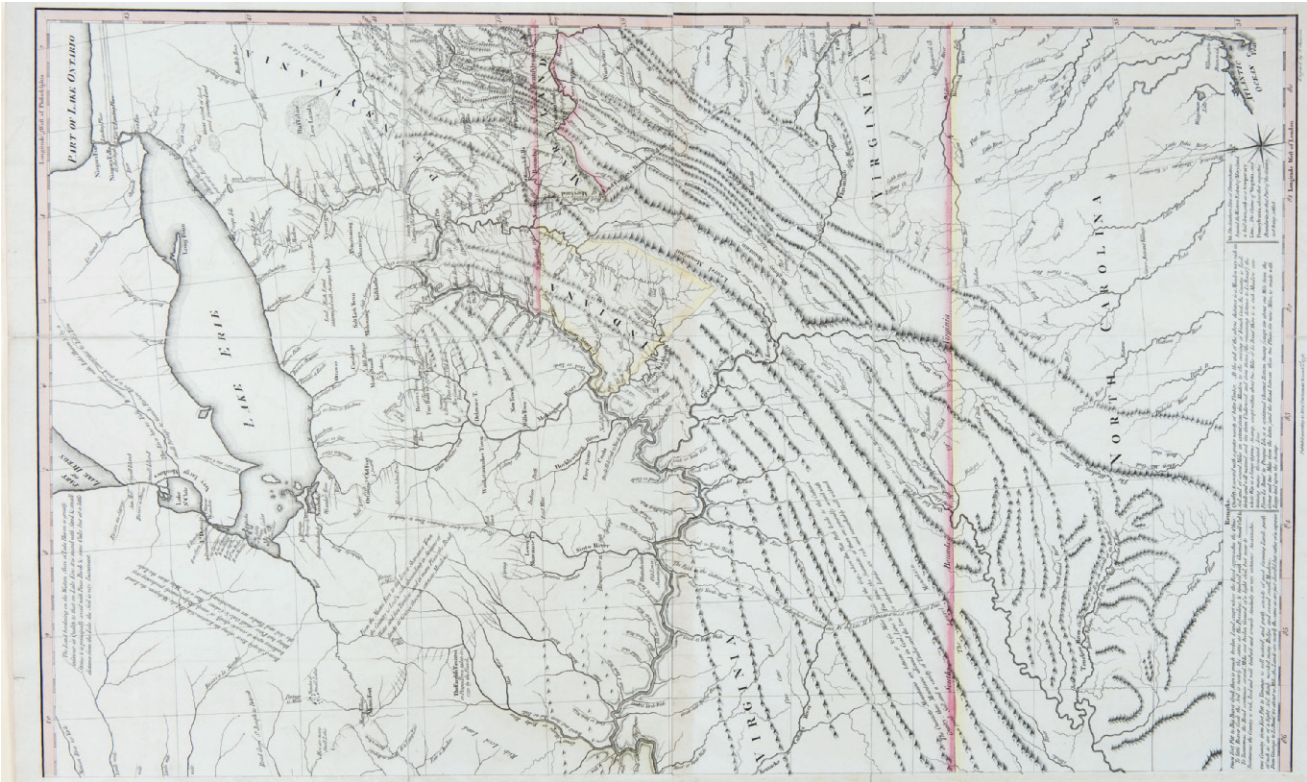
Yet because of their expense, systematic surveys rarely formed the basis of American-made maps. Few colonial legislatures financially supported surveys such as those that resulted in the plan of Connecticut probably printed in New London, Connecticut, in ca. 1766 (fig. 304) (Harlow 1963). Most American mapmakers drew on a variety of sources, including personal observation, local surveys, astronomical measurements, written and oral reports, and other printed maps. John Bonner's *The Town of Boston in New England* (1722) (see fig. 906), for example, was based on his knowledge of the town and sketches of fellow Bostonians. Bonner, a ship captain, made the first plan of a city printed in British America, filling it with pictorial renderings of buildings, wharves, etc. When Evans accompanied a diplomatic mission to the vicinity of Lake Ontario in New York, he mapped the route and collected topographi-

cal information that would appear in his first published map, *A Map of Pensilvania, New-Jersey, New-York, and the Three Delaware Counties* (1749). Evans's original surveys make the map particularly noteworthy, but he also incorporated manuscript and published sources into his work. Philadelphia merchant Joshua Fisher spent twenty years gathering information from mariners and local residents for his *Chart of Delaware Bay from the Sea-Coast to Reedy-Island* (1756) (Bedini 1975, 146–48) (see fig. 480). English cartographic publishers quickly duplicated Fisher's chart and issued it for more than twenty years.

Like their European contemporaries, some American map publishers simply copied British or other printed sources. Advertisements for Johnston's *A Chart of Canada River* (1746), and *A General Chart of all the Coast of the Province of Louisiana* (1763), engraved by Henry Dawkins and issued by merchant and publisher Matthew Clarkson, state that they replicated unnamed captured French charts. Later in the century, derivative maps became far more common. In 1790, Matthew Clark of Boston published a set of nautical charts that mimicked, albeit rather unsuccessfully, selected charts in *The Atlantic Neptune* (1774–82). Far more prolific was fellow Boston engraver-publisher John Norman, whose numerous charts and atlases printed in the 1790s and early nineteenth century slavishly copied British publications.

Prior to the American Revolution (1775–83), maps and charts published in British America exhibited certain parochial characteristics. The earliest printed maps issued from presses in Boston and New York (with the exception of Southack's inaccurate map of North America) reflected local or regional interests. Colonial wars between France and England broadened the geographic scope of those interests when New England militia fought in Canadian campaigns. By the 1750s, Philadelphia had emerged as a center of cartographic publishing. Along with generating maps of the city, nearby waterways, and the colony of Pennsylvania, Philadelphia mapmakers looked west. The geopolitical and economic importance of the Ohio Valley to Pennsylvania and contiguous colonies is reflected in Evans's landmark map, *A General Map of the Middle British Colonies, in America* (1755) (see fig. 235). But to the south of Philadelphia, cartographic publishing was virtually nonexistent. Consequently, few printed maps of the region or its constituent parts appeared until the end of the eighteenth century.

Maps and other cartographic works issued in London and continental European publishing centers could readily be purchased by eighteenth-century American consumers and long remained in circulation in the absence of a comparable American product. The pervasiveness of European-made maps seemingly constrained commercial mapmaking in British America until the period following the American Revolution. In examining

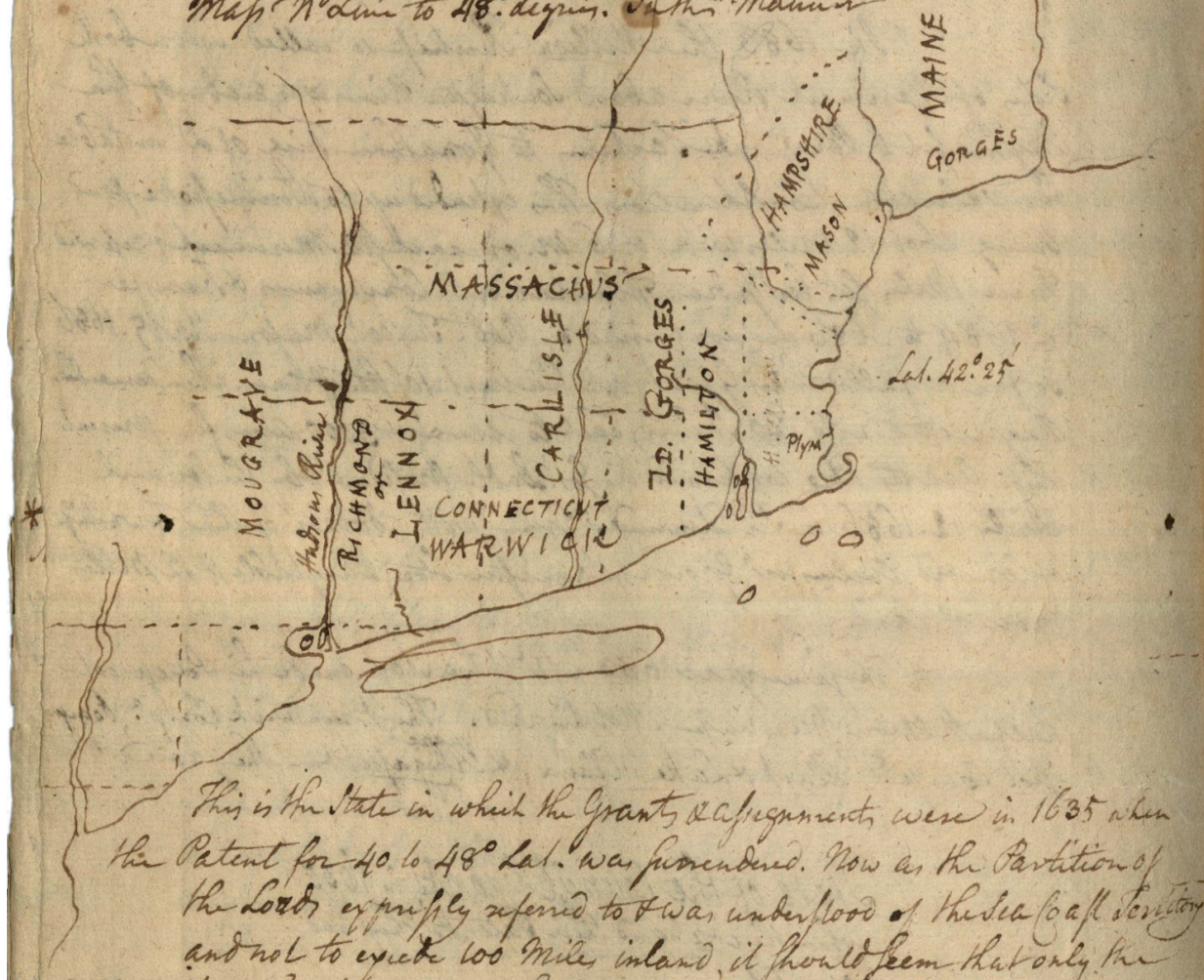


A
VERMAP
 of the Western Part of
 VIRGINIA, PENNSYLVANIA,
 MARYLAND and NORTH CAROLINA;
 Comprehending the GREAT APPALACHIAN MOUNTAINS
 and the CATAWHA, ROANOKE, and other Rivers;
 and the LAKES OF ST. CECILIA, HURON,
 and MICHIGAN;
 and the COUNTRY between the
 LAKES and RIVERS;
 By *Wm. H. Phillips*
 Surveyor-General of the State of Virginia.

This map was compiled from the original surveys of the State of Virginia, and from the best authorities. It is intended to show the general configuration of the country, and the location of the principal towns and cities. The names of the mountains, rivers, and lakes are given in their original form, and the names of the towns and cities are given in their present form. The map is intended to be used as a general reference, and not as a guide to the actual location of the towns and cities.

This map was compiled from the original surveys of the State of Virginia, and from the best authorities. It is intended to show the general configuration of the country, and the location of the principal towns and cities. The names of the mountains, rivers, and lakes are given in their original form, and the names of the towns and cities are given in their present form. The map is intended to be used as a general reference, and not as a guide to the actual location of the towns and cities.

These I think were all the Grants till the Surrender of the patent of the Council of Plymouth to the Crown in 1635, when the Partition of the Sea Coast among the Lords was made; all of which had been assigned by prior Grants except the Province of Maine to Sir Ferd. Gorges & Mason 60 Miles; unless the northern portions of the partitions extending above Map? N^o 41^o to 48^o degrees. In this manner



This is the State in which the Grants & Assignments were in 1635 when the Patent for 40. to 48^o Lat. was surrendered. Now as the Partition of the Lords expressly referred to was understood of the Sea Coast Territory and not to extend 100 Miles inland, it should seem that only the

FIG. 303. EZRA STILES, MANUSCRIPT MAP OF THE HISTORY OF NEW ENGLAND'S GRANTS. In his unpublished "Rights of the Crown of Great Britain to Lands in America & the Assignments Thereof," 1762, 12. Stiles drew maps frequently to visualize his political and historical writings, to

memorialize current events, and to keep track of his property investments. Image courtesy of the Beinecke Rare Book and Manuscript Library, Yale University, New Haven (Ezra Stiles Papers, Miscellaneous papers and volumes series, #291).

(facing page)
FIG. 302. THOMAS HUTCHINS, A NEW MAP OF THE WESTERN PARTS OF VIRGINIA, PENNSYLVANIA, MARYLAND AND NORTH CAROLINA (LONDON, 1778). On two sheets. This map was one of the first by the British to show the frontier lands west of the Appalachians in any detail.

Size of each sheet: 93.7 x 57.0 cm. Image courtesy of the William L. Clements Library, University of Michigan, Ann Arbor (Maps 1-K-1778 Hu).

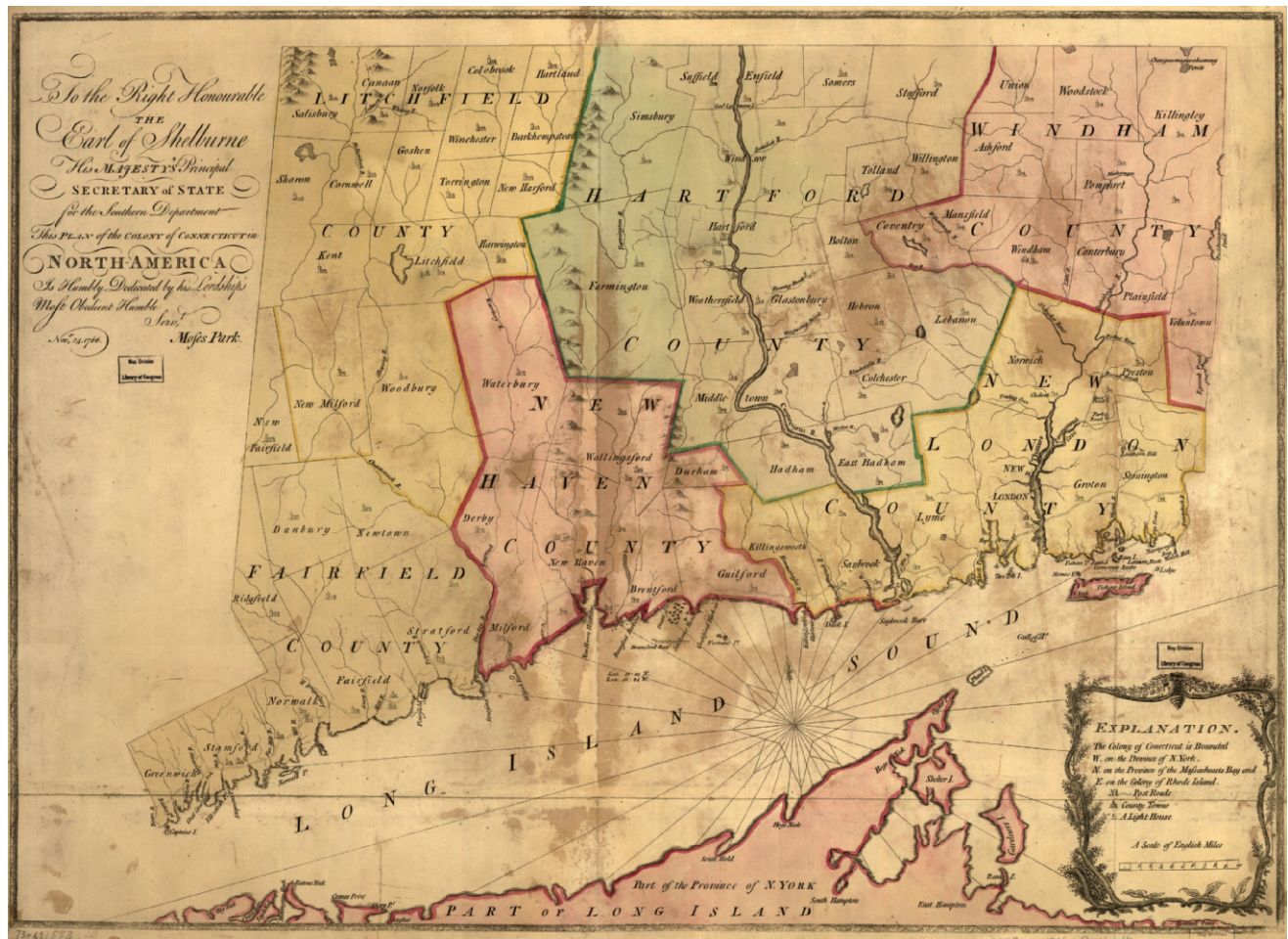


FIG. 304. MOSES PARK, PLAN OF THE COLONY OF CONNECTICUT IN NORTH-AMERICA, CA. 1766. One of the few maps whose basic survey was supported financially by a colonial legislature. Park was authorized by the colonial government to survey the lines on private land and was as-

sisted by Asa Spaulding and Samuel Mott. The map's engraver and printer are unknown, ca. 1:275,000.

Size of the original: 54 × 74 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C. (G3780 1766.P3).

the output of American map publishers, it becomes evident that they selectively competed with European cartography. In the post-1783 era of nationalism, American mapmakers appealed to the prevailing patriotic sentiment toward local manufactures by issuing maps of the new republic and individual American states. These works found a receptive market, of which newly established cartographic publishers such as Mathew Carey and John Melish took advantage, to the detriment of British and other European mapmakers.

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SEE ALSO: British America; Evans, Lewis

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Harlow, Thompson R. 1963. "The Moses Park Map, 1766." *Connecticut Historical Society Bulletin* 28:33–37.

Geographical Mapping in the Italian States. Throughout the seventeenth and eighteenth centuries, geographical mapping of Italy remained largely restricted to printed images, generally included in large atlases such as Giovanni Antonio Magini's, published in Italy or by printers elsewhere in Europe (initially Flemish and Dutch and subsequently French). Magini's map of Italy (1609) was followed by his atlas of regional maps, *Italia*, published posthumously in 1620 (Sereni 2007, 843; Woodward 2007, 791–92); thereafter, Italian cartographers did not construct any more innovative depictions of the peninsula. Only in the early decades of the eighteenth century were astronomical observations and geodetic measurements made by French and Italian scientists used to update existing cartography. Surprisingly, this task did not fall to the most prolific Italian cartographer of the day, the Venetian Vincenzo Coronelli, nor to Giacomo Cantelli da Vignola (*L'Italia con le sue poste e strade principali*, 1695). Rather, French geographers used the scant documentary sources and newly available geodetic and astronomic data to construct images that achieved a level of accuracy immediately hailed as innovative. In 1720 Guillaume Delisle produced *L'Italie dressée sur les observations de M^{rs}: de l'Académie royale des sciences*. Then Jean-Baptiste Bourguignon d'Anville produced an even more influential work: *L'Italie publiée sous les auspices de Monseigneur le duc d'Orleans premier prince du Sang* (1743), which established the model for the remaining century (see fig. 64). More precise in measurement and content with increasingly accurate depiction of borders and other topographical features, these French images of the peninsula and its regions enjoyed great commercial success. Even in Italy, enterprising printers and booksellers in Venice and Bassano, such as Paolo Santini and Francesco Santini, Antonio Zatta, and the Remondini family, published editions of these maps.

The slow development of small-scale cartography in Italy may be easily explained: prior to unification, the various individual states made no public investment in commissioning a comprehensive geographical image of the peninsula based on geodetic surveying and celestial observations. In fact, there were hardly any astronomical observatories that could be put to such use; the observatory in Pisa was founded in 1739, followed by establishments in Florence (1750 and 1775), Milan (1760–64), and Padua (ca. 1777). In each case it took years for the observatory to become fully operational. Thus cartographers compiling medium- to small-scale maps faced insurmountable difficulties. Practices in the seventeenth century had changed little from the sixteenth: “the cartographer was fortunate, of course, if he could get access to more refined and detailed information, to restricted government documents such as those that [at the end of

the sixteenth or beginning of the seventeenth century] the dukes of Mantua probably made available to Italy's greatest cartographer, Giovanni Antonio Magini, when he was working on his atlas of Italy.” Furthermore, such “state maps—intended for military or political/administrative use—were primarily geographical in nature and had been compiled from partial surveys carried out without the systematic application of criteria. This meant that any attempt to combine them to form a small-scale cartographic image of more extensive areas of territory ran the risk of falling into substantial approximations” (Mangani 2001, 364–65). In effect, the numerous cartographic depictions of the regions of Italy that appeared in the map collections printed in Italy and abroad during the course of the seventeenth and eighteenth centuries continued to rely on works produced in the sixteenth century or slightly later, explaining their mediocre achievement in topographical detail and metric accuracy.

To the middle of the eighteenth century, in all the small states of preunification Italy, “even the most expert and skilled cartographers [produced] an account of geographical reality in which there are clear, macroscopic geometrical distortions that are the result of the ad hoc methods adopted when taking on-site surveys of terrain; surveys of the countryside were based on direct or reported observations that, however careful or painstaking, totally failed to meet the necessary methodological criteria” (Arca 2004, 103). Only at the height of the Enlightenment would these criteria be applied with the necessary mathematical rigor.

Defects and distortions are clear even in those regional cartographic products considered the best of their day, such as the *Carta generale de stati di sua altezza reale*, commissioned in the early 1670s by Carlo Emanuele II of Savoy, which provided an exceptional account of Savoyard Piedmont for the seventeenth century. Constructed by the military engineer Giovanni Tommaso Borgonio, engraved by Giovanni Maria Belgrano, and published in Amsterdam in 1680 by the heirs of the printer Joan Blaeu, it is sometimes referred to as the “Carta di Madama Reale” because it was published at the behest of the duke's widow, Maria Giovanna Battista (Sereni 2007, 851–52) (see fig. 108). Significantly, the original manuscript is preserved in the classified portion of the state archive of Savoy (Turin, Archivio di Stato, Carte topografiche segrete, 18 A III rosso). Drawing on many large-scale official cartographic images available within the state administration, the map was also the fruit of actual on-site surveying carried out from 1675 onward using compass and *traguardo* (sighting vane), though not from the application of trigonometric measuring techniques. The scale (ca. 1:192,000) is large enough to allow substantial topographical detail, while

the mountains are rendered in perspective view with lateral shading.

While Borgonio's map was immediately adopted as an instrument of state administration, it also expressed the prestige of the ruling dynasty. It was reengraved as late as 1772 by Giacomo Stagnone and published, with some necessary updates, under the title *Carta corografica degli Stati di S. M. il Re di Sardegna data in luce dall'ingegnere Borgonio in 1683 [sic] corretta ed accresciuta nell'anno 1772* (Sereno 2007, 852, fig 33.11). This revised version, recognized as the best available account of the chorography of Piedmont, functioned as an instrument of political administration throughout the revolutionary and Napoleonic periods until the first years of the Restoration; it played a role in the large *Carte générale du théâtre de la guerre en Italie* prepared by Louis Albert Guislain Bacler d'Albe in two parts, 1798–1802 (Pelletier 2001, 89, 114; Massabò Ricci and Carassi 1987, 277n15).

Two other contemporary regional geographies also reflect Borgonio's work in certain ways, being based on the original (though partial) on-site surveying and using strikingly modern systems of representation. Produced by José Chafrión, a Catalan military engineer employed by the Milanese government, these maps were published in Milan as *Mappa geografica esattissima delle Provincie del Tortonese, Pauese, Alessandrino* (ca. 1680) and *Carta de la Rivera de Genova con sus verdaderos confines y caminos* (1685) (Quaini 2007, 859–65, fig. 34.7). Compared to contemporary cartographic depictions, the maps display a greater degree of accuracy and unusually modern techniques for rendering topographical features, such as the quasi-realistic depiction of the orography (Barozzi 1981; Quaini 2007, 863–64).

It could be argued that until the second half of the eighteenth century, Borgonio and Chafrión were the only mapmakers who gave a sufficiently detailed account of the areas they mapped (Piedmont and Liguria respectively), doing some justice to the complex array of numerous river basins and valleys of both regions. "Due to the stimulus to further knowledge exerted by the needs of war, the language of cartography was becoming not only more precise but also was adopting more complex symbolism: each inhabited center is classified according to size and military role; the navigability and fords of each watercourse are identified; woodlands as well as 'main roads' are indicated" (Quaini 1994b, unpaginated [4]).

The *Stati del serenissimo signor duca di Modena in Italia* (1746, ca. 1:200,000), prepared by Domenico Vandelli and engraved by Andrea Bolzoni, "both in terms of completeness of information and technical skill, [is] the best and most detailed account of the Este duchy . . . produced since Marco Antonio Pasi's manuscript map

of 1571" (Federzoni 2006, 186). The *Corso del Po per la Lombardia* (1703), prepared by Agostino Cerruti, a sergeant major in the papal guard, has been described as "the first modern chorographical map of the Po valley identified as both a geographical and human entity, . . . [a river] navigable from Piedmont to the sea, it constitutes the axis of political and economic life" (Milanesi 1990, 102).

Southern Italy was described in the less innovative *Carte de' Regni di Napoli e di Sicilia* (1692), an atlas by Antonio Bulifon (republished by his grandson, Luigi, in 1734). The atlas included a general map, *Accuratissima e nuova delineazione del Regno di Napoli*, and various regional maps prepared and engraved by the Milan-born Francesco Cassiano de Silva (Valerio 1993, 67–71, 73n2). Agatino Daidone printed a map of Sicily in 1714–18 based on some partial on-site measurements and original data; Antonio Bova drew upon Daidone's map for his own, published in Palermo in 1745, which included clear improvements and an inset map of the city of Palermo. In Bova's work "there is a detailed and full depiction of the hydrographical networks [while] the account of the orography is rather imprecise, being rendered with groups of hills that do not reflect the real distribution of the mountains. . . . However, the characteristics of the coastline are well rendered, with the mouths of rivers, peninsulas, and islands off the coast, though with just a simple indication of archipelagoes. Great care and attention are paid to the depiction of inhabited centers" (Ioli Gigante 2001, 275–77, quote on 276).

The manuscript depiction of Sicily produced initially at a scale of 1:40,000 by the Austrian baron Samuel von Schmettau, military engineer, has attracted some close study (Dufour 1995, 1999). Schmettau was sent by Prince Eugene of Savoy as quartermaster general to Sicily when the Habsburgs replaced the House of Savoy as rulers of the island. There from 1719 to 1720 he led a group of six topographical engineers to survey the island at a scale of ca. 1:40,000, using triangulation techniques and astronomical observations to establish latitudes of particular places (Dufour 1995, 25–29). Upon returning to Vienna in 1721, Schmettau supervised Lieutenant Michel (Miguel) Angelo de Blasco in the reduction of the original survey drawings to a large manuscript map, ca. 1:80,000, titled "Nova et accurata Siciliae. Regionum, Urbium, Castellorum, Pagorum, Montium, Sylvarum, Planitierum, Viarum, Sittuum . . . Descriptio universalis," in two copies. One copy was prepared on twenty-eight sheets for the emperor (Vienna, Österreichische Nationalbibliothek, a.B.141, reproduced in Dufour 1995) and the other on thirty sheets for the council of war (Vienna, Kriegsarchiv) (Valerio 1993, 316–18; 2014, 68–70; Valerio and Spagnolo 2014, 2:409–13,

no. 201). Clearly reflecting its military origins but also displaying economic interests, the map shows fortresses, coastal landing points and anchorages, the entire network of roads and inhabited settlements, and strategic woodlands (Ioli Gigante 1999, 20–22; Dufour 1995, 30–43; 1999, 83–85, pl. on 123–28, 131–36). Shortly after its preparation in 1722, the large manuscript map was reduced to ca. 1:312,000 and printed on two large sheets (fig. 305). It displayed the iconography of conquest with the inclusion of images of the fleet of the Austrian alliance, whose attacks seized the island from Spanish control. The plates were reprinted without the battle scenes around 1735; a later version, with additions, was printed on four sheets by Gian Giuseppe Orcei in about 1778 as *Descrizione geografica del Regno di Sicilia e sue isole adiacenti* (Valerio and Spagnolo 2014, 2:435–37, no. 219; 2:483–85, no. 250).

“The eighteenth century marked a clear turning point in the history of Italian cartography, with a move from pregeodetic to geodetic cartography. This shift resulted in a radical change not only in the operative procedures employed in drawing up a map, but also in the theoretical bases for the science of cartography itself.” During the second half of the Enlightenment, “Italy would see the rapid establishment of cartographic procedures based upon application of geometrical frameworks for high-precision surveying. This marked the triumph of the procedure of triangulation, which henceforward would become the principal method for the geometrization of territory within Italy” (Arca 2004, 103).

Aside from Schmettau’s survey in Sicily, the first examples of geodetic cartography are the printed map of the Papal States (*Nuova carta geografica dello Stato Ecclesiastico*, 1755) by the Jesuit Christopher Maire, based on the survey and observations by Maire and Ruggiero Giuseppe Boscovich (see fig. 90), and the body of cartographic depictions drawn up and printed by the Padua scientist Giovanni Antonio Rizzi Zannoni from ca. 1770 onward. Working on his own, Maire also prepared the detailed map of the Legazione di Urbino (1757), a treatment noteworthy for its accurate delineation of internal and external boundaries and its detailed depiction of the road network (Mangani and Mariano 1998, 194–95).

During his long career, Rizzi Zannoni produced many important medium- to small-scale geographical works. The five-sheet *Carta geografica della Sicilia prima o sia Regno di Napoli* (finished by Rizzi Zannoni in 1769, ca. 1:400,000) was a project resolutely promoted by Ferdinando Galiani, an influential figure in the Neapolitan Enlightenment. Compiling a wide range of published and manuscript material, Rizzi Zannoni drew the map in Paris. Engraving began in 1767 and final publication brought great success, due not only to its elegance, leg-

ibility, and convenient multisheet format, but also to its wealth of information and relative precision. Twenty-five years after d’Anville’s *Italie*, “the cartography of southern Italy now took a decisive step forward. It would not have been possible to do better without undertaking direct measurements on the ground” (Valerio 1993, 78–98, quote on 97).

Rizzi Zannoni’s second achievement comprised *La gran carta del Padovano* (see fig. 422) and its companion, the precise *Pianta della città di Padova* (see fig. 908), both prepared between 1778 and 1781. Though the large-scale *Gran carta* (ca. 1:20,000) remained unfinished (in 1780–81, only four of the envisaged twelve sheets were published in Padua, engraved by Antonio Buttafoco [Buttafogo] and Giovanni Valerio Pasquali), it nevertheless exemplifies “truly modern topographical surveying” and must be considered “the first example in Italy of a large-scale topographical operation based on trigonometric procedures” (Valerio 1993, 112–16, quote on 116).

In April 1781 Rizzi Zannoni moved to Naples in the service of the Bourbon monarch Ferdinand IV. There, with the help of a few assistants (including Antonio Moretti and Giovanni Ottone di Berger), he began the demanding project of mapping the entire kingdom at a scale of 1:114,545. The most impressive cartographic undertaking in eighteenth-century Italy, the *Atlante geografico del Regno di Napoli*, necessarily involved astronomical observations and trigonometric measurements. Between 1781 and 1786, Rizzi Zannoni set up an entire triangulation network, which may not have exemplified high-precision criteria but did provide the geometrical basis for the atlas, whose thirty-one plates were published in Naples from 1788 to 1812 (Arca 2004, 104; Cantile 2004, 106) (see fig. 270). Beginning with Calabria, the first plates were engraved primarily by the artist Giuseppe Guerra in 1787–89. However, because the work dragged on with necessary corrections to the original drawings, the publication was only completed in 1812. Nevertheless, the result was especially innovative in the representation of mountains, rendered with hatching and shading (Valerio 1993, 124–211). Thus, in the last two decades of the eighteenth century the Kingdom of Naples produced Italy’s most innovative cartography thanks to Rizzi Zannoni (Manzi 1987, 534).

Although it was the first region in Italy equipped with geometrically based cadastral maps, Lombardy did not benefit from a similarly based geographical map until the end of the eighteenth century. Because the depiction of peripheral areas and especially borders in cadastral maps of Lombardy was so disproportioned, various projects advocating a new geometrical map based on triangulation were proposed to the Austrian



Die, Regni Castellae, Regni Siciliae, Regni Sardiniae, Regni Corsicae, Regni Lipararum, Regni Aeolianarum, Regni Siciliae, Regni Sardiniae, Regni Corsicae, Regni Lipararum, Regni Aeolianarum.

REGNI SICILIAE
 REGNI SARDINIAE
 REGNI CORSICAE
 REGNI LIPARARUM
 REGNI AEOLIANARUM

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government by Rizzi Zannoni and the astronomers of the Brera Observatory, among others. The project was finally adopted and refined in 1783–86 by the astronomer Barnaba Oriani using the large scale (ca. 1:86,400) of the Cassini *Carte de France*. Geodetic surveys provided results that were combined with astronomical observations by Giovanni Angelo de Cesaris and Francesco Reggio. From these data, the draftsman Giacomo Pinchetti and engraver Benedetto Bordiga began creating the final image in 1792–93. However, the ten-sheet *Carta topografica del Milanese e Mantovano* was not published until 1804–7 by Benedetto Bordiga and his brother Gaudenzio. Complete with refined ornamental scrolls and figures, this map celebrated the state's power with a description of territory more detailed than that of the *Carte de France*; it distinguished four categories of roads and five categories of settlements, as well as land use: rice fields, bare and tree-lined fields of arable land, vineyards, heathland, pastureland, woods, vegetable gardens, the layout of farmland, and systems of terracing. The orography is rendered with shading from an overhead light source (Signori 1990, 43–45) (fig. 306; see also fig. 269).

In 1797, the Habsburg rulers of the Republic of Venice “invested great effort in the regular surveying and cartographic depiction of the Veneto and Friuli territories it had recently acquired. The complex operation was . . . entrusted to a colonel (later general) of the Austrian General Staff, Anton von Zach. . . . The *Topographisch-geometrisch[e] Kriegskarte von dem Herzogthum Venedig* was the product of a survey based on a regular geometrical division of territory calculated by Vincenzo Chiminello, a scientist at the Padua astronomical observatory, . . . and comprises 120 small plates (*Sectionen*) each at 1:28,800” (Cantile 2007, 36). For obvious political and military reasons, this large map was a highly classified document but served as the basis for *Il Ducato di Venezia astronomicamente e trigonometricamente delineato* (1806; 1:234,000) (Rossi 2005, 2007).

Maps of Italy that altered the image established by d’Anville did not appear until the last decade of the eighteenth century and the early years of the nineteenth. Primary credit for this is due to Rizzi Zannoni for his skills in compilation and use of more recent observations and measurements. For this he may justifiably be ranked

with Delisle and d’Anville. However, credit should also go to the head of Napoleon’s office of cartography, Bacler d’Albe, and to the Bordiga brothers, who worked as engravers and cartographers in the French military mapping service.

In 1795 Rizzi Zannoni published his *Nuova carta della Lombardia* (ca. 1:240,000), an important account of the entire Po River basin, incorporating Liguria and the northern Apennines. The French appreciated the work enough to requisition the copperplates in January 1799 and the extant printed copies in Rizzi Zannoni’s Naples workshop. A reduced-scale version (ca. 1:458,000) was reprinted as *Nuova carta dell’Italia Settentrionale* (1799–1800). Finally, in 1802, Rizzi Zannoni chose the Florentine Giuseppe Molini to publish his two-sheet map of Italy, intended to promote his more demanding project of a map of the peninsula in fifteen sheets at ca. 1:380,000. Ultimately, only sheet 11 (Naples) and sheet 14 (Sicily) were published (Valerio 1993, 179–81, 187–88, 200).

The French Armée d’Italie established a topography department (or Deposito) in Milan in 1797–98 that required *ingénieurs géographes* (initially from France) to survey the whole Italian territory. The most wide-ranging project was for a map covering the entire theater of the Napoleonic Wars in Italy: the *Carte générale du theatre de la guerre en Italie* (1798, ca. 1:259,000) was coordinated by Bacler d’Albe and engraved by the Bordiga brothers. Given the limited time allowed, “the work had to be put together by reworking the already available maps”—for example, the French maps of Delisle and d’Anville, and various other mutually incommensurate cartographical images—“with previously acquired geodetic measurements being used for certain areas” (Signori 1987, 499). The draftsman Pinchetti coordinated the entire scheme, which initially covered only northern Italy in thirty sheets. But in 1802 Bacler d’Albe added a further twenty-two sheets, the *Carte générale des Royaumes de Naples, Sicile & Sardaigne*, to cover the rest of the peninsula, a work largely based on the maps of Rizzi Zannoni. Despite the lack of homogeneity within the final product, this map was long used for military, political, and administrative purposes, thanks primarily to the wealth of its topographical information: settlements, roads, watercourses, state and departmental

(facing page)

FIG. 305. BARON SAMUEL VON SCHMETTAU, *NOVA ET ACCURATA SICILIÆ . . . DESCRIPTIO UNIVERSALIS*, PRESUMED VIENNA, CA. 1722–23. A reduction of the multisheet manuscript map of the island presented to the Holy Roman Emperor based on the strategic survey supervised by Schmettau from 1719 to 1720. The two vignettes show the Austrian-allied British fleet commanded by Admiral George Byng at the landing at Tindari (1719) (top right) and the Span-

ish fleet in retreat in the Battle of Capo Passero (1718) (bottom right), actions that both confirmed Austrian control of the island, further emphasized by the Imperial double-headed eagle in the cartouche.

Size of the original: 90.5 × 122.0 cm (neat line; on 2 sheets). Image courtesy of the Newberry Library, Chicago (Novacco 6F 34).



FIG. 306. DETAIL OF THE AREA AROUND MILAN FROM THE CARTA TOPOGRAFICA DEL MILANESE E MANTOVANO ESEGUITA DIETRO LE PIÙ ESATTE DIMENSIONI GEOGRAFICHE ED OSSERVAZIONI ASTRONOMICHE. By the astronomers of Brera Observatory in Milan, engraved (1792–93), printed (1804–7), foglio 3. The first large-scale geometrically based map of Lombardy was modeled on the Cassini *Carte de France* but employs more detail in its display of different types of roads, settlements, and land

use. Printed map, engraved in copper in ten *fogli* (nine map sheets plus title sheet); scale 1:86,400. (For a different sheet from this map, see fig. 269.)

Size of the entire sheet: 88 × 87 cm. Su concessione del Ministero dei Beni e delle Attività Culturali e del Turismo, Biblioteca Nazionale Centrale di Firenze, Divieto di Riproduzione/ By courtesy of the Ministry of Cultural Heritage and Activities and Tourism (MiBACT), Central National Library of Florence, Ban of Reproduction (PALAT.Cart.geog.357).

boundaries, and orography (the latter obliquely lit and rendered using hatching) (Signori 1987, 500–501n13).

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SEE ALSO: Italian States; Rizzi Zannoni, Giovanni Antonio

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Geographical Mapping in the Netherlands. Given that the Netherlands was a major center of commercial map production throughout the long eighteenth century, it will not be surprising that most of the general purpose, small- to medium-scale maps of the Netherlands and its provinces were commercial ventures. Indeed, the emphasis of Dutch mapsellers on supplying the European market with affordable atlases meant that none engaged in the costly intellectual effort of compiling new critical regional maps; it was easier to copy the work of French geographers. However, the local Dutch market did sustain an interest in new maps of the Netherlands and of its constituent regions. For general maps of the Republic of the Netherlands as a whole, H. A. M. van der Heijden and Dirk Blonk (2005) provide a comprehensive survey. The following summary of provincial geographical maps available during the period ignores, for the most part, derivative single-sheet maps. Of particular note are the maps engendered by boundary disputes or initiated

by local surveyors who petitioned local governments for support; these maps are detailed elsewhere in this volume.

The most important province of the Republic was Holland. The States of Holland never undertook to map their province, possibly because there were sufficient *waterschappen* (water management board) maps and commercial maps to satisfy any need. The main large overview wall map is the *Nova et accurata totius Hollandiae Westfrisiae topographia* by Balthasar Florisz. van Berckenrode, based on *waterschappen* maps, and published by Willem Jansz. Blaeu in 1621 (22 sheets, ca. 1:110,000). The Blaeu/Van Berckenrode map was reissued four times from the same plates, with changes, before 1682 (Schilder 1986–2013, 5:291–332, with full-size reproduction; Blonk and Blonk-van der Wijst 2000, 36–48, 221–28). An enlarged and improved version, *'t Graefschap Holland* by Jacob Aertsz. Colom, was published in 1639 (40 sheets, ca. 1:60,000) and reprinted, with some changes, by Frederick de Wit about 1720 and by Covens & Mortier at least as late as 1737 (Donkersloot-de Vrij 1981, 139, no. 704; Blonk and Blonk-van der Wijst 2000, 276–83, which describes over 100 maps of the province between 1542 and 1815).

Friesland had (and retains) a highly developed sense of independence from the nation as a whole that is reflected in the mapping of the province. On the initiative of Christiaan Schotanus à Sterringa, all rural municipalities (*grietenijen*) were surveyed and mapped in the period 1658–62. These maps were issued from 1664 by Christiaan's son Bernardus Schotanus à Sterringa in Christiaan's book *Beschryvinge van de heerlyckheydt van Frieslandt*. The scales of the maps vary from 1:50,000 to 1:100,000 depending on the size of the respective *grietenij*. The states of the province were not very happy with the maps and in 1682 gave Bernardus a new commission to survey the *grietenijen*. After many years of work the maps were finally published in 1698 in the *Friesche atlas*, of which only 125 copies were printed. The atlas contains maps of the twenty-seven *grietenijen* (scales 1:25,000 to 1:43,000), maps of the three *goën* (districts), and information on occupation and land use and an extensive toponymy. In the well-known edition of 1718, *Uitbeelding der heerlijkheit Friesland*, the original thirty maps were revised and an overview and eight historical maps were added (reproduced at full size in Schotanus à Sterringa 1970) (fig. 307). The most important single-sheet map of Friesland in the eighteenth century was probably Abraham Allard's *Frisiae dominium vernacule Friesland* (ca. 1702, ca. 1:130,000) (De Rijke 2006, 279–83, which describes more than 100 maps of the province between 1545 and 1850).

No official maps of the province of Groningen are known from the period. A commercial wall map was

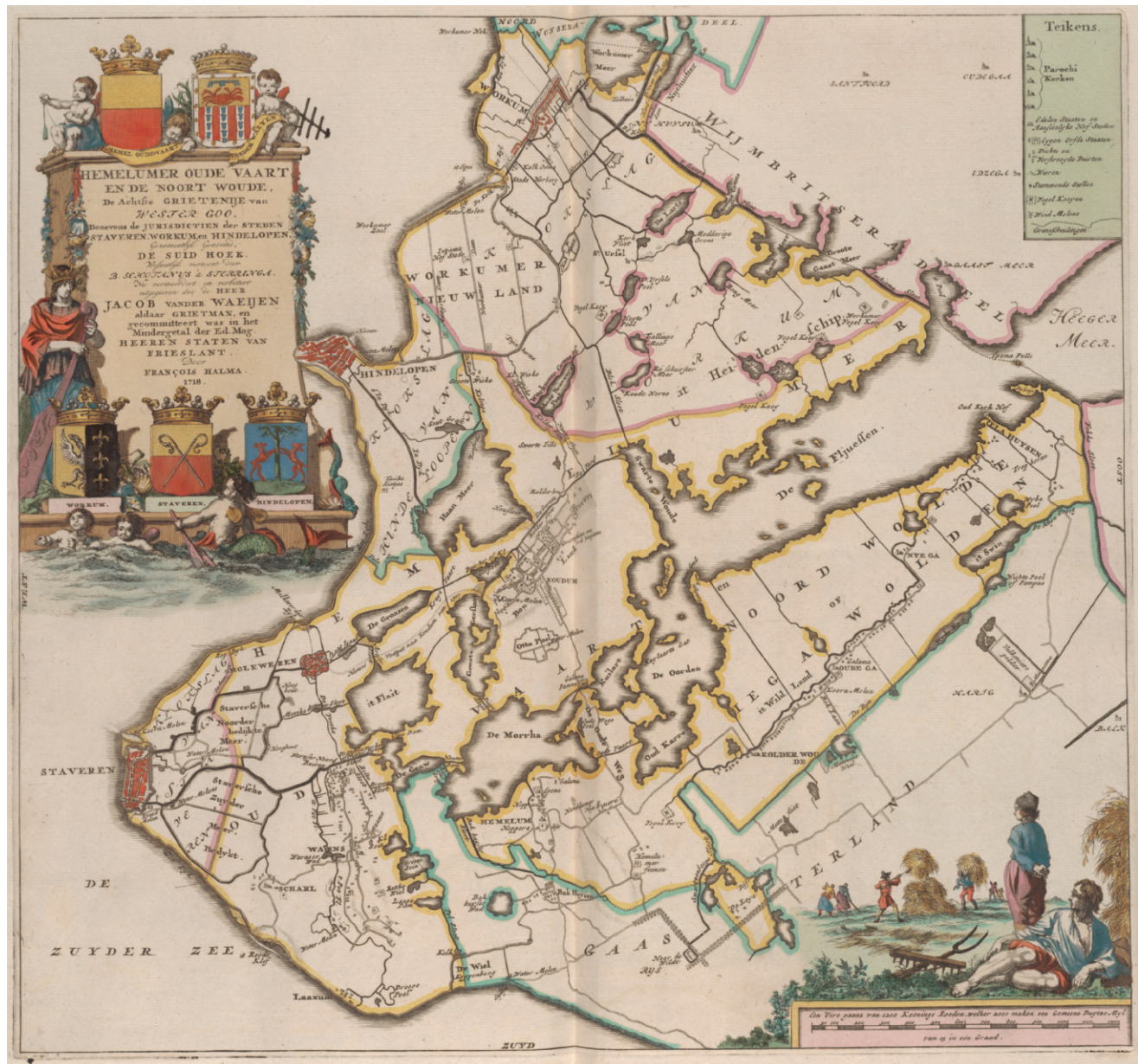


FIG. 307. BERNARDUS SCHOTANUS À STERRINGA, *HEMELUMER OUDE VAART EN DE NOORT WOUDE, DE ACHTSTE GRIETENIJE VAN WESTER GOO*, 1718. From Schotanus à Sterringa's *Uitbeelding der heerlijkheit Friesland* (Leeuwarden: François Halma, 1718). Copper engraving; 1:35,000. The Frisian rural municipality of Hemelu-

mer Oldeferd lay in the southwestern part of the province of Friesland. Most of the land has been reclaimed and the average elevation is one or two meters below sea level. Size of the original: 43.5 × 47.0 cm. Image courtesy of the Universiteitsbibliotheek Amsterdam (Bijzondere Collecties, OTM: HB-KZL I-2-A-7, map 40).

produced by the brothers Frederik and Wilhelm Coenders van Helpen (*Geographische beschrijvinge vande Pr: Stadt Gr. en Oml.*, ca. 1678, 4 sheets, ca. 1:100,000), but most of its detail came from the 1616 map of Balthold Wicheringe (Donkersloot-de Vrij 1981, 146, no. 743). The four-sheet map of Groningen and Ommelanden, 1781, by Theodorus Beckeringh (fig. 308) was based

partly on the map by the Coenders van Helpen brothers and partly on Beckeringh's own observations (Koeman 1963, 33; Vredenberg-Alink 1974, 80–91, 130–34; Wijk 2006 describes 160 maps of the province from 1545 to 1900).

Due to a boundary dispute between Groningen and Drenthe in 1634, a map of Drenthe and Wester-

wolde (the southeastern part of Groningen) was made by Cornelis Pijnacker. Titled *Drentia comitatus*, one sheet, at ca. 1:200,000, it was included in the atlases of Mercator-Hondius-Janssonius and Blaeu (Donkersloot-de Vrij 1981, 138, no. 701). The original copperplate continued to be used well into the eighteenth century by Petrus I Schenk and Gerard Valk and their successors and by Reinier and Josua Ottens.

A border dispute with Drenthe led the States of Overijssel to commission a map of the province that was completed under the leadership of Nicolaas ten Have, deputy head of the Latin school in Zwolle. He crafted an excellent overview on a scale of approximately 1:100,000 that appeared in four sheets in 1650. The copperplates came into the possession of the Deventer publisher Jan de Lat, who published an updated edition

in 1743 (Donkersloot-de Vrij 1981, 138, no. 702; Hogenstijn 2012).

Three of the four quarters (districts) of Gelderland belonged to the Republic: Arnhem (also called Veluwe), Nijmegen, and Zutphen. The fourth quarter, Roermond (also called the Upper Quarter), belonged to the Spanish Netherlands. The States of Gelderland never commissioned a map. The surveyor Nicolaas van Geelkercken made maps of the four quarters (ca. 1:170,000 to 1:210,000) and an overview map for the *Historia Geldrica* by Johan Isaaksz. Pontanus (1639) (Donkersloot-de Vrij 1981, 142–43, no. 721). Basically, all provincial maps of Gelderland in the eighteenth-century were based on Van Geelkercken's map. (For a general survey of the mapping of the province, see Vredenberg-Alink 1975.)

The western part of the province of Utrecht often

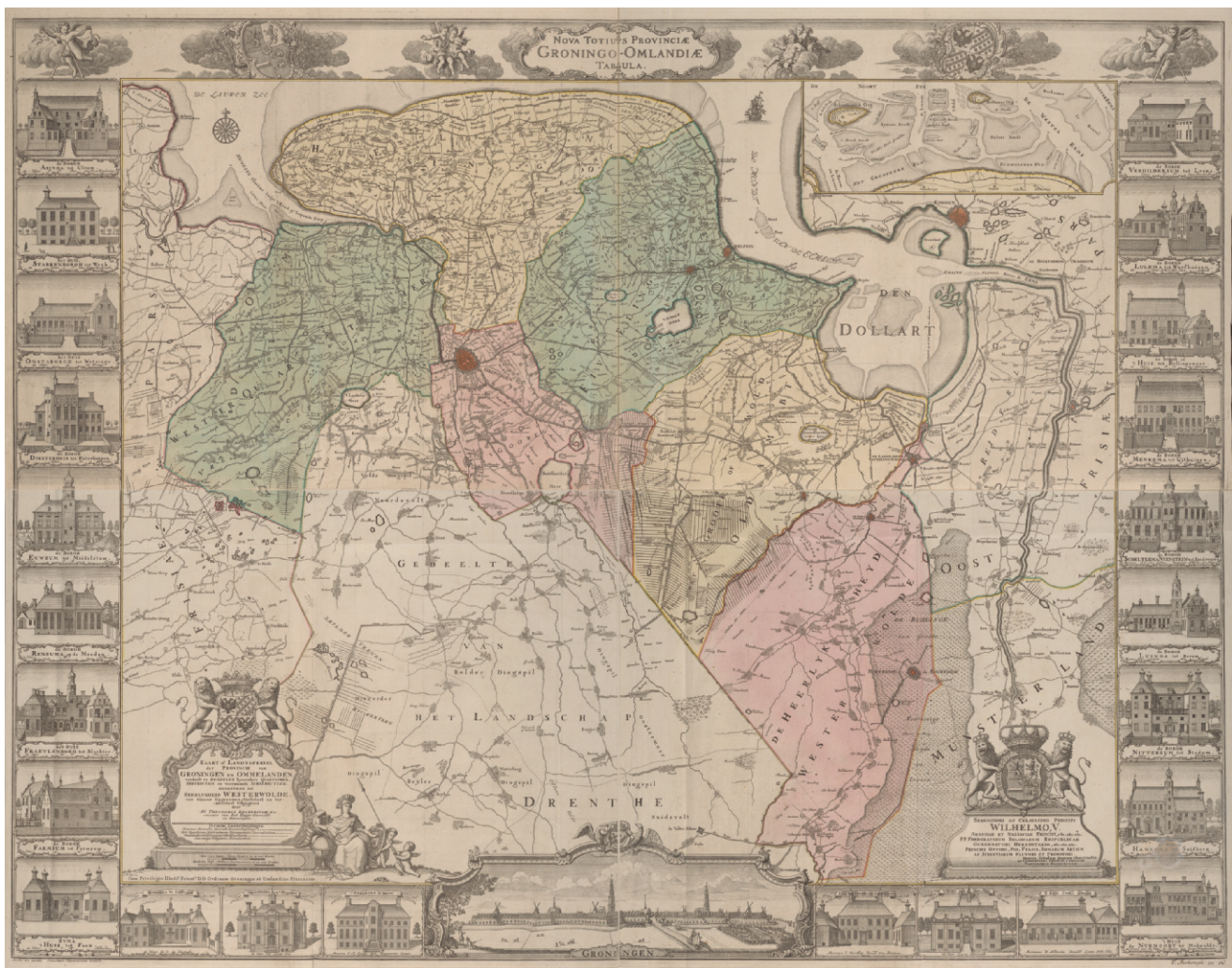


FIG. 308. THEODORUS BECKERLINGH, *NOVA TOTIUS PROVINCIÆ GRONINGO-OMLANDIÆ TABULA*, 1781. Ca. 1:60,000.

Size of the original: 105 × 134 cm. Image courtesy of the Universiteitsbibliotheek Amsterdam (Bijzondere Collecties, OTM: HB-KZL I-2-A-7, map 60–63).

appeared on maps of Holland (e.g., on the Van Berckenrode map) and also could be found on the *waterschap-pen* map of Rijnland. Commissioned by the States of Utrecht, the surveyor Bernard de Roij made the *Nieuwe kaart van den lande van Utrecht* (1696, 15 sheets, ca. 1:40,000). De Roij conducted the survey for this map largely himself, although he used the map of Rijnland by Steven van Broeckhuysen and Jan Jansz. Dou for the northwestern portion. The map was reprinted with only slight changes in 1743 (fig. 309) and 1799 and was reproduced at full size in 1973 (Sijmons 1973, which provides a list of general maps of the Province of Utrecht, 88 items, 1552–1837; Donkersloot-de Vrij 1981, 149, no. 754).

As a private initiative the large wall map, *Zelandiæ comitatus novissima tabula*, was compiled by Zacharias Roman and published by Nicolaas I Visscher in 1654/55 (9 sheets, ca. 1:40,000). It was reprinted three times in the Netherlands before 1725, and a French version, also

in nine sheets, appeared in 1747; a reduced-scale facsimile was published in 1973 (Donkersloot-de Vrij 1981, 154–55, no. 776; Blonk and Blonk-van der Wijst 2010, 62–68, 234–43). One of the many maps drawn and compiled by David Willem Coutry Hattinga and Anthony Hattinga was published on four sheets in 1753 as *Kaarte van de provincie Zeeland en der selver stroomen geheel meetkundig opgenomen volgens speciale order* (Koeman 1963, 33), but the copy at the Universiteitsbibliotheek Leiden seems to be unique. The 1760 *Atlas van Zeeland* by Isaak Tirion was derived from the large manuscript atlas of the province assembled by the Hattingas (Blonk and Blonk-van der Wijst 2010 provides descriptions of 129 maps of the province between 1549 and 1860).

Staats-Brabant, Staats-Vlaanderen, parts of the old Duchy of Brabant and County of Flanders, were assigned to the Republic in 1648; their boundaries followed the front line of military forces at the time. They

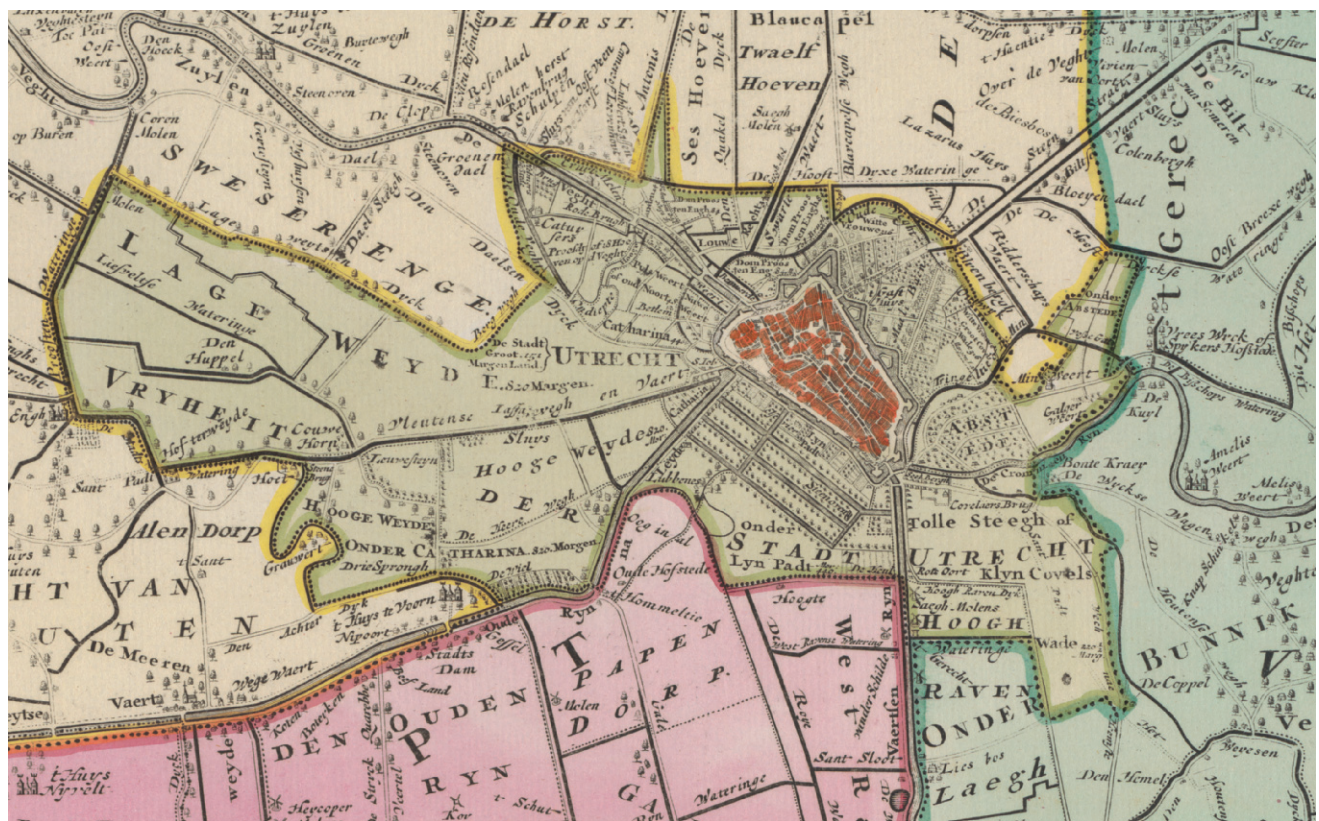


FIG. 309. DETAIL FROM BERNARD DE ROIJ, *NIEUWE KAAFT VAN DEN LANDE VAN UTRECHT* (AMSTERDAM: COVENS & MORTIER, 1743). Copper engraving on seventeen sheets; 1:40,000. This is the second edition of a map originally published in 1696. Even in its third edition (1799), a century after its original publication, the map proper was virtually unchanged.

Size of the entire original: 166 × 225 cm; size of each sheet: 56 × 37 cm; size of detail: ca. 15.5 × 25.0 cm. Image courtesy of the Universiteitsbibliotheek Amsterdam (Bijzondere Collecties, OTM: HB-KZL I-2-A-1, map 18).

were directly controlled by the States General, who never found it necessary to survey and map them. Until the end of the eighteenth century, maps of Flanders and Brabant often showed the regions in their old, undivided form. Roman and Visscher produced a map of Brabant in 1656 from existing material (*Ducatus Brabantiae novissima descriptio*), which was reprinted at least until 1692 (Donkersloot-de Vrij 1981, 154, no. 775). In the same year, Visscher published a companion map of the county of Flanders, in twelve sheets (*Comitatus Flandriae nova descriptio*; ca. 1:111,000) (Thorissen 2011). Blaeu's six-sheet map of Flanders was published in the year of his death, 1638, and was kept in print up to about 1670 (Schilder 1986–2013, 4:118).

The political history of Limburg is complex and chaotic. The current province only became part of the Republic in 1815, and the first map of Limburg with its (more or less) current borders did not appear until 1849. Prior to that, parts of northern Limburg appeared on maps of Brabant and of the Duchies of Jülich, Cleve, and Berg. Aegidius Martini made a map of Limburg in 1603 that formed the basis for most maps of the duchy in atlases well into the eighteenth century (Van Ermen et al. 1985 provides a brief survey).

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SEE ALSO: Netherlands, Republic of the United

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Geographical Mapping in Portugal. Although Portugal contributed significantly to the production of maps related to Europe's geographical discoveries from the fifteenth through the seventeenth centuries, in the restricted ambit of the Iberian Peninsula, Portuguese cartography of its own territory remained quite limited until the eighteenth century. The priority of imperial overseas cartography was largely responsible for this imbalance in geographical knowledge; contributing factors included the importance of Brazil (especially after the discovery of gold in the 1690s), the decreasing Portuguese presence in Asia, Portugal's war against Spain (1640–68), and its participation in the War of the Spanish Succession (1701–14). These factors help explain the essentially military nature of mapmaking in Portugal's European territory between the Restoration of 1640 and the Napoleonic invasions of 1807.

The initial period after the Restoration bore witness to a strong cultural heritage of earlier cosmographers and engineers, such as the Teixeira Albernaz and Pimentel families. Luís Serrão Pimentel's school for fortifications and military architecture, founded in 1647, was one of the first institutions directly linked to military cartography. Such institutions produced military plans as well as maps of ports, rivers, and coastal segments that were indispensable tools for Portugal's protracted wars against the Spanish, and they were frequently elaborated with the assistance of foreigners.

João V's interest in the sciences and arts, as well as his deft if sometimes contradictory political diplomacy, strengthened relations between Portugal and those European nations that had undergone significant technical, scientific, and cultural transformations. Several connections deserve special mention: the acquisition of texts, atlases, and engravings, especially of French extraction, for the royal library; the importance of astronomy as

developed in the observatories in Lisbon and Coimbra; and regular contact with institutions such as the Paris Académie des sciences and the Royal Society of London, especially following Guillaume Delisle's treatise, read at the Académie in 1720, that questioned the legitimacy of Portugal's territorial possessions in South America (Delisle 1722).

The inauguration of the Academia Real de História Portuguesa in 1720 also spurred Portugal's cartographic development. Under the patronage of Luís Caetano de Lima, the academy edited the *Geografia historica de todos os estados soberanos de Europa* (1734–36), which included the first map of Portugal published in Lisbon, drawn and engraved by Charles de Granpré in 1729 (Coutinho 2007), as well as regional maps of six provinces—Entre-Douro-e-Minho, Trás-os-Montes, Beira, Estremadura, Alentejo, and Algarve—a city plan of Lisbon, and maps of fortresses near the border. The map of Portugal was compiled from several foreign (primarily French) maps (fig. 310).

An especially important influence during this period was the work of Manoel de Azevedo Fortes. His *Tratado do modo o mais facil, e o mais exacto de fazer as cartas geograficas* (1722) taught the use of triangulation and field measurements in mapmaking. The maps resulting from his instructions were meant to complement the history of Portugal being planned by the Academia Real de História Portuguesa. Despite frequent calls to supply the materials necessary, the maps were never produced.

Through his agent, Sebastião José de Carvalho e Melo, marquês de Pombal, King José I (r. 1750–77) stimulated new functions for maps, diversifying their type and production. The exercise of absolutist power required improved maps in greater quantities and at various scales: not only nautical and military charts but also administrative maps, urban maps (especially after the Lisbon earthquake of 1755), and maps of streets, ports, and rivers. The Douro River was especially important because of the Port wine trade. The diversity of maps continued to increase over the course of the century, anticipating the division between topographic cartography, first undertaken using geodetic techniques in 1788, and thematic cartography.

However, several factors prevent an analytic assessment of this profusion of maps. First, the descriptive titles pointing to a map's genre are often complex and confusing. Simple expressions such as *carta geográfica* or *mapa geral* were normally reserved for maps of the country as a whole. For smaller regions, a map's title could include the nature of the map (e.g., chorographic, topographic, military, hydrographic, fluvial, of a city, road, itinerary) or a more generic description (map, configuration, sketch, illustration) in addition to identifying the location itself. The indication of the map type in its

title did not guarantee that it would be adequately classified. For example, a "topographical map" could show hydrographic features, while the ambiguous designation of "chorographic" could be applied to rivers, provinces, or even coastal areas.

Despite the imperfection of available inventories, the maps listed in them may still be broadly categorized. The most numerous are hydrographic maps showing rivers and coastal features, including ports, sandbars, bays, coves, and other nautical elements. In roughly equal number are plans of cities, castles, and forts. Topographical maps, often poorly designed with imprecise features due to imperfectly conducted surveys, were produced in similar proportions to those of cities and fortresses. Though less numerous, route maps and itineraries charted much needed information. Fewer still in number were the so-called chorographic and geographic maps, whose paucity is likely due to the imprecision of these categories. Thematic maps were exceedingly rare, with the exception of route maps and some of José de Sande Vasconcelos's maps of the Algarve showing soil usage.

The dominance of manuscript over engraved maps is evident. Between 1729 and 1800 there were only a dozen maps engraved in Portugal, not counting copies of provincial maps after 1730. The late adoption of engraving can be considered the "original sin" of Portuguese cartography. The distinction between the author of a map and the person who compiled, designed, copied, engraved, printed, and edited a map is likewise often uncertain. For some cartographers there are clues, but for others little is known. Among the cartographers engaged in geographical mapping in Portugal were: Luís Serrão Pimentel (fifteen maps of the coast of Portugal and Spain, 1673); Manoel de Azevedo Fortes (Mondego, 1703; region of Lisbon, 1734); Charles de Granpré, engraver (map of Portugal, 1729; maps of the six provinces, plan of Lisbon, 1730; other undated maps of urban strongholds); João Baptista de Castro (promoted new versions of Granpré's maps between 1754–58); João Silvério Carpinetti (principal diffuser of new versions of Granpré's maps, 1762); Gonçalo Luís da Silva Brandão (topographical map of the territorial boundaries of the Minho region, 1758); José de Sande Vasconcelos (multiple original maps of the Algarve, 1771–97); José Carlos Mardel (topographical maps of Lisbon and uncultivated lands, 1773); Custódio José Gomes de Vilas Boas (maps of the Minho region, 1786–1803); Isidoro Paulo Pereira (topographical maps of the Alentejo region, 1768–97; several hydrographical and coastal maps, 1776–97; map of Catalonia, ca. 1794); Francisco António Ciera (triangulation maps; geographical maps of Lisbon and Portugal, 1791–1803); and Lourenço Homem da Cunha d'Eça (hydrographical and military maps, 1801–9; route map of Portugal, 1809).



FIG. 310. CHARLES DE GRANPRÉ, REYNO DE PORTUGAL, 1729. From Luís Caetano de Lima, *Geografica historica de todos os estados soberanos de Europa*, 2 vols. (Lisbon, 1734–36), vol. 1, opp. 183.

Size of the original: ca. 24.5 × 16.0 cm. Image courtesy of the Lilly Library, Indiana University, Bloomington.

The social diffusion of these maps has not been well studied. Their poor circulation may be due to the small degree of improvement in the country's cartographic representation. Consumers of maps were few: the clergy and nobility to be sure, as well as some cultivated members of the bourgeoisie and those interested in the technical aspects of map production—a group whose numbers were increasing during the final decades of the eighteenth century. The institutions created by Maria I (r. 1777–92) represent another legacy of the Pombal period: Aula de Pilotos (1779), Academia Real da Marinha (1779), Academia Real das Ciências de Lisboa (1779), and Academia Real de Fortificação, Artilharia e Desenho (1790). Although it did not last long, the Sociedade Real Marítima, Militar e Geográfica para o Desenho, Gravura e Impressão das Cartas Hidrográficas, Geográficas e Militares, created in 1798, was nevertheless the site of the origin of Portugal's modern cartographic institutions, connected with geodesy, topography, and printing.

The adoption of geodetically based triangulation as the basis of cartography would only begin with Francisco António Ciera in the 1790s, and it found full expression in his edition of the *Carta dos principaes triangulos das operaçoens geodezicas de Portugal* (1803). The French invasions that began in 1807 marked a long interregal period. It was not until 1830 that Pedro Folque and Filipe Folque took up Ciera's work, beginning the next phase of cartography in Portugal.

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Geographical Mapping in Portuguese Africa. The Portuguese presence in Africa during the eighteenth century was quite restricted. In the Atlantic archipelagos and along the coast a series of small-scale fortifications are legacies of the Portugal-India maritime route (Cape Verde, Mozambique Island). Some were used as staging points for the trade in slaves and products from the interior of the continent (Guinea, São Tomé, and Luanda). Larger regions traversed by the Portuguese were along the west coast, stretching from Congo to Angola and in the east in the valley of the Zambezi River.

Although a sixteenth-century alliance with Ethiopia disappeared from Portugal's geopolitical interests, geographic curiosity in the region remained. Copies and published variants of the map of Ethiopia made by the Jesuit Manuel de Almeida (ca. 1645; published 1660) were produced in foreign editions through the end of the seventeenth century (Alegria et al. 2007, 1025–28). These images served as the basis for new maps of that area for many years.

The archipelago of Cape Verde was the subject of one of the few maps printed in Lisbon late in the eighteenth century. The *Plano das ilhas de Cabo Verde* (1790) by Francisco António Cabral was censored in 1799 by the recently founded Sociedade Real Marítima, Militar e Geográfica, whose remit was to control the production of Portuguese cartography; Cabral's map was criticized for being too incorrect (Guerreiro 1985). This censure did not prevent Cabral from editing *Memória hydrographica* in 1804, complementing his earlier map, although that work was also criticized by the same institution.

The northern islands in the Cape Verde archipelago, which had greater economic importance early on, became the objects of more detailed maps, such as those drawn by Manuel Isidoro Marques in 1768 (Santa Luzia, São Vicente, and Santo Antão) or by António Carlos Andréis at the end of the century (São Vicente, Santo Antão, Sal, Santa Luzia, and Maio). However, these manuscript maps were not widely circulated (Teixeira da Mota 1961).

Portuguese presence in the Gulf of Guinea began in the fifteenth century, and since then many Portuguese maps have shown its coasts and archipelagos in detail. For the island of Príncipe there exists a chart by José António Caldas from 1757, and for Fernando Pó (Bioko) there is an anonymous chart dated 1772 (Cortesão 1971). Portugal ceded this island to Spain by the Treaties of San Ildefonso (1777) and El Pardo (1778).

As for the southwestern coast of Africa, and Angola in particular, the Portuguese geographical image was formed by a series of separate regional maps that

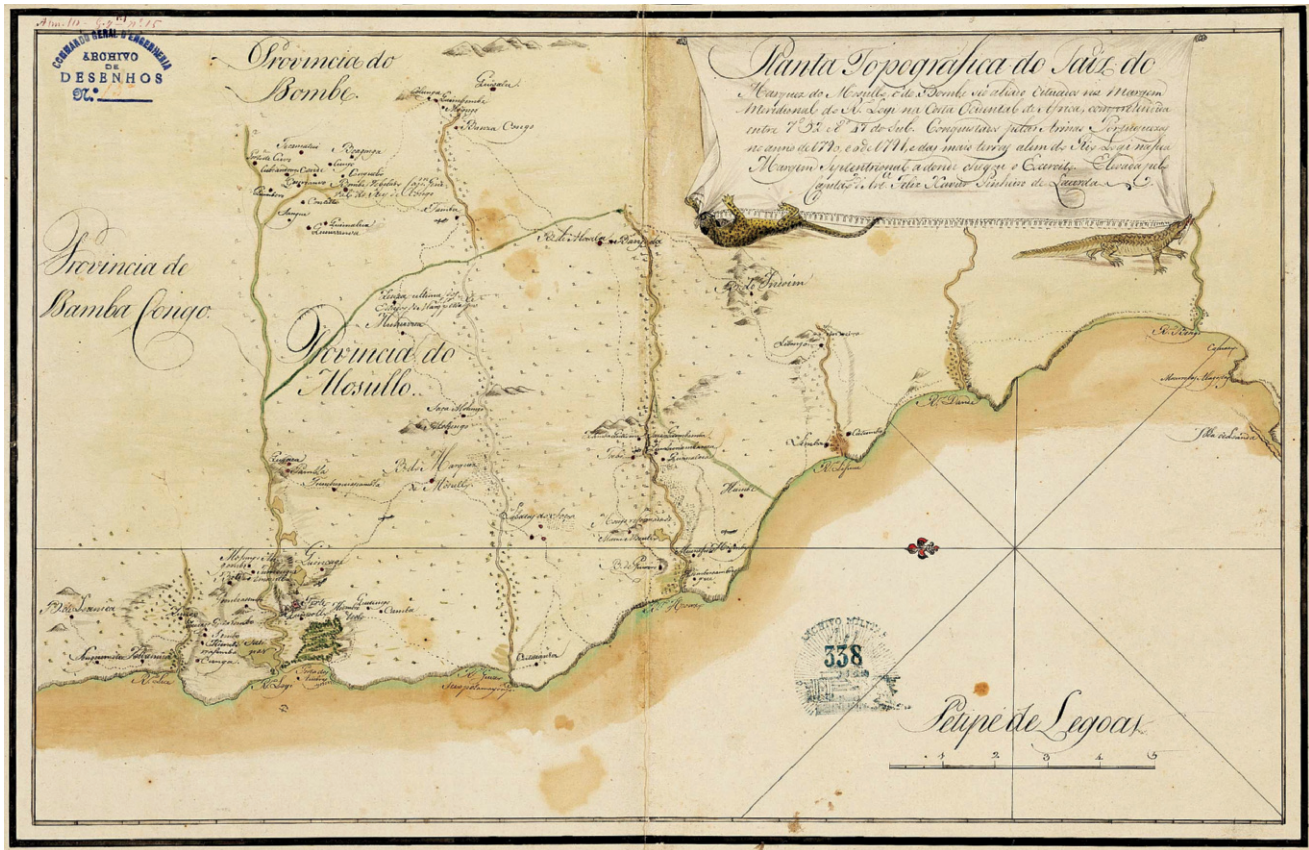


FIG. 311. FELIX XAVIER PINHEIRO DE LACERDA, "PLANTA TOPOGRAFICA DO PAIZ DO MARQUEZ DO MOSULLO E DE BOMBE," 1791. This example of regional colonial cartography provides a detailed image of northwest Angola based on several itineraries.

Size of the original: 29 × 44 cm. Image courtesy of Portugal/Gabinete de Estudos Arqueológicos da Engenharia Militar/Direção de Infraestruturas do Exército, Lisbon (4218-3-41-56).

provided a fragmented view of the area due to both the absence of territorial unity among the African kingdoms and the minimal European interest in and knowledge of these spaces (Santos 1998). The maps, at small or medium scale, portray the coast, the hydrographic network, and the various expeditions carried out for military, economic, and scientific purposes, such as those of the naturalist Joaquim José da Silva in the Benguela region in 1785–86. These documents provided the knowledge necessary for the political and economic domination of the region, especially providing a better understanding of the fluvial networks in the valleys of the Zaire (Congo) and Cuanza Rivers, which were essential components of commercial routes to the interior of the continent. Control of these principal hydrographic basins and of the communities who lived there, along with the agriculture and minerals they produced, was fundamental to European power (Santos 2010).

The "Planta topografica do Paiz do Marquez do Mosullo" (1791; ca. 1:70,000) by Felix Xavier Pinheiro de

Lacerda is one of the best examples of this regional colonial cartography. It was based on several itineraries and provides a detailed image of northwest Angola (fig. 311). The second visconde de Santarém had the map revised, edited, and published in Lisbon in 1855 on the occasion of diplomatic negotiations with other colonial powers concerning the mouth of the Zaire River.

International political pressure during the last quarter of the eighteenth century contributed to more detailed surveys regarding the territories, exemplified by the work led by Luís Cândido Cordeiro Pinheiro Furtado (from 1773), who coordinated the combined survey of Angola and Benguela in 1790, advancing work carried out decades earlier by explorers and merchants that had resulted in various regional maps. A new image of that kingdom was achieved in manuscripts distributed to military officials, diplomats, and administrators. Furtado's "Mappa geografico da costa occidental de Africa" (1790) was engraved in London in 1824 and in Paris in 1825, for lack of printing facilities in Lisbon.

Similar efforts resulted in another important map of the southern Benguela territory, which reflected the occupational strategy along the coastal areas of the desert of Moçâmedes (present-day Namibe province in Angola): “Mappa de uma parte da costa occidental de Africa compreendida entre a cidade de S. Filipe de Benguela e a anciada de Arêas” (1786).

Along the eastern coast of southern Africa, the Portuguese presence extended from Cape Delgado in the north to Delagoa Bay (Maputo Bay) in the south. Unlike the situation in Angola, the regional maps depicting the future territory of Mozambique were fewer in number and their content not as rich. The Portuguese occupation along the coast was discontinuous, and the interior was explored only along the principal river, the Zambezi (*Catálogo* 1960). Among important historical sources for this area is the “Carta do Cabo de Boaesperança ate Monbasa com a demonstracão do Rio Zanbeze” by João Teixeira Albernaz II, from 1677. By the eighteenth century, more detailed regional maps began to appear, such as the “Carta dos Rios de Sena” (1745) by Inácio Caetano Xavier. Scientific expeditions also produced maps, including the twenty-three carefully rendered manuscript maps made by Francisco José de Lacerda e Almeida of his journey between Tete and Cazembe in East Africa in search of a route to cross the continent (1797–99). His maps note magnetic compass variations and topographical detail, and several mark precise longitude and latitude readings. They illustrate his travel diary (“Instrucçoens, e diario da viagem q’ fez ao centro d’Africa, o governador q’ foi dos Rios de Sena Francisco Joze d’ Lacerda e Almeida, no anno ae 1798,” now in Rio de Janeiro, Biblioteca Nacional do Brasil). The diary was published in *Annaes Maritimos e Coloniaes* (1844–45). The complete image of Mozambique would only be elaborated in the second half of the nineteenth century.

JOÃO CARLOS GARCIA AND
JORGE MACIEIRINHA RIBEIRO

SEE ALSO: Portuguese Africa

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Geographical Mapping in Portuguese America. From the end of the seventeenth century, Brazil was considered the most important part of the Portuguese Empire, even though through the first half of the eighteenth century Portuguese America corresponded to a discontinuous space with various centers of power and ill-defined borders. The Treaties of Utrecht (1713–15), which ended the War of the Spanish Succession, recognized Portuguese dominion over the region north of the Amazon basin and in 1715 returned to Portugal the Colônia do Sacramento in the Río de la Plata estuary from occupation by Spain. The treaty negotiations presented Portuguese diplomats with an urgent need to commission new maps of Brazil. The Portuguese responded quickly, spurred on by two events. First, in 1720 Guillaume Delisle presented to the Académie des sciences in Paris his “Détermination géographique de la situation et de l’étenduë des differentes parties de la Terre” (published 1722). Using new longitudinal calculations, Delisle placed the line of Tordesillas, which divided Spanish and Portuguese territory, much farther to the east than the Portuguese Crown wished. Second, news arrived concerning the advance of Spanish Jesuit settlements along the Paraguay River near the region where gold had been discovered in 1718.

Thus in 1722, the Portuguese Crown contracted two Jesuit mathematicians from Italy, Giovanni Battista Carbone and Domenico Capassi, to create new maps of Portuguese America based on geographic coordinates established with new scientific instruments. In 1729 the king decided to keep Carbone in his service in Lisbon and replaced him with Diogo Soares, a Portuguese Jesuit, who was sent to Brazil with Capassi to map Portuguese America from the Maranhão to the Río de la Plata, to propose new boundaries between different captaincies and bishoprics, and to prepare for a future border treaty with Spain. The result was an unfinished project, the “Novo atlas da América portuguesa,” comprising a series of maps covering the South American coast between Río da la Plata and the Cape of São Tomé, at scales of ca. 1:350,000 for bays and estuaries and ca. 1:900,000 for larger parts of the coast (fig. 312). Notable maps in this collection include those of Minas Gerais, one of which is a map of the diamond area (ca. 1734; ca. 1:350,000), and a group of four maps at ca. 1:900,000 corresponding to an area of about 140,000 square kilometers between the latitudes 16°30’S and 21°30’S. No less relevant is a map of the captaincy of Rio de Janeiro (ca. 1730) by Capassi, and especially the “Nova e 1.^a carta da terra firme, e costas do Brasil ao meridiano do



FIG. 312. DIOGO SOARES, “CARTA 10 DA COSTA D’BRASIL: AO MERIDIANO DO RIO DE JANEIRO,” CA. 1740. Scale: ca. 1:900,000. This map is part of the unfinished project of the “Novo atlas da América portuguesa” and exemplifies the quality of the Jesuit mathematicians’ cartogra-

phy. Note the prime meridian marked over the bay of Rio de Janeiro.

Size of the original: ca. 20.0 × 32.5 cm. Image courtesy of the Service historique de la Défense, Vincennes (GR 6 M U.21.7.F.83 [7]).

Rio de Janeiro, desde o R.^o da Prata até Cabo Frio” (ca. 1740, ca. 1:3,500,000) by Soares, which synthesizes most of the cartographic work accomplished along the coast (Almeida 2001a, 100–142). The interior of the country, and particularly the outlines of the Paraná and Paraguay River basins, was based on the *Paraquariæ provinciae Soc. Iesu*, a map published in Rome in 1732 (Almeida 2001b, 45–49) (see fig. 757).

Around 1740, Luís da Cunha, the Portuguese ambassador in France, commissioned Jean-Baptiste Bourguignon d’Anville to create a map of South America that would include a line of demarcation between Brazil and Spanish territories. In 1747, an initial manuscript version of the map was sent to the Portuguese ambassador in Madrid, but it seemingly was not used in the boundary negotiations with Spain. D’Anville’s map *Amérique méridionale*, based on Portuguese manuscript maps as well as Spanish and French cartography, was printed in Paris in 1748, although it circulated only after 1750. It was reprinted several times throughout the eighteenth century and copied by other

European cartographers (Cortésão 2009, 2:260–61, 269–72; Furtado 2012).

To serve as the basis for the Treaty of Madrid in 1750, the “Mapa dos confins do Brazil com as terras da Coroa de Espanha na America meridional” (1749, ca. 1:8,500,000) (see fig. 447), also known as the “Mapa das Cortes,” was created in Lisbon through a synthesis of various sources, both cartographic and verbal: the contributions of sketch maps by *sertanistas* that were used in maps compiled under the auspices of colonial governors, namely the “Descripçam do continente da America meridional” (1746); the work of Soares and Capassi for Brazil’s coast; the reports on the Amazon and Rio Negro by Portuguese Carmelites; the efforts of Spanish Jesuits as found in the 1732 *Paraquariæ provinciae*; and French contributions as found in Charles-Marie de La Condamine’s map of the Amazon (Ferreira 2007) (see fig. 431).

The Treaty of Madrid compelled the Crown to commission teams of surveyors to establish the borders of Brazil based on colonial occupation and so-called nat-

ural borders. But a good part of this ill-defined space was entirely unknown. The cartographic effort entered a new phase after the Treaty of San Ildefonso (1777), which, with a few alterations, confirmed the borders defined in 1750.

Thus, during the second half of the eighteenth century, the territory of Brazil was constructed by the creation of new maps based on topographical surveys by military engineers, as well as the creation of a network of new cities and towns. This policy was followed above all in Grão-Pará and Maranhão and in the new captaincies of Mato Grosso and Goiás, created in 1748. Important maps were subsequently prepared on a regional scale, between ca. 1:500,000 and ca. 1:2,500,000, along with maps of the principal rivers, namely the Amazon and the Paraguay with their tributaries. For Grão-Pará, notable maps include the “Mapa geografico do Rio das Amazonas” (1758, ca. 1:1,500,000) by João André Schwebel, and the “Mappa geral do bispado do Pará” (1759) by Henrique Antonio Galluzzi, and later, after 1780, numerous maps of the Amazon, Negro, Branco, and Japurá river basins completed by José Simões de Carvalho, Manuel da Gama Lobo d’Almada, and José Joaquim Victorio da Costa. In the captaincy of Goiás, the first governor, Marcos José de Noronha e Brito, commissioned Francisco Tosi Colombina to prepare a general map of the captaincy. This map, known as “Mapa geral da capitania de Goyaz,” was finished in 1751 but was largely based on preexisting sources. In 1778 Thomas de Souza drew a new map titled “Plano geografico que mostra a capitania de Goyaz huma das do centro da America meridional e Domínio Portuguez” (ca. 1:2,600,000), which marked the administrative divisions of Goiás and the borders with the adjacent captaincies (Garcia 2002, 390–91).

However, in the captaincy of Mato Grosso, a key territory connecting south and north Brazil, where the border was established by the creation of new settlements, cartographic activity was more intense, especially under Governor Luís de Albuquerque de Melo Pereira e Cáceres. Between 1778 and 1781, he was personally involved in the preparation of several important maps that combined previous maps with observations and measurements made on site. Among these were the “Mapa de todo o vasto continente do Brazil ou America Portugueza” (1778, ca. 1:2,700,000) (Garcia 2002, 346–47), followed by the “Carta topographica de huma parte da vasta capitania de Mato Grosso” (1781, ca. 1:600,000) and the “Carta geographica dos extenços territorios e principaes Rios do Governo, e Capitania General do Matto Grosso” (1781, ca. 1:900,000) (Garcia 2002, 394–95, 404–5; Araujo 2015). These maps furthered his project of defining the border between Portuguese and Spanish control in the region (Araujo 2000,

1:467–539). From 1782, he could rely on the work of mathematicians and military engineers who arrived at Mato Grosso to establish the boundaries according to the treaty of 1777.

The transfer of the capital of Brazil from Bahia to Rio de Janeiro in 1763 gave rise to a new interest in mapping the city and its port as well as the captaincy. In 1767, the viceroy, Conde da Cunha (Antônio Álvares da Cunha), commissioned a series of new topographical charts and a map of the captaincy of Rio de Janeiro. An important area of the interior of the captaincy of São Paulo was mapped during the rule of Luís Antônio de Sousa Botelho Mourão, fourth Morgado de Mateus (1765–77), who commissioned a general map of the region around 1773. In the captaincy of Minas Gerais, José Joaquim da Rocha is notable for creating from 1777 to 1793 a general map of the captaincy (ca. 1:1,600,000), followed by the “Carta geographica da capitania de Minas Geraes” of Caetano Luís de Miranda (1804, ca. 1:1,600,000) (Costa 2004, 145–61, 190; Garcia 2011, 102).

In the extreme south in Rio Grande de São Pedro, which only became a separate captaincy in 1760, the exploration of the territory and settlement was affected by the war between Spain and Portugal (1763–77). The process of urbanizing this territory intensified during the final three decades of the eighteenth century, a period in which several important maps were produced by military engineers, including the “Carta da capitna. do Rio Grande de S. Pedro e suas circunvisinhanças athé o R^o da Prata” (1778) by Francisco João Roscio, the *Plano topografico do continente do Rio Grande e da Ilha de Santa Catarina* (1797, ca. 1:1,000,000) by José Correia Rangel de Bulhões (Garcia 2001, 120–21), and the “Mappa corographico da capitania de S. Pedro” (1801) by José de Saldanha.

In 1789, Cáceres sent to Martinho de Melo e Castro, secretary of state for the navy and the overseas territories, the “Nova carta da América meridional,” compiled under his direction by the mathematicians Francisco José de Lacerda e Almeida and Antônio Pires da Silva Pontes Leme. This map was the culmination of an extended effort to represent the border of Mato Grosso vis-à-vis the remaining territory of Brazil (Safier 2009, 149–55; Araujo 2015) (fig. 313).

Finally, in 1795, Rodrigo de Sousa Coutinho, secretary of state for foreign affairs, commissioned José Joaquim Freire and Manuel Tavares da Fonseca to create, in Lisbon, a general map of Brazil under the direction of Pontes Leme, professor of mathematics at the Academia Real da Marinha. This map of South America, titled “Carta geografica de projecção espherica da Nova Lusitania ou America portugueza e estado do Brazil” (1797) (see fig. 633), constitutes a monumental synthesis of all the efforts to map the territory of Brazil, resulting



FIG. 313. FRANCISCO JOSÉ DE LACERDA E ALMEIDA AND ANTÔNIO PIRES DA SILVA PONTES LEME, "NOVA CARTA DA AMÉRICA MERIDIONAL," 1789. The map is dedicated to the governor of the Mato Grosso, Luís de Albuquerque de Melo Pereira e Cáceres, who ordered its compila-

tion in order to be sent to the secretary of state for the overseas territories. Manuscript in two sheets. Size of each sheet: 152.5 × 274.5 cm. Image courtesy of The National Archives of the U.K. (TNA), Kew (MR 1/649).

from the borders established by the treaties of 1750 and 1777 (Corrêa-Martins 2011).

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SEE ALSO: Portuguese America

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Geographical Mapping and Topographical Surveying in the Portuguese East Indies. In contrast with the late sixteenth and early seventeenth centuries, only a few general nautical charts were produced in the Portuguese East Indies after 1650. André Pereira dos Reis, a native of Goa who served the Portuguese Crown as a soldier and pilot, is the only cartographer known to have attempted a systematic representation of the coasts between the Cape of Good Hope and Timor. His surviving work is gathered in an atlas of ten charts (1654) and in a

codex of eighteen charts and views (1656–60) (Corteseão and Teixeira da Mota 1960–62, 5:27–30).

Apart from these works, there are great numbers of manuscript maps and charts on a larger scale representing particular areas under Portuguese administration or influence, mostly places under pressure from other European nations or regional powers. The production of these maps and charts can often be related to moments of intensified diplomatic and military activity of the state (Estado da Índia), such as the handover of Bombay (Mumbai) to the British (1661–65), the increasing pressure from local powers on Bassein (late 1600s) and the Maratha attacks on major Portuguese possessions in the so-called Northern Province of India (Daman, Bassein, Tana [Thāne], and Chaul, 1720s to 1740s). While some of these maps show extensive stretches of the coastlines and inland territory, others were conceived in order to detail the physical contours of strategic places and illustrate particular sieges. Most seem to have been made in haste and with limited use of high-quality measuring and surveying instruments.

Another relatively coherent corpus of manuscript maps was produced between the mid-1740s and late 1780s mostly in the context of the Portuguese territorial conquests around Goa. A typical set would include three to four sheets of paper displaying richly colored and decorated maps and views and plans of particular fortresses and their surroundings in varying scales and perspectives; many of these plans were also accompanied by textual, often propagandistic narratives of military campaigns.

A few exceptionally large works representing the Goan territories as a whole were painted in oil on canvas during the eighteenth century (fig. 314). Although some of these panoramic maps were made in Portugal, they were clearly based on charts or sketches originally produced in the East Indies.

The increasing detail and accuracy of maps may be related to the reforming activities of the enlightened Portuguese government of Sebastião José de Carvalho e Melo, marquês de Pombal (1750s–70s), which found fertile ground in Goa. An unsigned manuscript geographical map of the Goan territories made in 1784 corresponds to one of the earliest medium-scale surveys executed by a professional body of military engineers and draftsmen explicitly working for the authorities of Lisbon and Goa (fig. 315). These included quite sophisticated representations of the relief, vegetation, paths, hydrographic networks, and urban centers of the conquered territories. The results were further improved in a map prepared in 1801 by the *engenheiro de Sua Magestade* (royal engineer) João António Águia Pinto Sarmiento and in a series of large-scale manuscript maps signed in 1812–18 by the engineer Francisco Augusto Monteiro Cabral, as well as



FIG. 314. “MAPA TIPOGRAFICO DAS ILHAS E PROVINCIAS DE GOA E DAS TERRAS DOS SEVS VEZINHOS,” [1760s–70s]. Map of the Goan territories based on an Indo-Portuguese model, ca. 1:79,000, oil on canvas.

Size of the original: 104 × 145 cm. Image courtesy of the Biblioteca Nacional de Portugal, Lisbon (cota INV-10922).

a general chart of the Goan territory printed in 1814 under the supervision of James Garling, a British engineer from Madras (Teixeira da Mota 1979, 35–37, 52–55). Contemporary British and French cartographers usually relied on Portuguese maps for the representation of the Portuguese possessions (e.g., Alexander Dalrymple, 1775 and later).

Comparable attempts to improve the quality of maps during the Enlightenment took place in East Africa, historically a part of the Portuguese Indies (Thomaz 1994, 207–43; Saldanha 2016, 368–72), but this occurred most notably after the separation of this region from the Estado governed by Goa (1752). While earlier charts, maps, and views of Inhambane, the Monomotapa Empire, Sofala, Quelimane, Mozambique and Ibo Islands, and Cape Delgado reveal serious technical limitations, the surveys carried out from the 1750s by the

military engineers António José de Mello and Gregório Taumaturgo de Brito among others greatly increased the available data. During a pioneering though incomplete cross-continental scientific expedition in 1797–99, initiated by the governor of the Portuguese Zambezi region, Francisco José de Lacerda e Almeida generated the first set of accurate astronomic observations made within the African continent, recorded in a series of twenty-three topographical sketch maps covering an area from Tete to Kazembe, which accompanied the manuscript diary of his journey (Rio de Janeiro, Biblioteca Nacional do Brasil, published in 1844–45).

Dispersed and varied samples of maps and cartographic sketches also cover the remaining areas of Portuguese interest in the East Indies, including Meliapor (Mylapore), Laos, Timor, Macao, and maritime South China. Very few maps were printed until the 1820s,



FIG. 315. "CARTA GEOGRAPHICA DOS ESTADOS DE GOA LEVANTADA EM OS ANNOS 1776, 1777, E 1778," 1784. An unsigned manuscript map of Goan territories, reflecting the military training of the engineers who surveyed the region.

except for some seventeenth-century items in books (e.g., Ceylon, Ethiopia). Large collections of manuscript maps may be found in repositories in Lisbon (Sociedade de Geografia, Biblioteca Nacional, Arquivo Histórico Ultramarino, Arquivo Histórico Militar, and others), Évora, Porto, Paris, and London. There are at present no comparable collections in Asia or the Americas.

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SEE ALSO: Portuguese East Indies

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Geographical Mapping in Russia. Until the early eighteenth century, the main form of mapping in Russia was geographical drawing (*chertëzh*) performed in a distinctively artistic manner, almost always without strict mathematical references and with the inclusion of a great number of place-names and various explanatory notations. About 1,300 such Russian drawings survive, all of them in manuscript except for six printed examples (Kusov 1993). Most are large-scale maps prepared for inventories and recording borders. There are few medium- and small-scale drawings representing large parts or the whole of Russia. Their notations indicate distances between settlements and describe towns and villages, but generally do not show orientation with cardinal points.

The mapping of Siberia was actively pursued after the mid-seventeenth century. Maps covering the whole of Siberia were compiled under Pëtr Ivanovich Godunov (untitled, 1667); by an anonymous author, *Chertëzh vsey Sibiri do Kitayskago tsarstva i do Nikaskago* (ca. 1672); by Nikolay Gavrilovich Spafariy (untitled, 1678); by Semën Ul’yanovich Remezov (untitled, 1698); and others (Goldenberg 2007, 1873–83). The drawing of the whole of Siberia on canvas by Remezov is the largest among them measuring 213 × 277 centimeters with 5,110 geographical names (Goldenberg 2007, 1892).

The “*Chertëzhnaya kniga Sibiri*,” an atlas compiled in 1701 by Remezov on the order of Peter I, represented a historical turning point in the development of Russian cartography. This atlas included twenty-three drawings representing the whole of Siberia, its *uyezds*, their capitals, and the town of Tobol’sk, as well as a valuable summary of distances from Tobol’sk to other Siberian towns. The maps and atlases by Remezov demonstrate a particular technique of mapmaking in the era of Peter I, based on river networks, the use of the compass, and data on distances by river and land in sazhen’ (1 sazhen’ = 2.134 m) (Goldenberg 2007, 1884–1902).

The compilation of maps of the entire course of a river constituted a form of atlas production that heralded later more geographically oriented works. Instrumental river surveys had been performed in Russia from the late seventeenth century. Up to the 1720s, they were carried out mainly by foreign officers in Russian service. The survey of the Don River, performed by Vice-admiral Cornelis Cruys and Peter I personally in 1699, was used as a basis for the compilation of an atlas of the river consisting of seventeen maps with explanatory text. Published in Amsterdam by Hendrik Doncker in 1703 or 1704, the atlas had titles in both Russian and Dutch: *Prilezhnoye opisaniye reki Donu / Nauw-keurige afbeelding vande rivier Don*. The bilingual approach continued in its dedication to czarévich Aleksey Petrovich in Dutch, a discourse on the Don River and the city of Azov with interesting historical and ethnographic information about the Cossacks, profiles of the Black Sea coasts, a general map of the Don with inscriptions in Dutch, and detailed maps of individual sections of the Don River with geographical names in Dutch and Russian, as well as maps of the Azov and Black seas with notations in Dutch. Many geographical names on the maps are supplemented by explanations; there is also information on a planned canal aimed to connect the Don with the Volga River. The atlas illustrates the transition from the methods of simple drawing to those based on instrumental measurement and observation.

The reforms of Peter I encouraged the adoption of such methods of mapmaking in tune with developments in Western Europe. With the establishment in 1701 of the Moscow mathematical navigation school, *Moskovskaya matematiko-navigatskaya shkola*, geodesists who initiated the instrumental surveys of the country were trained in Russia. The first maps and atlases based on Western European sources were compiled by Vasiliy Onufriyevich Kipriyanov and printed in his Moscow printing house, *Grazhdanskaya tipografiya*, founded in 1705 (Bagrow 1975, 135).

Between 1706 and 1717, Kipriyanov issued thirteen educational maps of the world, its continents, and individual countries. Five maps of this set (the world in

hemispheres, Europe, Asia, Africa, and the Americas constituted the first printed Russian atlas of the world, *Atlas mira* (1713). The maps of the atlas had no common title page and were unbound; nevertheless, these five map sheets were an integrated edition that can justifiably be called an atlas. The maps were mainly reprinted copies of Dutch maps (of Theodorus and Justus Danckerts and Frederick de Wit) with geographical names translated into Russian; they were supplemented by some new engravings and texts. In 1711, Kipriyanov compiled, personally engraved, and printed *Guberniya Moskovskaya* with statistical data on homesteads throughout the whole area (see fig. 428). Geographical maps were also printed in St. Petersburg by Mikhail Avramov's Grazhdanskaya tipografiya (1714–27), the Morskaya akademiya printing house (after 1721), and by the printing house in St. Petersburg of the Akademiya nauk (after 1732).

By order of Peter I, astronomical and topographical field surveys and the compilation and publishing of maps were subordinated to the senate, the highest state authority under the czar after 1711. Instrumental regional surveys had begun in Russia in 1715 when geodesist Fëdor Molchanov surveyed the area along the Irtysh River (Goldenberg and Postnikov 1990, 31). A systematic instrumental survey of the whole country for the compilation of the first precise geographic map of Russia began with the senate order of 9 December 1720. The survey was carried out in accordance with a special instruction concerning the use of the quadrant, astrolabe, and a thirty-sazhen'-long measuring chain and was based exclusively on astronomical observations for latitude. Longitudes were determined through geometrical calculations. There was no standard meridian for longitudes; in some cases it was an *uyezd* capital or the meridian of Ferro (Hierro Island, westernmost of the Canary Islands) or Dagö (Hiiumaa Island in the Baltic Sea, the westernmost point of the Russian Empire at the time).

The maps were compiled on a conic projection. Astronomical reference points were plotted by coordinates on the geographical grid, while the area in question was surveyed by bearings with the use of protractor and by distances measured in the field or determined through local inquiries. There was no single scale prescribed for map compilation. The first maps of three Russian *uyezds* were compiled as early as 1722; thirty *uyezds* already were mapped by the beginning of 1725; and all 190 *uyezds* by 1744. The first countrywide survey covered about 40 percent of European Russia; in Siberia the survey mainly followed the principal rivers.

Ivan Kirilovich Kirilov, the *ober-sekretar'* of the senate, played a significant role in the mapping of Russia during 1720s and 1730s. He compiled a map of north-eastern Siberia and the Kamchatka Peninsula in 1724 ("Tabula geographica") with Latin notations and at a

scale of ca. 1:1,800,000. Kirilov published three editions of the *Atlas vserossiyskoy imperii*, in 1731, 1732, and 1734. The first edition consisted of ten maps of individual *guberniyas* of European Russia printed from 1724 to 1731 and was bound as a single volume. Each subsequent edition added new maps to the previous edition. The second edition consisted of twelve *guberniya* maps, while the third included fourteen *guberniya* maps of European Russia and a general map of Russia (see fig. 737). Kirilov's main sources for this atlas were *uyezd* maps produced from the first instrumental surveys in Russia; seven latitudinal-longitudinal astronomical reference points served as a mathematical basis of the maps. The maps are decorated with title cartouches designed with symbolic and ethnographic elements. Geographical names are noted in Russian and Latin. For Russia at this time, Kirilov's atlas incorporated the scientific practices of the era.

Joseph-Nicolas Delisle joined the St. Petersburg Akademiya nauk in 1726. He quickly developed guidelines for the compilation of Russia maps in 1727–28 (Gnucheva 1946, 120–31) and later began to compile an atlas and a general map of Russia. He also contributed to the geographical mapping of Russia by delivering in 1732 to the Akademiya nauk a map accompanied by a memoir describing the best routes for exploration of the western coast of North America. In 1737, Akademiya nauk issued his small-sized (22 × 26 cm) world atlas under the title *Atlas sochinennyi k pol'ze i upotrebleniyu yunoshestva i vsekh chitateley vedomostey i istoricheskikh knig* containing twenty-two maps compiled on the basis of foreign and Russian sources, drawings of the cosmological systems as conceived by Claudius Ptolemy, Tycho Brahe, and Nicolaus Copernicus, as well as images of armillary spheres and of the wind rose. There are few geographical names on the maps, and they do not agree with each other on different maps. For example, the water area between Korea and the Japanese Islands is shown on four maps and labeled differently on each.

The Akademiya nauk established a geographical department, Geograficheskiy departament, for cartographic works in 1739; in 1745 it published the *Atlas Rossiyskoy, sostoyashchey iz devyatnattsati spetsial'nykh kart* in three editions: Russian, Latin and French, and German. This was the first atlas of Russia to cover the entire country, including the first general map of Russia compiled by the academy (fig. 316) as well as thirteen maps of European Russia and six maps of Siberia. This atlas is distinguished from Kirilov's atlas of 1734 by richer and more accurate content and by the presence of maps of Asian Russia (i.e., Siberia). The maps of the 1745 atlas were based on sixty-two astronomical reference points. It was the first Russian atlas to contain a table of conventional signs (forty-eight items) (fig. 317).



FIG. 316. THE FIRST GENERAL MAP OF RUSSIA BASED ON EXTENSIVE RUSSIAN SURVEYS. *Mappa generalis totius imperii Russici* from the German edition of *Atlas Rossiyskoy, Rußischer Atlas* published by the Akademiya nauk (St. Petersburg: Academie der Wissenschaften, 1745).

Size of the original: 55 × 97 cm. Image courtesy of the David Rumsey Map Collection, David Rumsey Map Center, Stanford Libraries.

Basic data for compiling the maps were drawn from instrumental surveys performed by geodesists during the reign of Peter I; they surveyed 190 *uyezds* (66 percent of Russia's area), while Kirilov's atlas was based on surveys of 115 *uyezds* (45 percent of the area).

The *Atlas Rossiyskoy* successfully fulfilled a principal task of state cartography: to compile a complete map of Russia on the basis of systematic countrywide instrumental surveys. The maps of the *Atlas Rossiyskoy* are characterized by internal consistency in methods of compilation, a rich variety of conventional signs, unified design, and high-quality engraving. The critical processing of source materials was supported by the newest cartographic materials from the Russian expeditions led by Vitus Bering to America's northwestern coasts in 1733–44 (they are depicted on the general map), Morten Spangberg to the Kuril Islands and the northern part of Japan in 1738–39, and others. The atlas has an interesting foreword, explaining the projection used and the methods of compilation. By depicting the physical extent of Russia based on precise instrumental surveys by Russian geodesists, the *Atlas Rossiyskoy* constituted a major achievement.

Mikhail Vasil'yevich Lomonosov headed the Geo-

graficheskii department of the Akademiya nauk from 1757 to 1765; he led work on a new atlas of Russia (*Rossiyskiy atlas*) that was to comprise sixty to eighty beautifully decorated special maps and a detailed political and economic description of the whole empire. The new atlas set out to correct one of the chief deficiencies of the 1745 atlas, that the most populated and economically developed central parts of European Russia were depicted on only two maps. Many maps showed only a small number of extant populated places. For the new atlas, Lomonosov organized expeditions to carry out astronomical observations to determine longitudes and latitudes of various places in Russia and to undertake geographical descriptions and meteorological observations. Twelve of the maps were published in the 1770s. Lomonosov's own cartographic work was limited to a *tsirkumpolyarnaya karta* of 1763 (see fig. 440), a circumpolar map of the Arctic Ocean intended to guide the first polar expedition organized by Lomonosov and led by Vasilii Yakovlevich Chichagov in 1765–66.

Astronomical observation expeditions of the Akademiya nauk in the third quarter of the eighteenth century determined the latitudes and longitudes of fifty points

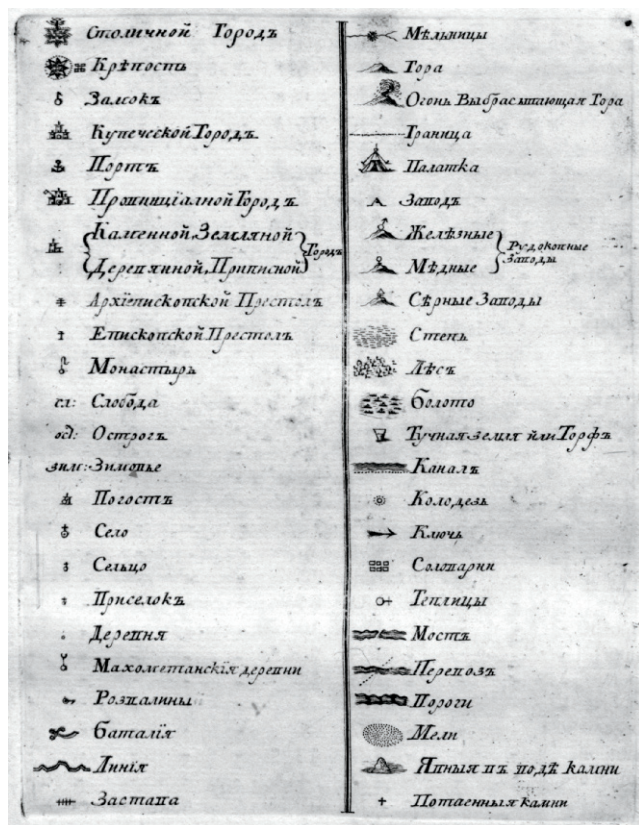


FIG. 317. ENGRAVED TABLE OF CONVENTIONAL SIGNS. Detail from the preface to the *Atlas Rossiyskoy* (St. Petersburg: Akademiya nauk, 1745), 20.

Image courtesy of the Rossiyskaya gosudarstvennaya biblioteka, Moscow (Cartographical Department, Code No. Ko 108/II-2).

by 1773 and provided valuable geographical and cartographic information. The results of these expeditions were incorporated in a set of general maps of Russia: *Pochtovaya karta Rossiyskoy imperii* (1771), *General'naya karta Rossiyskoy imperii, po noveyshim nablyudeniyam i izvestiyam sochinennaya* (1776), and *Novaya karta Rossiyskoy imperii, razdelennaya na namestnichestva* (1786; in Latin 1787); this last depicted changes in the administrative territorial divisions of the country. Based on materials from the academy's expeditions, the Geograficheskiy departament compiled and published many new maps of the different regions of Russia as well as several atlases, including the atlas of the Volga River from Tver to Dmitrov (*Geograficheskoye opisaniye reki Volgi ot Tveri do Dmitriyevska*) in 1767, *Karmanny atlas Rossiyskoy imperii* in 1773, and *Atlas Kaluzhskago namestnichestva* in 1782 (Gnucheva 1946) (see fig. 687).

Mathematician and physicist Leonhard Euler carried out scientific research in mathematical cartography and theoretical geodesy at the Geograficheskiy departament in the 1770s and 1780s. His detailed mathematical study in 1777 of the conic projection, known as the Delisle

projection, led him to propose his own conic equidistant projection with a secant cone and to develop a general theory of all conic projections and a general equation of all equal-area conic projections. He also modeled the curvature of the earth's surface. The exact measurement of Russia's area on the spheroid was performed by Wolfgang Ludwig Krafft in 1786 and by Fëdor Ivanovich Shubert in 1795 (Gnucheva 1946, 89). The Geograficheskiy departament of the Akademiya nauk published 324 printed maps in 1726–1800. During the eighteenth century it was the only Russian scientific geographic mapping center that combined scientific research with practical work for the government.

After the establishment of the General Staff in 1763 and the beginning of the general land survey, General'noye mezhevaniye, in 1765, the majority of state mapping was performed by these institutions (fig. 318). Paul I assumed oversight of cartographic activities in the country in 1796. Ego imperatorskogo velichestva chertëzhnaya, the imperial majesty's drawing office, was established in late 1796 and transformed into the map depot, Ego imperatorskogo velichestva depo kart, in August 1797.

During the eighteenth century, medium- to small-scale mapping was also carried out by other institutions. The Orenburg Expedition (later Commission) was established by Kirilov in 1734, and a geographical department within the office of the Orenburg Commission, created in 1741, issued the first *General'naya karta Orenburgskogo kraya* in 1742 and *Atlas Orenburgskoy guberniy* in 1755. The Komissiya ob uchrezhdenii narodnykh uchilishch, a commission on public schools established in 1782, published educational atlases of Russia (1787) and Europe (1790).

To create a complete set of maps of the Russian Empire, a special cartographic authority (Geograficheskiy departament) was established within the cabinet in 1786 under Catherine II and headed by the director of the mining school (Gornoye uchilishche) in St. Petersburg, Pëtr Aleksandrovich Soymonov. The printing house of the Gornoye uchilishche published all the scientific reference atlases of Russia compiled by the cabinet's Geograficheskiy departament, including *Rossiyskoy atlas iz soroka chetyrekh kart* in 1792, which was compiled by Aleksandr Mikhaylovsky Vil'brekht and served as a basis for all other atlases of the Russian Empire; *Atlas Rossiyskoy imperii i sostoyashchiy iz 46 kart* in 1792; *Atlas Rossiyskoy imperii i sostoyashchiy iz 52 kart* in 1796; as well as two educational atlases: of the world, *Novyy atlas ili sobraniye kart vsekh chastey zemnogo sharain* 1793; and of Russia, *Atlas rossiyskoy imperii, izdannoy* in 1794. These atlases of Russia were the standard reference works of their time and reflected current methods of mapmaking and design as well as a high degree of engraving skill. The cabinet's Geograficheskiy departament was transferred to the authority of the senate in 1797 and to the Depo kart in 1800.

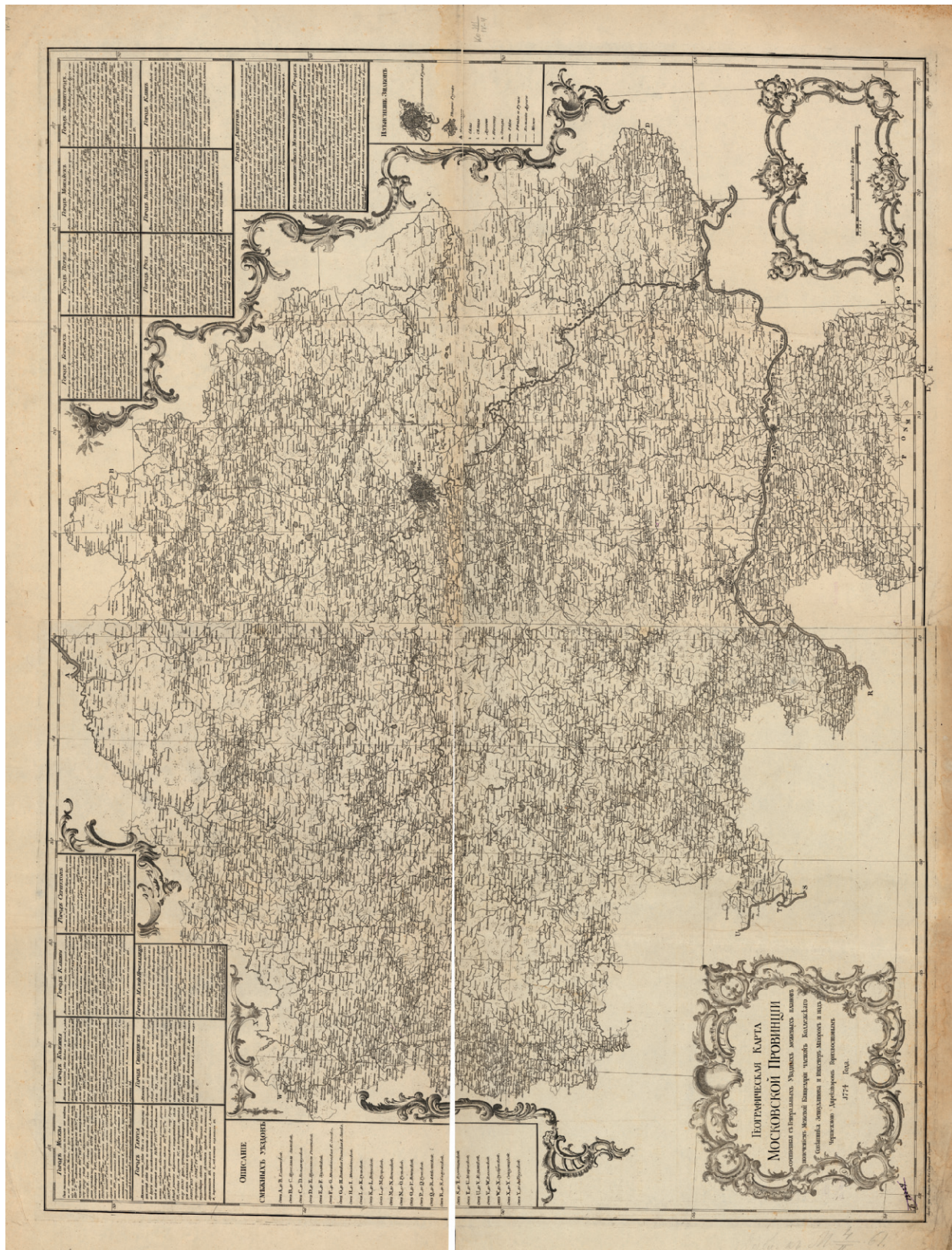


FIG. 318. GEOGRAFICHESKAYA KARTA MOSKOVSKOY PROVINTSIИ, 1774. Map of Moscow at 1:252,000. Size of the original: 90 × 120 cm. Image courtesy of the Rossiyskaya gosudarstvennaya biblioteka, Moscow (Cartographical Department, Code No. Ko 111/IV-4).

The development of Russian geographical mapping demonstrated that despite the large extent of the territory it was possible to coordinate and direct large survey teams to acquire sufficient data to produce several atlases of the realm and to fill the archives with medium- to large-scale maps. Such achievements portended further successes in the century to come.

NIKOLAY N. KOMEDCHIKOV

SEE ALSO: Delisle Family; Euler, Leonhard; Kipriyanov, Vasiliy Onufriyevich; Kirilov, Ivan Kirilovich; Lomonosov, Mikhail Vasil'yevich; Pallas, Peter Simon; Russia; Tatishchev, Vasiliy Nikitich

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Geographical Mapping in Spain. Geographical mapping of Spain does not appear to have been a preoccupation of the last Habsburg monarch. Carlos II (r. 1665–1700) had other more pressing worries, following military defeats, economic decline, and the resulting exhaustion of the country. The need to map Spain began with the Bourbons (Felipe V, r. 1700–1746; Fernando VI, r. 1746–59; Carlos III, r. 1759–88; and Carlos IV, r. 1788–1808)

and some of their ministers, who had decisive policies of centralization and territorial intervention. The desire for administrative and economic reforms to develop a modern state emphasized the gravity of the situation. By the last decades of the century, the fruits of this change in policy were exemplified by the *Atlas geográfico de España* (completed in 1792) by Tomás López and the *Atlas marítimo de España* (1789) by Vicente Tofiño de San Miguel (Capel 1982).

The policy of secrecy adhered to by many sixteenth-century monarchs contributed to the extinction of a brilliant tradition of marine chartmaking that had enjoyed well-earned prestige and had created a favorable atmosphere for political and economic expansion. Its harmful effects were felt in terrestrial and marine mapping in the lack of projects and leaders and, above all, in the absence of a demand that would have encouraged cartographic production. Not until the dawn of the eighteenth century was the poor state of the country's cartographic representation acknowledged and actions taken. The first steps to remedy the situation were taken by the *Cuerpo de Ingenieros Militares* (created 1711), but these proved ineffective. What proved more effective was sending young students supported by the state—*pensionados*—to Paris and instructing them in cartographic drawing and engraving (1752–60). The result was that by the last years of the eighteenth century, although lacking the rigor demanded by academic circles, there were printed maps of all regions of Spain (Hernando 2005).

Despite the lack of Spanish maps of the country throughout the eighteenth century, foreign geographers continued to produce images of all or part of the Iberian Peninsula. These were obsolete compositions, compiled from sixteenth- or early seventeenth-century maps cosmetically enhanced with data from Baroque or Enlightenment literary sources. The maps that appeared in the Spanish editions of the atlases of Johannes Janssonius (*Nuevo atlas*, 1653–66) and Joan Blaeu (*Atlas nuevo/Atlas mayor*, 1659–72) are just two examples. Given the potential profits to be made, French geographic publishers produced similar cartographic collections focused on Spain. The first was by Nicolas Sanson (*L'Espagne, descrite en plusieurs cartes*, in his atlas *La France, l'Espagne, l'Italie, l'Allemagne, et les Isles Britanniques*, 1651); much later, Roch-Joseph Julien published maps by Jean-Baptiste Nolin in his *Atlas d'Espagne et de Portugal* (1762). Careful examination of the data contained therein shows that the vast majority of information came from a previous period (Hernando [1995], 189–215; 2005, 18–19).

Regarding maps of Spain drawn in Spain during this period, the oldest one (1706) is very simple and quite decorative, with an unconventional design produced for an erudite audience (fig. 319). A second example, cited as "España y Portugal por [Gregorio] Fosman" and of



FIG. 319. CLEMENS PUICHE, *DESCRIPCIÓN DE ESPAÑA Y SUS REYNOS*, 1706. This is the only known example of a map of Spain from the early eighteenth century. It has an unusual western orientation but little is known about its publication and it remains unstudied. Scale ca. 1:2,200,000; 10 leguas [=3.3 cm] (Madrid: Casa de Santiago Ambrona).

Size of the original: 61 × 44 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge DD 2987 [1599]).



FIG. 320. CARLOS MARTÍNEZ AND CLAUDIO DE LA VEGA, “EXPOSICION DE LAS OPERACIONES GEOMETRICAS” OF THE IBERIAN PENINSULA. Manuscript map in thirty-six sheets; scale ca. 1:445,800. This incomplete map shows only the eastern half of the peninsula.

Size of the original: 225 × 228 cm. Image courtesy of the Biblioteca Nacional, Madrid (SG/M.XXXIII n° 224).

unknown date, is not extant but is listed in an 1808 sales catalog of Juan López (Hernando 2008, 204). Not until the middle of the eighteenth century was there a stream of diverse images of Spain composed by Spanish authors. An early one is a modest print from 1765 by Pablo Minguet with geographical text along the side to allow the audience to better assimilate its informa-

tion. Others include those by Tomás López, produced in single sheets and inserted in several compilations. To these we should add other simple cartographic prints illustrating literary works.

There is an enigmatic, large but unfinished manuscript wall map of the entire Iberian Peninsula; however, the circumstances of its production are unknown (fig. 320).

Its cartouche gives the authors as Jesuit priests of the Colegio Imperial de Madrid, Carlos Martínez and Claudio de la Vega, who executed it between 1739 and 1743 on the orders of Zenón de Somodevilla y Bengoechea, marqués de la Ensenada (Núñez de las Cuevas 1987, 54–55; Líter Mayayo, Martín-Merás, and Sanchis Ballester 2001, 109–11, no. 20).

Maps produced of some regions, especially those of the old Crown of Aragon such as Valencia (by Francisco Antonio Cassaus, 1693; Tomás López, 1762 and 1788; and Antonio José Cavanilles, 1795), Catalonia (by Josep Aparici, 1720, reedited 1769; Oleguer de Taverner i d'Ardena, comte de Darnius, 1726; Francisco Xavier de Garma y Durán, ca. 1760; and Tomás López, 1776), and Majorca (by Antoni Despuig i Damento, 1785), were of greater significance. Other regions, such as Galicia, Castile, Extremadura, and Andalusia, lacked printed single-sheet representations until those produced by Tomás López, although detailed manuscript maps of provinces such as Galicia were compiled during this period and served as sources for Tomás López's later printed maps (Manso Porto 2010–11). Aragon, for example, was represented by the continued reprinting of the drawing by João Baptista Lavanha (1620) and by those of Juan Seyra y Ferrer (1715) and Tomás López (1765). Military engineers drew a few regional maps, such as the large manuscript "El Principado de Cattalvña y condados de Rossellon y Cordaña" (1687) by Ambrosio Borsano (Líter Mayayo, Martín-Merás, and Sanchis Ballester 2001, 133–35, no. 30) or the printed *Mapa del Reynado de Sevilla* (1748) by Francisco Llobet, while civil engineers mapped the water canals. Land surveyors produced simple drafts of areas affected by irrigation projects, such as water canals, particularly in Valencia. There was also mapping of some episcopal dioceses, such as that of Toledo (by Luis Manuel Fernández de Portocarrero, 1681). As for urban cartography, warfare was the main reason behind the mapping, with illustrations of cities and towns appearing in foreign atlases. Many remained in manuscript form with some exceptions, such as Madrid (by Pedro Teixeira Albernaz, 1656), Valencia (by Tomás Vicente Tosca, ca. 1738), Seville (by Francisco Manuel Coelho, 1771), and Granada (by Francisco Dalmau, 1796; see fig. 928).

When the Spaniards Jorge Juan and Antonio de Ulloa joined the French expedition charged with measuring the arc of the meridian near the equator (1735–43), a new period in geographical mapping began. The resounding success of this mission and the increased fame of the *Carte de France* by the Cassinis encouraged these two government advisors to propose a *carta geométrica de España* (Reguera Rodríguez 2000). However, the lack of qualified personnel, the economic resources required for its production, and the absence of a learned society or academy to support it prevented this project

from flourishing in the eighteenth century. Nonetheless, an administrative desire for cartographic images of territories to aid implementation of reforms remained, producing results that, in the long run, proved to be more appropriate and more efficient. Tomás López and Juan de la Cruz Cano y Olmedilla, after their training as *pensionados* in Paris, undertook the preparation of maps required by government officials and the country. Tomás López's cartography visualized the diverse landscapes of the Iberian Peninsula. Cano y Olmedilla, on the other hand, lacking the intuition, capacity, or good fortune of his colleague, prepared fewer maps.

The *Atlas marítimo de España* (1789) attained greater fame. This project, directed by Tofiño, mapped the Spanish coast on a consistent scale. General agreement about the potential benefit for allocating human and economic resources led to the creation of the Depósito Hidrográfico (1789). Its task was to update information in these charts and to expand mapping into the colonies in America and the Philippines.

These were the significant maps, proposals, activities, and individuals related to geographical mapping in Spain during the Enlightenment. At the turn of the century, contacts with French scholars, who traveled to Spain to establish the Dunquerque-Barcelona arc (1792–1810), encouraged inquisitive youth to emulate their work and resuscitate the execution of the much desired *carta geométrica de España*. The results of these efforts did not appear until the map of Galicia (1845) drawn by Domingo Fontán.

AGUSTÍN HERNANDO

SEE ALSO: López de Vargas Machuca, Tomás; Spain; Tofiño de San Miguel y Vandewalle, Vicente

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Geographical Mapping in Spanish America. The spatial construction of Spanish American territories between 1650 and 1800 is a substantial topic, explored here through the specific example of the geographical mapping of New Spain. Four distinct and simultaneous sets of mapping processes fulfilled the needs of the Spanish Crown during the period. Various institutions and individuals expanded the use of these map genres in an increasingly complex Spanish administration so that a large number and variety of maps of American territories were produced by the end of the colonial period. The presence of many early maps in the archives offers new insights into the study of the Spanish Enlightenment and opens new lines of questioning about established problems in colonial inquiry (Moncado Maya 2009).

In the first mapping genre, the Spanish considered their American territories to be fragmented into discrete provinces and communities. These smaller regions were mapped, starting in the second half of the sixteenth century and continuing into the eighteenth, as part of the *relaciones geográficas de América*. Following traditional practices, the *relaciones geográficas* comprised answers to standardized questions that were printed in Madrid and circulated to the colonial authorities throughout Spanish America. The questions addressed multiple topics and also requested the preparation of regional and communal maps. Preparation of the answers fell to the political officials familiar with the local geographies; they questioned the most prominent people in each locale, who remembered the vestiges of a world ruined by biological and religious conquest. After the seventeenth century, administrative officers of the Crown replaced the key indigenous sources in the ongoing surveys, producing imbalanced reports: they varied widely in their descriptions of human characteristics, the quantity and quality of the information, and the number of their maps. The maps in the *relaciones geográficas* were consistently syncretic, combining indigenous with European modes of graphic expression; this syncretism did not give way in the eighteenth century to an overtly European form of cartography. The painted maps survive today as an independent body of images that link each territory with indigenous traditions of color signification and spatial models (Mundy 1996; Ruiz Naufal 2000, 63–69).

The image presented in the *relaciones geográficas* of the vast and disproportionate space of New Spain gave rise to a more uniform genre of ecclesiastical mapping in the work of José Antonio de Villaseñor y Sánchez, a criollo who became comptroller of taxes and of mining revenues in New Spain. As tensions between the Bourbon Crown and the Church increased, questions about the work of the missionaries across Spanish America pushed Felipe V to seek information about the state and progression of the Catholic missions. In 1743, Villaseñor y Sánchez was given the further title of cosmographer of

New Spain and commissioned to prepare and distribute a questionnaire among the prominent mayors and governors of each jurisdiction; he compiled their responses into his two-volume *Theatro americano, descripción general de los reynos, y provincias de la Nueva-España, y sus jurisdicciones* (1746–48), published in only fifty copies in Mexico City (Antochiw 2000, 73–77; Carrera 2011, 50–56, who also analyses the emblematic globe on the title page).

The *Theatro* described an “ecclesiastical republic” (Villaseñor y Sánchez 2005, 127). For each bishopric—of Mexico, Puebla, Michoacán, Oaxaca, Guadalajara, and Durango, but excluding Yucatán—it reported the status of the towns and ranches, including names, distances, boundaries, and geographical coordinates. It noted the number of families and the priests and vicars of each religious order (Franciscans, Augustinians, and Dominicans) with their convents, churches, and parishes. For each region it noted estates, language, commerce, livestock, agriculture, and minerals (Villaseñor y Sánchez 2005). While the *Theatro* itself did not contain graphic maps, Villaseñor y Sánchez’s patient information gathering, and his access to maps produced by Franciscan and Jesuit missions in the north, allowed him to construct a new general map of New Spain in 1746 (fig. 321) that would in turn serve as the basis for future maps (Trabulse 1983, 23–24). For example, in 1767, the criollo Jesuit mathematician and educator José Antonio de Alzate y Ramírez, who was a member of the Parisian Académie des sciences, extended Villaseñor y Sánchez’s geographical frame considerably, so as to accommodate the province’s territorial growth northward while maintaining the territorial organization of New Spain by bishoprics (fig. 322). Alzate y Ramírez’s work would also be published in Paris after 1775 (Antochiw 2000, 76–82; Carrera 2011, 59–60).

The greatest challenge for Spain was the need to map and understand the vast extent of the Spanish American coastline, producing the third genre in the geographical mapping of New Spain, that of maritime territory. In the second half of the eighteenth century, marine expeditions under the auspices of the Crown surveyed these strategic territories, and the secretary of the Marine in Madrid ordered the preparation of marine charts and more general maps of the Gulf of Mexico, Florida, the Tierra Firme, and the Antilles for the use of naval officers to protect and defend Spanish American possessions in anticipation of a growing English and Russian presence on American shores (Martín-Merás 2008). The *Portulano de la América septentrional* (1809) resulted from this work and comprised 112 detailed regional maps in four sections: the Antilles (15 maps); Colombia, Florida, and Gulf of Mexico (41 maps); Cuba (34 maps); and Haiti and Jamaica (22 maps) (Orozco y Berra 1871, 216–22). In addition to the treatment of coastlines, the



FIG. 321. JOSÉ ANTONIO DE VILLASEÑOR Y SÁNCHEZ'S 1746 MANUSCRIPT MAP OF NEW SPAIN. The map's title—"Yconismo hidrotterreo, o mapa geographico de la America septentrional"—did not refer to its nature as an ecclesiastical geography of the missions, convents, and churches of New Spain.

maps provided the Spanish Crown with a precise image of the system of fortresses constructed by military engineers for the defense of the Atlantic shore. Between 1806 and 1810, sailors and officers used primary observations and surveys to complete the *Derrotero de las islas Antillas, de la costas de Tierra Firme y de las Senos Mexicano* (1810). These expeditions produced small-scale maps of the Atlantic Ocean, medium-scale regional maps of the eastern coasts of America, and large-scale plans of areas around the ports (Martín Merás 2008).

Bourbon reforms and economic transformations in Spain led to the creation of a corps of military engineers that added to the technical transformation of geographical mapping, producing the fourth genre of geographical mapping in New Spain. Totalling nearly a thousand individuals and divided into different military ranks, the corps was trained in engineering and artillery at the Real Academia Militar de Matemáticas de Barcelona (opened

1720). From 1720 to 1808, ninety-five military engineers were employed in New Spain to construct a defensive circle throughout the Caribbean and the Antilles, creating a socioeconomic territory represented instrumentally in a series of maps of the region. The engineers were charged with directing public works of major economic importance in the ports and in the colonial cities, a veritable catalog of Enlightenment architectural improvements, comprising customs and money houses, town halls, academies, and even botanical gardens, tobacco factories, grinding mills, and foundries of iron and steel. Their labors also included studies of the mineral districts and maps of the mines (Moncada Maya 1993).

Their activity coincided with the desire of the Spanish Crown to extend its influence over the economic bounty of its American colonies. The Bourbon "reforms" under Carlos III in Madrid modified the political map of New Spain by breaking up the vast centralized power of the



Dedicado al Ill. Sr.
D. Felipe Antonio de
Caceres, Marqués de
S. Felipe, Virrey de
Nueva España, por el
Sr. D. Juan de Alarcón,
Ayudante de Campo,
y Comandante de
Armas de la Plaza de
S. Felipe de Mexico.



FIG. 323. DETAIL FROM THE “MAPA DE TODA LA FRONTERA DE LOS DOMINIOS DEL REY EN LA AMERICA SEPTENTRIONAL,” CA. 1768. A huge manuscript map of New Spain’s northern frontiers by military engineers Nicolás de Lafora and José de Urrutia.

Size of the entire original: 148 × 345 cm; size of detail: ca. 95 × 172 cm. Image courtesy of the Mapoteca Manuel Orozco y Berra, Servicio de Información Agroalimentaria y Pesquera, SAGARPA, Mexico City (1138, mapero 40, varilla 2, parciales 721).

viceroy. In 1786 new territorial divisions were introduced, establishing twelve new political units, or *intendencias*: Sonora, Guadalajara, Valladolid, Guanajuato, San Luis Potosí, Zacatecas, Durango, México, Puebla, Oaxaca, Veracruz, and Yucatán. Each enjoyed its own jurisdictional power and authority in the person of the *intendente*, who ruled autonomously from the political class of the New Spanish capital.

Within this new balance of power, some military engineers were stationed in the more distant, inhospitable, and unpopulated northern territories of New Spain, where they traveled extensively, inspecting roads and various other building projects. Their reports allow for the interpretation and construction of the economic space of these regions; they contained numerous economic valuations and suggestions for populating the land and were accompanied by maps of the New Spanish ports, from San Blas to the coast of California and the large territorial extensions of Sinaloa, Sonora, Chi-

huahua, upper and lower California, New Mexico, and also from the north coast of the Pacific (fig. 323) (Orozco y Berra 1881; León García 2009). The work of the military engineers in the southern regions represents the techniques of using more precise measuring instruments, the application of geometrical principles of surveying, and the addition of explanatory texts to accompany maps. These modernizing techniques were applied by the Spanish Crown not only in the older more distant colonial areas but, more importantly, in its strategy and new economic approach for the American territories, where the Crown sought to build up its finances in order defend itself against the growing and ever-enhanced power of the European states.

The work of Spanish geographer Tomás López reflected the technical debate surrounding new approaches to compilation mapping. His *Atlas geográfico de la America septentrional y meridional* (1758) dedicated eight of its thirty-eight maps to New Spain: provinces of México,

(facing page)

FIG. 322. JOSÉ ANTONIO DE ALZATE Y RAMÍREZ, “NVEVO MAPA GEOGRAPHICO DE LA AMERICA SEPTENTRIONAL ESPAÑOLA . . . DIVIDIDA EN OBISPADOS Y PROVINCIAS,” 1767. Alzate y Ramírez listed his

many sources on this large manuscript map of Spanish North America.

Size of the original: 177 × 210 cm. Image courtesy of the Museo Naval de Madrid (7-A-8).

Mechoacán, and Pánuco; provinces of Yucatán, Tabasco, Guaxaca, and Tlascalá; provinces of Guadalajara, Jalisco, Chiametlán, and Zacatecas; provinces of Nueva Vizcaya, Culvacán, and Sinaloa; provinces of Guatemala, Soconusco, Chiapa, and Vera Paz; and the more distant territories, like Nuevo México, California, and Nuevo Reyno de León; and Nueva Navarra, Pimeria, Sonora, Hiaqui, and Mayo. In his preface, López outlined some of his sources for the contents of the atlas, which provided an image of New Spain to a wider audience.

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SEE ALSO: Spanish America

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Geographical Mapping in Sweden-Finland. Until the 1740s, the *Orbis arctoi nova et accurata delineatio*, the large map of Northern Europe in six sheets by Andreas Bureus published in 1626 (Mead 2007, 1801 [fig. 60.18]), was the only domestically printed geographical map of quality to cover Sweden-Finland. Its unchanged copperplates were used for decades to print new copies

for use mainly in Sweden-Finland. Bureus's work served as the basis for many atlas and wall maps published elsewhere in Europe.

The Bureus map was copied first in Holland by Claes Jansz. Visscher (1630) and Willem Jansz. Blaeu (1634). In 1635 Henricus Hondius published a six-sheet edition by Hessel Gerritsz. and Isaac Massa. It corrected some mistakes made by Bureus (mainly in Denmark), but as a map of Sweden-Finland it was not better than the original. New mistakes were introduced, especially in Lapland and eastern Finland. Practically all printed general maps of Sweden-Finland up to 1747 were based either on the original Bureus map or its Gerritsz.-Massa edition.

One of the tasks of the surveyors sent to the Swedish provinces from 1628 onward was to draw geographical maps of each region (Mead 2007, 1802). During subsequent decades they sent to Stockholm maps of administrative regions, coastal maps, road maps, lake maps, and military maps. These maps usually lacked a coordinate system, although Carl Gripenhielm's compilation map of 1688 is an exception (see fig. 811). The emphasis was on Sweden proper; in Finland and in the Baltic provinces mapping went more slowly.

In the eighteenth century, the military became active as both map consumer and producer. After the Russo-Swedish War of 1741–43 Finland received higher priority. A civilian mapping commission was sent there in 1747 to produce manuscript maps of every parish at a scale of 1:20,000.

The production of printed geographical maps was almost nonexistent in Sweden-Finland during the years 1627–1738. One small general map of the kingdom was issued by Erik Dahlbergh (*Nova et accurata orbis arctoi tabula geographica*, 1696), and a provincial map showing Count Per Brahe's possessions in northeastern Finland was also published (*Tabella geographica Caianiae, illustrissimi et generosiss . . .*). From 1739 onward, printed geographical maps were published by Landtmäterikontoret (the land survey office) and by its employees privately—especially by Georg Biurman. The source materials for these maps included the maps sent to Stockholm by the surveyors and geodetic data produced from the 1730s. The following regional maps were printed: Lake Mälaren (1739), Uppland (1742), Västmanland (1742), Stockholm (1743), Södermanland (1743), Närke (1745), Bay of Finland (1742, 1788), Skåne (1752), watersheds surrounding the country (1771; 2 maps), Lake Vänern (1773), Lakes Vänern and Vättern (1774), southern Sweden (1778), episcopacy of Linköping (1779), Skaraborg province (1781), Älvsborg province (1781), Karlstad province (1783), Stockholm and Uppsala provinces (1785), Jönköping province (1788), Kronoborg province (1788), Blekinge province (1788), Åland Islands (1789), Heinola province (1793) (Lönberg 1903). Of these twenty-four maps only five depicted Finland.

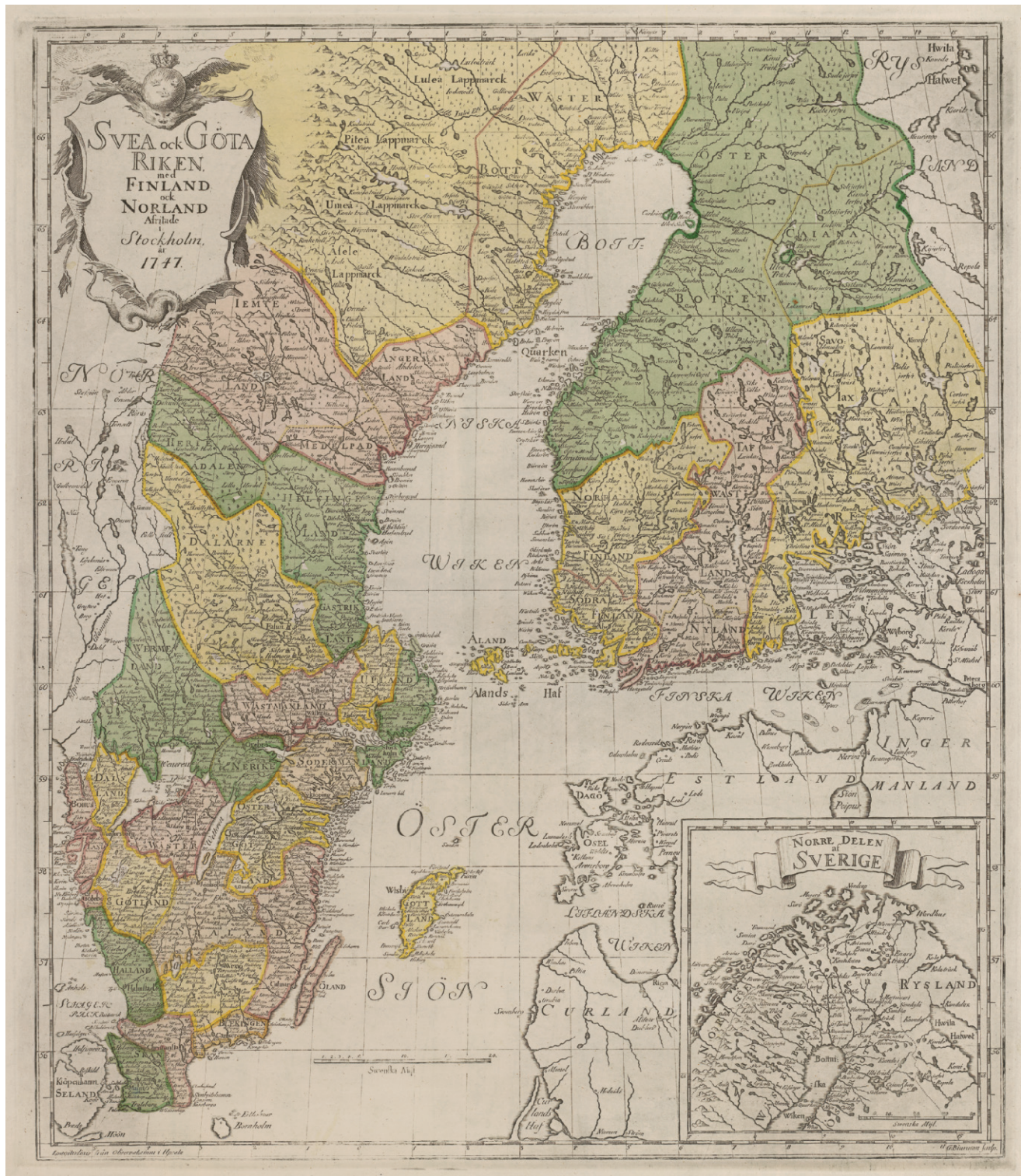


FIG. 324. GEORG BIURMAN, *SVEA OCK GÖTA RIKEN MED FINLAND OCK NORLAND* (STOCKHOLM, 1777). Copper engraving, ca. 1:2,500,000. This was the first domestic accurate general map of the country since the Bureus map of 1626. It corrected the worst mistakes of Bureus and became

the model for European mapmakers during the second half of the eighteenth century.

Size of the original: 57 × 50 cm. Image courtesy of Kungliga biblioteket, Stockholm (KoB 1 ab).



FIG. 325. CARL ERIK ENAGRIUS, *CHARTA ÖFVER SWERIGE MED TILGRÄNSANDE LÄNDER* (STOCKHOLM, 1797). The engraved map of Scandinavia in the Hermelin atlas was the first general map of the country giving it a “modern” look.

Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge CC 2618).

In 1747 Biurman published the first domestically produced accurate map of Sweden-Finland since Bureus (fig. 324). The map was not large but included enough correct details to surpass every earlier map. The major shortcomings of the Bureus map, the exaggerated extent of the country in the east-west direction and the faulty orientation of the Bay of Bothnia, were corrected. Biurman earlier issued a small general map of Sweden-Finland (1742) and two road maps (1743). The only

Swedish world atlas of the period was a small school atlas, *Atlas Juvenilis*, by Anders Åkerman (first edition 1768). Åkerman also made the first Swedish globes (1759) (Lönborg 1903, 179; Bratt 1968).

A new era started in 1797 with the publication of the first comprehensive atlas of the kingdom, *Geographiske chartor öfver Swerige*, containing thirty-three provincial and general maps (fig. 325). The atlas was a private effort by its initiator, Samuel Gustaf Hermelin. Hermelin

appointed a young Finnish cartographer, Carl Petter Hällström, as the “main geographer” (editor-in-chief) of the project, and he completed twenty-two of the atlas’s maps; Hällström has a good claim to be “the most prominent cartographer of Sweden and Finland ever” (Strang and Harju 2005, 3, 21).

The geographical maps of Sweden-Finland were made either on the conic projection or without any projection at all. Bureus had calculated longitude from the Azores. From the 1740s, the prime meridian or zero longitude was designated as the observatory at Uppsala. Scale was usually in Swedish miles (10.688 km).

In the peace treaties of 1721 and 1743, Sweden-Finland surrendered southeastern Finland (Finnish Carelia; Swedish Karelia) to Russia. The civilian surveying and mapping in Russian Finland became very similar to that on the Swedish side, but normally lagged about twenty years behind. The following double-page folio geographical maps were printed by Russian authorities: Russo-Swedish boundary (Ivan Kirilovich Kirilov, 1724), Viipuri/Viborg province (Kirilov, 1724; Jacob-Friedrich Schmidt, 1772; Aleksandr Mikhaylovsky Vil’brekht [Wilbrecht], 1792 and 1800), Käkisalmi/Kexholm province (Kirilov, 1727), Finland (Johann Elias Grimmel, 1743), Ingria and Carelia (Grimmel, 1743), Gulf of Finland (Schmidt, 1770), and Southern Finland (Vil’brekht, 1788) (Strang 2014). Smaller maps were also printed.

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SEE ALSO: Sweden-Finland

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Geographical Mapping in Switzerland. See Switzerland

Geographical Mapping in the Ottoman Empire. See Ottoman Empire, Geographical Mapping and the Visualization of Space in the

Geography and Cartography. The intersection between the spheres of cartography and geography in the age of the Enlightenment could appear, in definitional terms, so close as to amount to synonymy. At one level, this is driven by semantics: the history of language use shows “cartography” as a term did not exist in the En-

glish or French language until the mid-nineteenth century (Edney 2019). While Samuel Johnson’s *A Dictionary of the English Language* (1755), for example, contains entries for “map” and “chart,” the former being a land map, the latter a sea map, there is no entry for “cartography.” Equally, this is not mere semantics: the lack of the need for a separate term for the realm of mapmaking indicates the extent to which it was perceived as an activity that could be understood under the rubric of geography.

Enlightenment definitions of geography bear out this contention in that they either (and most commonly) suggest that the making of maps is a subset of the total set of geography’s activities or (less frequently) make geography out to be the science of mapmaking wherein the congruence between geography and mapmaking is closer still. That both variants exist in contemporary definitions suggests the extent to which the precise relationship between geography and cartography remains blurred and untheorized.

A good example of the first position, that mapmaking is a subset of geography’s activities, is contained in Johnson’s *Dictionary*, which in its approach reflects the web of interrelations established by a host of lexicographical projects in the Enlightenment. Johnson’s definition of “geography” is taken from the popular pedagogical tracts of Isaac Watts: “*Geography*, in a strict sense, signifies the knowledge of the circles of the earthly globe, and the situation of the various parts of the earth. When it is taken in a little larger sense, it includes the knowledge of the seas also; and in the largest sense of all, it extends to the various customs, habits, and governments of nations” (Johnson 1755). The first two clauses in this definition clearly could pertain to cartography, or at least suggest that cartography would have a major role in geographical instruction. Yet even here, to the extent that geography concerns knowledge of the globe and the seas, it is at some potential distance from the graphic representation of that knowledge that maps and globes represent. The final clause in Johnson’s definition sets up a still more apparent gap between the entirety of the project of geography and that of cartography, suggesting the centrality to geography of essentially prose-based forms of description in the arena we can designate (anachronistically) as human geography. If geography is more than that encompassed by mapmaking, however, in Johnson’s definitions mapmaking is entirely subsumed by geography: “Map . . . A geographical picture on which lands and seas are delineated according to the longitude and latitude” (Johnson 1755). In essence, Johnson’s *Dictionary* and many like it retain a definition of geography’s scope and practice derived from Strabo, wherein there will always be a larger set of activities for the subject than can be encompassed by the information encoded in maps and globes.

The second definitional position common in the

Enlightenment, wherein geography is closer to being encompassed by the activities of the mapmaker, is derived from the Ptolemaic understanding of the scope and methods of geography. If dictionaries tended to the Strabonic position, encyclopedias and dictionaries of the arts and sciences perhaps unsurprisingly moved toward the Ptolemaic position, concentrating as they did on the scientific and craft skills by which objects were made. A good example of this can be found in the treatment of geography in Ephraim Chambers's influential encyclopedia, *Cyclopædia* (1728). The "Preface" explains geography as "the Doctrine of the EARTH, OR GLOBE: its Circles; Parallel, Tropic, Horizon, Axis, Poles, &c . . . Instruments relating thereto, Globe, Map, &c" (Chambers 1728, 1:v). This definition of geography is self-evidently couched in the language of cartographic representations. It also makes a close connection between geographical knowledge and the manner in which that knowledge is represented, either in the form of a globe or map—a consideration that is entirely missing from Johnson's lexicographical approach but fits neatly with Chambers's desire to produce a dictionary of the crafts in Enlightenment Europe. This understanding of the cartographic practices of geographical representation as being central to the definition of geography is reinforced by a long entry concerning the construction of maps that addresses questions of map projection for global and small area maps. Yet Chambers's entry concerning geography makes a clearer categorical distinction between two ways to define geography: geography can be "the Doctrine or Knowledge of the *Earth*" or it can be "a Description of the Terrestrial Globe" (Chambers 1728, 1:140). These definitions suggested geography was not only a discipline that subsumed mapmaking but was also a broader activity concerned with the real nature of the earth, not just its description (as Johnson suggests). These definitions create a further distinction in that geography could be described in prose as well as in maps and globes. During the Enlightenment, *description* equally embraced prose or graphic forms, such that definitions of geography as a descriptive subject by no means excluded that description being in the form of maps or globes. Care should therefore be taken not to project the restrictive modern prosaic understanding of the word "description" onto the Enlightenment term.

Either approach to defining the relationship between geography and mapmaking—the Strabonic or the Ptolemaic—however, makes it apparent why the Enlightenment did not develop a semantic field for cartography as a separate discipline or practice: mapmaking was a mathematical craft whose disciplinary location was squarely within geography. The point of contention was whether geography was an inquiry far broader than mapmaking, concerning knowledge rather than its modes of repre-

sentation, not whether mapmaking was to be seen as an essentially geographical descriptive practice.

This sense of geography and cartography as being either synonymous or of mapmaking being a subset of geography is confirmed by two further sets of evidence. First, the attempts to develop encyclopedic trees of knowledge throughout the age of the Enlightenment persistently fail to locate mapmaking as a separate practice or realm of knowledge (even where, as in Chambers's *Cyclopædia*, they have an entry about the principles of mapmaking and globemaking), but they do include a definition of geography that allows for the subsumption of cartography under that rubric (fig. 326). From the time of Johann Heinrich Alsted's *Cursus philosophici encyclopaedia* (1620) through to the celebrated *Encyclopédie* of Denis Diderot and Jean Le Rond d'Alembert (1751–72), geography is consistently placed in the realm of "mixed" (i.e., applied) mathematics (Hotson 2000, 71; Withers 1996) (see fig. 226). This positioning ignores the Strabonic aspect of geography as the "eye" of history, one of the great commonplaces of Enlightenment geography books, preferring to locate geography through its Ptolemaic definition as a mathematical inquiry. Within such divisions of knowledge, cartography is not given an independent role, but is implicitly central to geography, being the graphic representation of the findings of an applied mathematical inquiry.

Second, the Enlightenment sees the first attempts at consolidated histories of geography as a discipline that also allies geography and cartography. Most influential was Didier Robert de Vaugondy's *Essai sur l'histoire de la géographie* (1755), which meshed together a history of exploration with advances in the theory of map projections, taking this to amount to a history of geography. For Robert de Vaugondy it was self-evident that the history of maps was an element of the history of geography (Godlewska 1999, 33–34). Closely comparable and the most notable contribution to this genre in the English tradition was John Blair's "On the Rise and Progress of Geography" of 1768 (reprinted as Blair 1784), an essay that was used extensively in the construction of the entry on geography in the second edition of the *Encyclopædia Britannica* (1778–83). In Blair's account, the titular "progress" in geography is equated with the development of more skilled mapping techniques and more accurate maps. Blair elides any separation between maps and geography because, akin to encyclopedic trees of knowledge, he views geography as a mixed mathematical subject with close relations to astronomy: "It is not my present Intention to register all the particular Discoveries of *Astronomy*, but only to explain such of them as are intimately connected with *the Progress of Geography*; for their Advances were so often made by the same Steps, that the one is not to be clearly

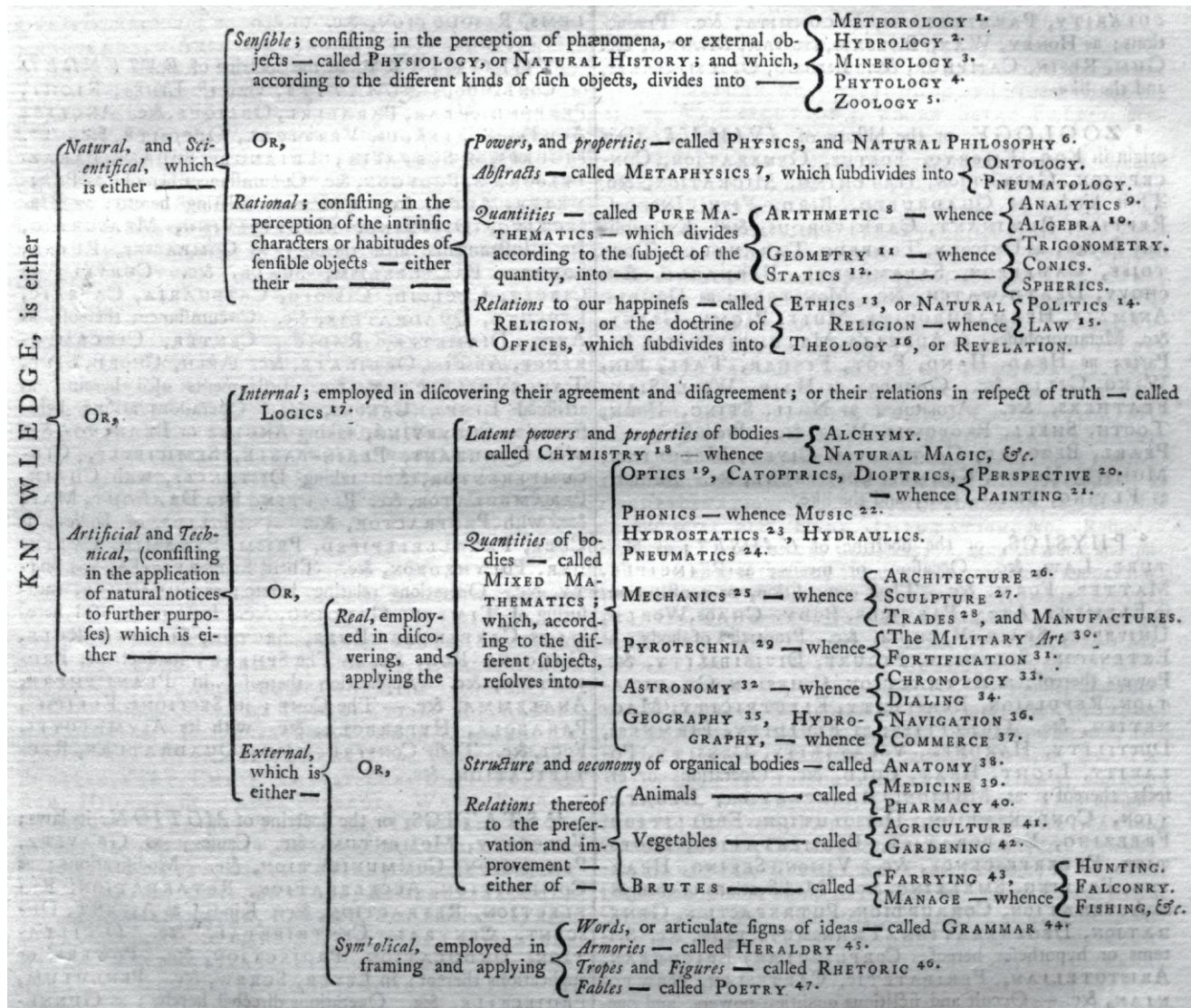


FIG. 326. CLASSIFICATION OF KNOWLEDGE IN EPHRAIM CHAMBERS'S CYCLOPÆDIA. From the preface to Chambers's *Cyclopædia; Or, An Universal Dictionary of Arts and Sciences*, 2d ed., 2 vols. (London: Printed for D. Midwinter et al., 1738), 1:iii.

Size of the detail: 16 × 19 cm. Image courtesy of the Department of Special Collections, Memorial Library, University of Wisconsin-Madison.

understood without the other” (Blair 1784, 14). Blair’s *History* narrates the advancement in the techniques for determining longitude and latitude and the increasing mathematical sophistication of the maps this facilitated, true to the Enlightenment spirit of optimism in progress, but he concludes that “Geography is a Science even still many Stages removed from Perfection” because “every new Map . . . seems to blast all those that went before them” (Blair 1784, 183–84). For Blair, Robert de Vaugondy, and the Enlightenment historians of geography in general, maps at the very least were the key surviving archival evidence for a narrative of geography’s ad-

vancement, and often by conflation the history of maps simply amounted to the history of geography.

Pedagogic theory and educational practice in the Enlightenment largely supports the intersection of geography and cartography, which the lexicographical and encyclopedic evidence canvassed so far suggests. Map-making and map reading had no separate space in the curricula of the era, but they were so central to geographical instruction as to amount to its entirety in the accounts of some educationalists and at the very least to the key means of geographical instruction for most writers. Vital here was John Locke’s *Some Thoughts Con-*

cerning Education (1693). Locke depicted geography as a subject suitable to young boys because it could be taught (at least in its rudiments) as an ocular subject, using only maps and globes: “Geography, I think, should be begun with: For the learning of the Figure of the *Globe*, the Situation and Boundaries of the Four Parts of the World, and that of particular Kingdoms and Countries, being only an exercise of the Eyes and Memory, a child with pleasure will learn and retain them” (Locke 1989, 235). *Some Thoughts Concerning Education* was probably the most influential educational treatise in the Enlightenment (Pickering 1981, 9–12), and its strictures concerning geography, tying the discipline inextricably to maps and globes, ramified across the world and down the long eighteenth century. Thus the influential French educationalist Charles Rollin maintained that the simplest, easiest, and most memorable way to teach geography was to point out places on a map (Rollin 1735, 21–22), while a century after Locke, Vicesimus Knox’s image of liberal education in geography was still entirely Lockean: “I would not place a geographical treatise in his [the pupil’s] hands. I would not burden his memory. . . . I would, at first, only give him a map of Europe, a map of Italy, and a map of Greece” (Knox 1781, 159).

This conjunction of geography and maps was not merely in the realm of pedagogic theory but demonstrably impacted actual teaching practice at all ages and in all educational contexts. Thus in grammar schools John Clarke reported on his curriculum in Hull suggesting the subject was learned “with a great deal of Ease and Pleasure: For the Sight of a *Map* is as entertaining to them as a Picture” (Clarke 1730, 93–94). Likewise, university education in geography, while not a formal part of the curriculum, pivoted around the use of globes and maps, drawing on the previously mentioned connection between geography and astronomy (Withers and Mayhew 2002). John Keill’s astronomical lectures at Oxford University, for example, encompassed the “doctrine of the sphere” and included a lecture on the description and use of globes, together with a set of trigonometrical problems based on longitudes and latitudes on the globe (Keill 1721, 218–31, 381–96). A century later, precisely the same material was a key part of the Cambridge tripos examination, details of which could be found in *Cambridge Problems* (1821), the published version of past examination questions, which included sections on “projection of the sphere” and the “figure of the earth” (40, 194). In the less privileged world of self-education, Thomas Wise recommended the use of maps in discussing “how to learn Geography without the directions of a Master” (Wise 1754, 240). Likewise, it was the Lockean depiction of geography as an easy subject to learn via ocular demonstration that made it generally accepted as a subject suitable for female education in the sciences



FIG. 327. FRONTISPIECE FROM BENJAMIN MARTIN, *THE YOUNG GENTLEMAN AND LADY'S PHILOSOPHY*, 2 VOLS. (LONDON: W. OWEN, 1759–63), VOL. 1. Image courtesy of the American Philosophical Society, Philadelphia.

in the Enlightenment, with works such as Benjamin Martin’s *The Young Gentleman and Lady’s Philosophy* (1759–63) catering to this market (Mayhew 1998) (fig. 327).

It was only at the end of the Enlightenment period that the symbiosis between maps and geographical education was called into question together with so many other educational truisms of the age by Jean-Jacques Rousseau’s *Émile, ou de l’éducation* (1762). In *Émile*, Rousseau argued that geography had to be learned by directly experiencing real environments rather than through the mediations of prose or graphic representations: “In the first operations of the mind let the senses always be its guides. No book other than the world. . . . You want to teach ge-

ography to this child, and you go and get globes, cosmic spheres, and maps for him. So many devices! Why all these representations? Why do you not begin by showing him the object itself, so that he will at least know what you are talking to him about?" (Rousseau 1979, 168). Powerful as this clarion call was, the majority of Enlightenment pedagogy chose to retain Locke's map-driven approach to geographical education. It was only in the nineteenth century that Rousseau's ideas, compounded and inflected by the ideas of Johann Heinrich Pestalozzi and Philipp Emanuel Fellenberg, began to uncouple geographical education from maps (Elliott and Daniels 2006).

As print practices, the intersections between geography and cartography in the Enlightenment were rather more vexed and complicated than the harmonious synergy that definitional and educational evidence suggests. Furthermore, the nature of the intersection varied over time and space because of the varied print cultures of different nations in the Enlightenment. Comparing England and France, for example, one finds widely divergent relations between geography and maps driven by the different print practices in the two nations and by differing conceptions of the sphere of geography (Withers 2007).

In Britain, printing was driven by cutthroat commercial considerations: booksellers had sovereign authority in a system where authors were paid pro rata, a system encouraging recycling and plagiarism if authors were to survive and booksellers were to make their margins (St Clair 2004). The result for geographical publishing in particular was the endless recycling of geographical publications with little new in them except a new title page in the hope of clearing stocks (Mayhew 2000, 25–42). The result for cartographic publishing was much the same: "Copying, reengraving, and selling someone else's labor were lifeblood to the map trade throughout the eighteenth century" (Pedley 2005, 96). This commonality between the print practices for maps and geography books was in good part because the British print tradition did not develop the concept of a specialist map printer-publisher; the Grub Street publishers of textual and cartographic geographical descriptions were often one and the same. Putting the two together, the maps contained in geographical texts were often of very low quality, being copied from previous editions or even simply carried over from other projects. As a result, the maps in geographical textbooks sometimes contradict the text itself and frequently embody information that does not correlate with the places and patterns contained in the prose description. A good example of the sorts of conjunctions between geographical text and maps encouraged by British Grub Street publications is provided by Richard Blome (Mayhew 2010). In *A Geographical Description of the Four Parts of the World* (1670), Blome had spliced together his translation of

Bernhardus Varenius's *Geographia generalis* (1650) with material translated from Nicolas Sanson, as well as twenty-eight global, continental, and national maps taken from Sanson's French original. This was not commercially successful, so in 1682 he enlarged it to two volumes with the title *Cosmography and Geography*. When this also failed to sell, Blome then conjoined it with a set of John Speed's county maps of England, re-issuing the whole as a new edition in 1693 with fifty maps in the hope of clearing his stocks and recouping his invested capital. Clearly, the three geographical projects had no coherence and were not designed to be conjoined, working as they did at different spatial scales, from the global (which was normally defined as the appropriate scale for geography in the Enlightenment) to the local in Speed's maps (which was normally deemed to be a separate inquiry in this era, that of chorography). They also conflated contradictory conceptions of geography in that Varenius's mathematical approach and Sanson's descriptive understanding of the geographer's task were juxtaposed, the two texts being translated without their contradictions being addressed. The cartographic element of the project was likewise chaotic, splicing together two sets of maps with no real interrelation, local maps being appended exclusively to the description of Britain in a text that otherwise (as was standard for geographical descriptions) contained only global, continental, and national maps. The project also conjoined maps from very different eras, none of them being originally designed for Blome's project, Speed's maps first having been published nearly a century prior in 1606, well over half a century before Sanson's. The commercial pressures of English print culture made such projects entirely common in the world of geographical and cartographic publishing. Commercial expediency led to the juxtaposition of cartographic and geographical material in British publishing that was dissonant or contradictory rather than the harmonious ocular demonstration of geographical information via maps and globes that education theory proposed.

French print practices differed considerably from those in England and created a different and far closer interaction between the spheres of geography and cartography in the age of the Enlightenment (Godlewska 1999). First, France had a set of engravers who specialized in map production. Furthermore, French privilege seems to have been more effective in securing intellectual property rights in maps than was the English copyright system (Pedley 2005). Likewise, French geographers were trained humanists where their English counterparts tended to have no specific affinity for geography, merely having turned to it to make a commercially viable product. Partly as a result of the training French geographers received, French geographical culture defined the role of

the geographer differently and less commercially than did British print culture. In France, geography revolved around the creation of maps, which involved the scholar in sifting through textual accounts of places and previous maps for information wherein contradictions were adjudicated and reconciled to create a final, authoritative map. The geographer's task was the collation that led to a cartographic construction—not, as in England, the creation of a freestanding (mainly plagiarized) prose geographical description to which maps (often wholly contradictory or simply unrelated) were then appended. “The defining feature of a French map from the first half of the eighteenth century was the printed *mémoire*, explaining how the map was made” (Pedley 2005, 29). Looked at the other way around, the main genre of geographical writing in France was the *mémoire*, whose rationale was wholly map-led: “in the eighteenth century, geography straddled map and text and measurement and erudition. . . . In form and function they share a single descriptive purpose which makes the texts read like maps and the maps difficult to evaluate without their textual context” (Godleswka 1999, 37). This model influenced some British geographers, notably James Rennell (Mayhew 2000, 193–206), but it was the mainstay of French geographers such as Jean-Baptiste Bourguignon d’Anville and Philippe Buache, and the great geographical dynasties, the Delisles and the Robert de Vaugondys. As a result, in French print practice geography was inextricably tied to cartography, the two projects forming a seamless unity that was unthinkable in Britain thanks to the different training deemed necessary for the geographer and the different print culture in which the production of geographical and cartographic works occurred.

In sum, during the Enlightenment, geography was understood to subsume mapmaking within itself, the only question being the extent to which geography amounted to more than the science of graphically representing the earth. Educational theory and practice in the wake of Locke reinforced this intellectual filiation, making cartography the key conduit for instruction in the essentially ocular realm of geographical education throughout the eighteenth century. As descriptive practices, the relationship between geography and cartography varied considerably between places because of different educational and print regimes.

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SEE ALSO: Education and Cartography; Encyclopedias; Geographical Mapping; History and Cartography; Imaginary Geographies and Apocryphal Voyages; Map Trade; Public Sphere, Cartography and the

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Geological Map. See Thematic Map: Geological Map

German States. As used in the present volume, the “German states” approximate the political realities of Central Europe in the period between 1650 and 1800.

Contemporaries distinguished between two ambiguous regional concepts. First, Deutschland or Teutschland—Germania (Latin), Allemagne (French), Germany (English)—referred to the lands of the German people or *Volk*, itself an idealization, and as such drew on classical and medieval conceptions of the extent of the ancient German tribes as well as the more contemporary understanding of the extent of speakers of the German language. This multifaceted region was territorially indistinct. As Friedrich Schiller and Johann Wolfgang von Goethe observed in 1797, “Deutschland? But where is it? I know not how to find the country” (quoted in Reed 1980, 87). What Schiller and Goethe would have found on maps was the *Reich*, the Holy Roman Empire of the German nation. Even in the eighteenth century, after many provinces, notably the Dutch Republic and the Swiss cantons, had broken away or had been annexed by France, the *Reich* extended far beyond the German-speaking areas to embrace the Southern Netherlands (today’s Belgium and Luxemburg), the mixed-linguistic Kingdom of Bohemia (the only kingdom within the *Reich*), and much of northern Italy (although the precise borders were disputed).

As an institution, the *Reich* retained many of its feudal characteristics. The German emperor and his nominated successor, the so-called King of the Romans (Römischer König), had always been elected. With extensive territories within and beyond the *Reich*, the Catholic Austrian Habsburgs had long controlled the imperial throne. Territorial authority was dynastic in nature and was divisible and inheritable. Over the centuries, the *Reich* had fragmented into a *Flickenteppich* (patchwork carpet) of almost three hundred imperial estates (*Reichsstände*), each ruled by a *Landesherr*, who variously enjoyed the titles of prince (*Fürst*), duke, or count. In the eighteenth century, eight or nine *Landesherren* were also electors (*Kurfürsten*), who selected each new emperor. The 1648 Treaties of Münster and Osnabrück—forming the Peace of Westphalia that ended the Thirty Years’ War (1618–48)—ensured freedom of confession within the *Reich* for Catholics and Protestants alike. But in doing so, the treaties promoted the autonomy of the *Landesherren*, permitting the most powerful of the territorial magnates to contest the authority of the emperor and the imperial system. Even so, the *Reich* continued to organize the estates within ten regional *Kreise* (circles), by which the imperial judiciary, taxes, and military levies were coordinated. The major *Landesherren* tried to ignore the authority of the *Kreise* assemblies, in which they were outnumbered by the minor *Landesherren*, but the *Kreise* remained an important counterweight to the magnates’ increasing autonomy.

The resultant *Kleinstaaterei*, or “petty particularism” (Wilson 2004, 5), lasted until 1801, when the *Reich*’s

system of military levies and mutual defense, organized through the *Kreise*, finally broke down during the French Revolutionary Wars and when the smaller estates began to be rapidly absorbed by both Napoleon and the greater magnates. The *Reich* itself formally dissolved in 1806. The Habsburgs’ own disparate territories extended far beyond the *Reich* and formed a largely distinct political entity; for this period, the Habsburg territories are most appropriately known as the Austrian monarchy. Thus, between 1648 and 1801, the German states made up the *Reich*, with the addition of Brandenburg’s Prussian territories, but not the territories of the Austrian monarchy, which are the subject of separate entries in this volume. The literature elucidating and detailing all the nuances of the *Reich*’s organization and history in this period is understandably extensive; Peter H. Wilson (2004) provides a detailed and comprehensive overview.

After 1648, the *Landesherren* asserted their own independence, contested the emperor’s authority, and participated in wider European politics and wars, even as they competed among themselves for new titles and status that only the emperor could grant. The greatest prize, of course, was the position of elector. The largest autonomous estate was that of the Calvinist Hohenzollern dukes of Brandenburg, in the north. Already electors, the dukes progressively challenged the Habsburg emperors directly: they used their possession of lands to the east of the *Reich* to secure sovereign status in European political affairs, first through their recognition by the Polish Crown to be kings *in* Prussia in 1701 and then, after the First Partition of Poland-Lithuania in 1772, as kings *of* Prussia; in between, they annexed Habsburg Silesia during the War of the Austrian Succession (1740–48). The Lutheran Welf dukes of Brunswick-Lüneburg were created electors of Hanover in 1692, largely as a counterweight to the Calvinist electors of Brandenburg; in 1714, Elector Georg Ludwig succeeded the Protestant Stuart dynasty as George I of Great Britain. The Lutheran electors of Saxony converted to Catholicism to enable their election as kings of Poland between 1697 and 1763. A few other imperial estates were large enough to sustain the pretensions of their rulers, such as the Wittelsbachs, different branches of which were dukes and electors of both Palatine and Bavaria. Rather than seeking foreign titles, the Wittelsbachs consolidated their power by obtaining election to ecclesiastical positions for their younger sons, often acquiring territories and electoral rights in the process. Indeed one Wittelsbach, Charles VII, reigned as Holy Roman Emperor between 1742 and 1745. But most of the estates were quite small, some only a few square miles in extent. In total, the eighteenth-century *Reich* comprised ten *Kreise* with over two hundred estates, ruled by various electors,

Fürsten, dukes, counts, and prelates; fifty-one largely autonomous imperial cities, including Augsburg, Nuremberg, Frankfurt, and Hamburg; and some 1,500 tiny estates held by imperial knights (Wilson 2004, 10, 41).

Cartographic activities in the eighteenth-century German states were very much shaped by these political, territorial, and historical trends. It took many decades for the economy to regain its former vibrancy after the devastation wrought by the Thirty Years' War. The war had reduced Central Europe's population by a staggering 25 to 40 percent and had severely disrupted agriculture, manufacturing, and trade throughout the *Reich*. As suggested by the slow expansion of commercial map production in the imperial cities, the economy remained weak even as late as 1750.

Without a major stake in colonial designs or world trade, there was little impetus for Germans to sustain or develop a detailed interest in the geography of overseas countries. German geographical practice thus remained dominated by an intellectual approach to the systematic description of the entire world, as in Anton Friedrich Büsching's huge geographical works, and by the pragmatic elucidation of the German states's territorial complexities. To accomplish the latter, geographers adhered to the traditional division of the *Reich* into its ten *Kreise*. In the early 1700s, Johann Baptist Homann did attempt a new, "natural" definition of Germania made up of the watersheds of major rivers (see fig. 296), but otherwise he adhered to the established practice of presenting first the *Reich* in its entirety (see fig. 375) and then each *Kreis* in turn. Maps of the Habsburg and Hohenzollern provinces outside of the *Reich* were therefore arranged within separate sequences of maps of Eastern Europe. Early eighteenth-century bibliographies of the best maps available to German consumers followed the same organization: *Reich*, *Kreise*, and then, within each *Kreis*, any maps that had been produced of particular estates (Gottschling 1711, 86–96; Gregorii 1713, 474–522; Hauber 1724, 70–91). Eighteenth-century atlases published outside the *Reich* used the same territorial organization of *Reich* and *Kreise* (fig. 328).

The fragmentation of territorial responsibilities between the estates and *Kreise*, and the lack of a standing *Reich*-wide imperial army, meant that there were no attempts to topographically survey and map the *Reich* as a whole in the way that the Habsburgs mapped their own territories. Detailed surveying and mapping were a function of each individual estate, and only a few were large enough either to carry on such surveys or to support the absolutist ambitions of the *Landesherren* who sought to emulate the prestige of the French kings. The major *Landesherren* actively redesigned and expanded their main residence-towns (*Residenzstädte*), such as Berlin, Munich, and Hanover. These administrative-military centers became boomtowns, growing much faster than

the established manufacturing centers in the imperial cities. The growth of the residence-towns, and their rulers' grandiose plans, drove much of the urban mapping in the German states during the eighteenth century.

The wealthier *Landesherren* were also able to establish new scientific academies and universities that became centers of cartographic thought and practice. In Brandenburg-Prussia, Friedrich I created the *Societät der Wissenschaften* in Berlin in 1700 to promote the natural sciences and the humanities and also to stimulate mapping projects. For example, the academy undertook the first German marine atlas for the government after Brandenburg-Prussia acquired the coastal territories of East Frisia and Emden in 1749. In 1734, Elector Georg August of Hanover (i.e., George II of Great Britain) founded Göttingen University to promote scholarship censored only by the ruler and not by any church. In the 1750s, the university attracted several members of the privately organized and cartographically active *Kosmographische Gesellschaft* in Nuremberg, notably the astronomer and geographer Tobias Mayer, who would focus on the lunar observations needed to solve the problem of determining longitude at sea.

What most estates undertook were detailed topographical and property surveys. Both kinds of surveying were marked by the steady development not only of standards but also of a coterie of trained individuals who moved across the German states, the Austrian monarchy, and other states beyond the *Reich*. Property mapping was primarily a local affair, carried on by landowners and also by administrations interested in rationalizing their finances. Not all property surveys, not even the cadastral surveys of large estates, were intended to produce graphic property maps; rather, assessments of quality and area measurements remained in written tabular form, as for example with the cadastral survey of the Duchy of Württemberg (1713–36). Moreover, the cadastral surveys were concerned only with the properties from which the estates took income, and so did not provide comprehensive coverage of each estate.

Topographical mapping for military purposes was widely undertaken, especially mapping fortifications and their environs, but the Seven Years' War revealed the lack of more systematic topographical knowledge. A variety of new surveys were undertaken during the war, as when Brandenburg-Prussia occupied and mapped a large part of Saxony, and more surveys were undertaken after the conflict. Most lacked a triangulated basis, as was the case with Friedrich Wilhelm Carl von Schmettau's survey of Brandenburg-Prussia and neighboring territories from 1767 to 1787 (Flint and Jordan 2009; Scharfe 1972, 48–90). French-style triangulation-based surveys were progressively adopted: César-François Cassini (III) de Thury's 1761–62 triangulation from Paris to Vienna proved too inaccurate to serve as the foundation



FIG. 328. GERMANY AS THE REICH. Non-German geographers generally mapped Germany as the Holy Roman Empire: *La Germania divisa ne suoi circoli di nuova proiezione*, originally published in 1776, from Antonio Zatta, *Atlante novissimo*, 4 vols. (Venice, 1779–85[99]), vol. 2.

Size of the original: 37 × 48 cm. Image courtesy of the John Carter Brown Library at Brown University, Providence.

for the survey of Bavaria, but promoted the concept of such a work (Schlögl 2002, 99–107). At the end of the century, the French Revolutionary Wars led to a series of triangulation-based surveys at 1:86,400 or larger, in Swabia (after 1793), in Westphalia by Brandenburg-Prussia (1796–1805), and in Bavaria and the Rhineland by the French (after 1801) (Meurer 1986, 1:170). Only after 1763, in conjunction with this new wave of mapping, were topographical surveys routinely compiled into detailed smaller-scale regional maps of each estate. Older concerns for secrecy gave way as estates sought to modernize and reform. *Landesherren* engaged in a variety of cartographic exercises to control territory, clarify boundaries, and marshal economic resources. Large estates such as Bavaria pursued such work (Schlögl 2002) (see fig. 191), as did smaller ones, such as the bishopric of Augsburg (Wolfart 2008).

Given the nature of the eighteenth-century *Kleinstaaten*, German scholars have necessarily focused on the progressive mapping of each estate or particular region before 1800. Ingrid Kretschmer (1987, 1), Wolfgang Scharfe (1997, 23–25), and Markus Heinz (2010, 187–88) have all argued that this dominant historiographic pattern originated with the region-by-region historical accounts of Gottschling (1711), Gregorii (1713), and Hauber (1724). The local character of the relevant archives has perpetuated the several regional foci, as has a persistent German localism (Heinz 2010, 190). The result is the distribution of the literature on German cartography in the long eighteenth century across a variety of local history journals, monographs published by local societies, the proceedings of the Kartographiehistorisches Colloquium (1982–), and also the *Lexikon zur Geschichte der Kartographie*, with its par-

ticular emphasis on Central Europe (Kretschmer, Dörflinger, and Wawrik 1986). Recent studies that have sought to understand eighteenth-century mapping activities in terms of the Enlightenment absolutism of the major *Landesherrn* have adopted a narrow focus in their spatial extent (e.g., Schlögl 2002; Fieseler 2013). Such fragmentation has informed the entries in the present volume that deal with the larger-scale detailed mapping modes (property, urban, and topographical mapping), and more conclusive statements about the character of cartographic practices as pursued across the German states await further comparative archival research.

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SEE ALSO: Academies of Science; Austrian Monarchy; Büsching, Anton Friedrich; Geographical Mapping; Map Trade; Marine Charting; Military Cartography; Poland-Lithuania, Partitions of; Property Mapping; Thematic Mapping; Topographical Surveying; Urban Mapping

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Globe.

GLOBES IN THE ENLIGHTENMENT

TERRESTRIAL GLOBE

CELESTIAL GLOBE

INSTRUCTIONAL TEXTS FOR THE USE OF GLOBES

POCKET GLOBE

LUNAR GLOBE

RELIEF GLOBE

CULTURAL AND SOCIAL SIGNIFICANCE OF GLOBES

Globes in the Enlightenment. Globes were a pervasive element of the material culture of Europe's elites and middling sorts throughout the Enlightenment, serving prominently as symbols of power, authority, and knowledge. Most commonly, they were produced in pairs, following the practice developed in the Renaissance in which globes representing the terrestrial and celestial spheres were mounted in identical stands (Dekker 2007, 136). At the same time, the globe concept was understood generically; the *Encyclopædia Britannica* (1771, 2:722) accordingly offered the definition of "an artificial spherical body, on the convex surface of which are represented the countries, seas, &c. of our earth; or the face of the heavens, the circles of the sphere, &c." The concept could therefore be applied to other phenomena, notably the moon (lunar globes), and to new, specialized forms (particularly relief globes and precession globes, a form of celestial globe). This entry reviews the overall character of Enlightenment globes and globe production; the following entries provide more specific discussions of the types and uses of globes.

In addition to symbolizing earth and the heavens, terrestrial and celestial globes served as didactic, problem-solving devices with which to demonstrate a whole series of phenomena as described in numerous instructional manuals. In this respect, the standard globe pair was a very successful formula that was barely affected by the Copernican idea that the earth moves around its own axis and around the sun. Instead, the standard globes perpetuated the Ptolemaic understanding that placed the earth at the universe's immobile center. Joseph Harris (1734, 37) represented most globemakers when he justified this persistent practice: the cosmos is observed from a geocentric perspective, so it is more effective to explain it with Ptolemaic models. When moved, the spheres of

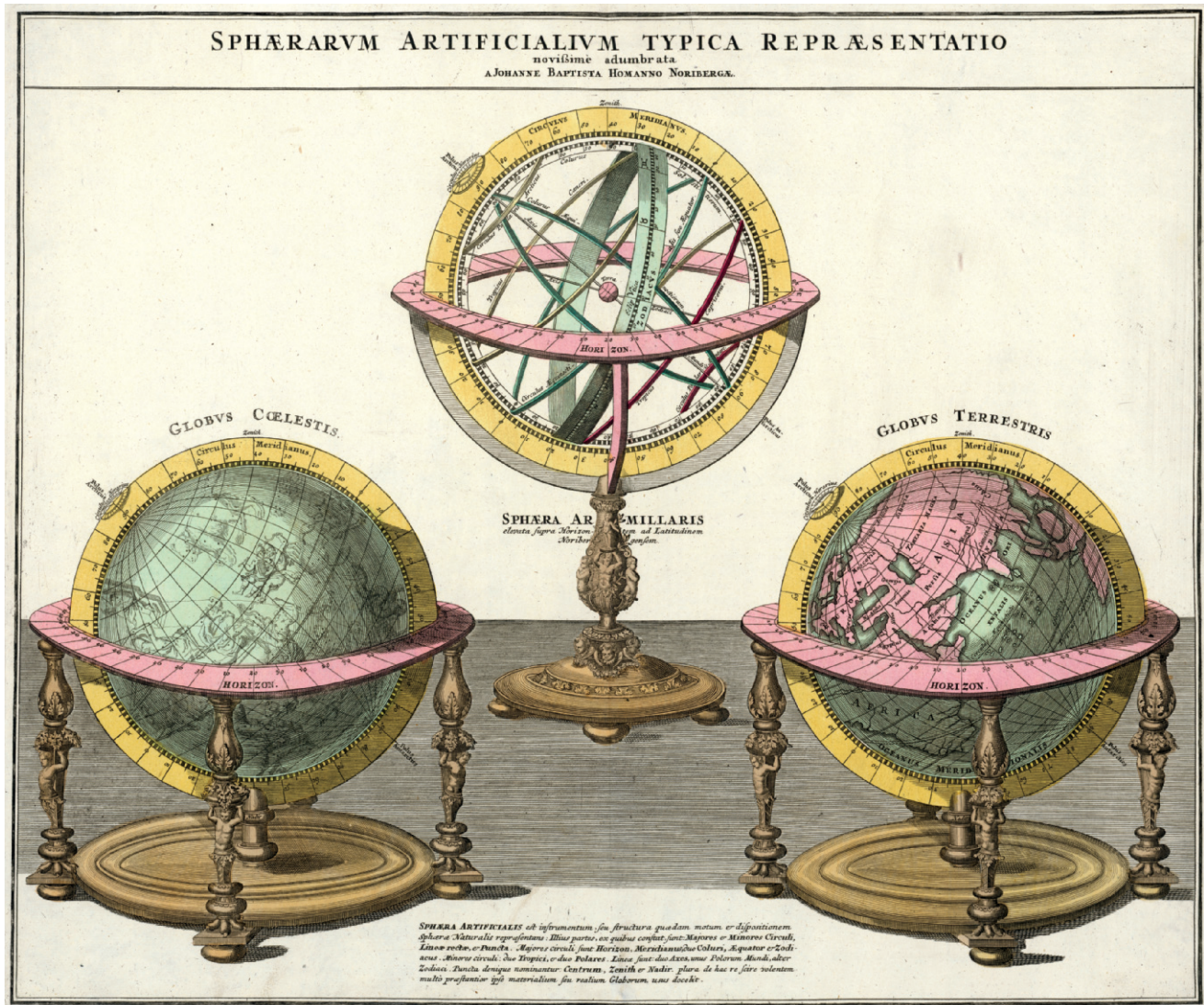


FIG. 329. JOHANN BAPTIST HOMANN, *SPHÆRARVM ARTIFICIALIVM TYPICA REPRÆSENTATIO*, CA. 1710. A relatively common image of the three interrelated “artificial spheres”: left to right, celestial globe, armillary sphere, and terrestrial globe.

Size of the original: 56 × 64 cm. Image courtesy of the Staatsbibliothek zu Berlin, Stiftung Preußischer Kulturbesitz (Kart. 27290). Permission courtesy of bpk Bildagentur/Art Resource, New York.

the standard pair should always be turned around the axis of the world from east to west, in keeping with the motion of the so-called First Mover (that is, the apparent motion of the sun, the planets, and the stars, reflecting the daily motion of the earth around its own axis). Indeed, the standard globe pair is closely connected to the Ptolemaic armillary sphere, the main circles of which are marked on both terrestrial and celestial globes to express the correspondence between them all; moreover, globes and armillary spheres were generally mounted in the same way, within a meridian ring, with an hour circle on top or below, and resting in a stand supporting a horizon ring (fig. 329).

In some designs, even the spherical shape of the earth or the heavens could be disregarded. In 1785 Christlieb Benedict Funk von Hartenstein, of Leipzig, made a globe consisting of a central cylinder representing the zone between the tropics and two truncated cones for the zones north and south of the tropics (Dolz 1994, 45–46). One invention that particularly emphasized the immobility of the earth was the globe designed by Roger Palmer, earl of Castlemaine, and described in his *The English Globe: Being a Stabil and Immobil One, Performing What the Ordinary Globes Do, and Much More* (1679). It featured a terrestrial globe without the usual horizon ring, meridian ring, and hour circle. Because it is im-

mobile it was said to represent the earth more naturally. As a problem-solving device the English globe could compete with the common globe, by using it as a sort of sundial for solving time-related phenomena (Dekker 1996, 547–48).

After 1700, a few attempts were made to convert globes to the Copernican perspective. Clockwork-driven globes maintaining the basic features of the matching pair were produced in which the terrestrial globe was made to rotate from west to east in 24 hours (mean solar time) and the celestial globe from east to west in 23 hours 56 minutes (sidereal time). Such a pair was described by the Amsterdam watchmaker Denys Audebert in a 1736 treatise on mobile globes written in Dutch and French. The celestial globe was a continuation of the clockwork-driven globes produced in the Renaissance. The terrestrial globe was supposed to model the diurnal motion of the earth around its own axis, but this was not actually compatible with a sphere placed in a conventional stand with a fixed horizon: in the Copernican model the horizon of a place on earth moves in conjunction with that place. Even so, a number of pairs of clockwork-driven globes were produced, especially in France (Betts 1999, 64–66).

For a student to solve problems by turning the sphere of the terrestrial globe from west to east, in agreement with the true rotation of the earth around its own axis, George Adams Sr. proposed new methods in midcentury for operating globes, but this new approach was not very useful from an educational point of view (Dekker 1996). The question remained of how to make a proper Copernican globe. George Adams Jr. pursued a logical solution by borrowing techniques used in a tellurian (see fig. 72), although he made only one pair of globes, in about 1790, for Martinus van Marum, director of the Teylers Museum in Haarlem (fig. 330). Another Copernican globe was designed around 1800 by Cornelis Covens (Dekker 1996, 554–62).

Globes were occasionally produced in manuscript for special purposes. For example, in 1725 an anonymous Austrian painted a terrestrial globe, “Sciatherion cosmicum seu horologiu[m],” on a metal sphere and mounted it with eight sundials as a time measurement device (Dekker 1999, 225–27). But the great majority of Enlightenment globes were consumer objects, made from gores printed from copperplates, generally 30–45 centimeters in diameter, and published in Ptolemaic pairs by a variety of mapmakers, instrumentmakers, and astronomers. They were produced all over Europe, serving mostly local markets (Zögner 1989; Dekker and Van der Krogt 1993; Allmayer-Beck 1997; Dahl and Gauvin 2000).

In Austria and Sweden, globemaking was a very incidental affair. Peter Anich, a cartographer from Oberperfuss, and Anders Åkerman, a member of the Swedish Cosmografiska Sällskapet in Uppsala, are known to



FIG. 330. COPERNICAN TERRESTRIAL GLOBE BY GEORGE ADAMS JR., 1789/91. Diameter of the original: 45.5 cm. Image courtesy of the Teylers Museum, Haarlem (FK 726).

have produced pairs of globes in the 1750s and 1760s (Dekker 1999, 250–55; Dekker and Van der Krogt 1993, 84–87).

A fragmented market existed in Germany. In the early 1700s, astronomers Georg Christoph Eimmart and Erhard Weigel were involved in globemaking, but not as major producers. The same can be said of Johann Ludwig Andreae and his son Johann Philipp. Johann Baptist Homann in Nuremberg issued only small (pocket) globes; the Homann Heirs published some globes by Georg Moritz Lowitz from 1747 to 1818 (see fig. 7). Matthäus Seutter set up his own firm for globe production in Augsburg in 1707. The most widely distributed German globes were published in Nuremberg after 1730 by the astronomer Johann Gabriel Doppelmayr in collaboration with Johann Georg I Puschner; their production was continued by Johann Georg II Puschner. At the turn of the eighteenth century Johann Georg Klinger, a Nuremberg art dealer and publisher, reissued globes by Johann Philipp Andreae and collaborated with the engraver Johann Bernard Bauer and his sons Carl Johann Sigmund and Peter in the production of small globes. Luxury celestial and terrestrial globes were published by David Beringer in Nuremberg in 1790 and 1792 respectively. These globes, based on the work of the astronomer Johann Elert Bode and the geographer Daniel Fried-

rich Sotzmann, were reissued by Johann Georg Franz in the first decade of the nineteenth century (Hagen 2002).

In the Netherlands, the tradition established by the Blaeu firm in the seventeenth century was continued after 1700 by Gerard Valk together with his son Leonard. After Gerard's death in 1726, the business was continued first by his widow Maria and then by Leonard. The globe factory was taken up in 1746 by Leonard's widow Maria Schenk and was subsequently acquired by her nephew Petrus Schenk Jr. Toward the end of the century Cornelis Covens took over the Valk globe factory. With his death in 1825, globe production in the Netherlands came to an end (Van der Krogt 1993, 299–336).

In France, the instrumentmaker Nicolas Bion began to produce globes—rather cheap examples on simple pedestals—at the turn of the seventeenth century. He was soon followed in the new century by quite a number of other globemakers: Guillaume Delisle, Jean Antoine Nollet, Jacques-Nicolas Baradelle, Jacques Hardy, and Hardy's successor Louis-Charles Desnos. Of all the globes they produced, Delisle's stood out for their high scientific standards. In the middle of the eighteenth century Didier Robert de Vaugondy gave new ambition to the French globe industry with the production of luxury globes. His firm was taken over by Jean Fortin and subsequently by Charles-François Delamarche, the most successful French entrepreneur in globemaking (Pelletier 1987). Delamarche also incorporated the stock of Jean Lattré, who had in 1775 and 1783 published pairs of globes based on the work of the astronomer Joseph-Jérôme Lefrançois de Lalande and the hydrographer Rigobert Bonne.

The Italian globemaker Vincenzo Coronelli acquired international fame—and an international market—by making in 1683 the pair of grand manuscript globes (390 cm diameter) for Louis XIV (see fig. 182). Working in Venice, he produced many other globes, ranging from 5 to 108 centimeters diameter, and in many forms; in particular, his 108-centimeter globes found a market across Catholic Europe (see fig. 187). Coronelli's innovative approach to globemaking was exemplified by his *Libro dei globi* (1701), an atlas containing the printed gores of a number of his globes. With his death in 1718, Italian globemaking ceased until the end of the century, when Giovanni Maria Cassini again started to produce globes (Valerio 2005).

Great Britain possessed the most competitive market for globes in Europe, a condition related to the boom in instrumentmaking induced by the triumph of Newtonian experimental philosophy. Even before this trend fully developed, the publisher Joseph Moxon had already begun to design and produce globes. He was soon followed by globe- and mapmakers such as Robert Morden, William Berry, and Philip Lea. Of the next generation of globemakers in the early eighteenth century—Charles Price, John Senex, and Richard Cushee—only

Senex seems to have been successful in business. Most of Senex's copperplates were bought after his death in 1740 (auctioned in 1755 by Senex's widow) by James Ferguson, a lecturer in popular science (Millburn with King 1988, 79–81). By then, manufacturers were creating all sorts of demonstration astronomical models, to which globemaking was a successful adjunct. However, Ferguson was not successful as a globe producer and in 1757 he passed Senex's copperplates on to Benjamin Martin, another London lecturer and instrumentmaker (Millburn 1976, 103). Martin's main competitor was George Adams Sr., who published a similar array of instruments that included, after 1766, a pair of newly designed globes. After Adams died in 1772 his sons George Jr. and Dudley Adams continued globe production. Important globes were also published ca. 1780 by Gabriel Wright, who may have been initially in charge of the manufacture of Martin's globes, and William Bardin, who started out as a “cordwainer” or shoemaker (Clifton 1999, 45–57, esp. 47). Their collaboration seems to have ended by 1794–95. Business was thereafter continued by Bardin and his son, Thomas Marriott Bardin. Around 1798, the Bardin firm extended its globe production to include so-called New British globes that were made in collaboration with the firm of William Jones and his brother Samuel. At the turn of the eighteenth century globemaking firms, such as the Cary and Newton families, entered the market and carried globe-making until far into the nineteenth century.

ELLY DEKKER

SEE ALSO: Astronomical Models; Consumption of Maps; Education and Cartography; Geographical Mapping; Science and Cartography

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Terrestrial Globe. The standard terrestrial globe produced during the Enlightenment was a sphere onto whose convex surface were pasted printed gores showing the distribution of lands and seas; like the matching celestial globes with which they were paired, terrestrial globes were usually mounted in a meridian ring with an hour circle on top or below and resting in a stand that supported a horizon ring (fig. 331). Conceptually a terrestrial globe mounted in this way can be seen as a model of the earth only if seen from a Ptolemaic perspective. Once the globe has been set according to the local meridian and latitude, the earth ball has to be considered immovable.

Terrestrial globes have always displayed new geographical knowledge. After 1700, they became, in particular, vehicles to display the rapid growth of improved geographical knowledge prompted by the program of the Académie royale des sciences to improve the measurement of geographic longitudes (Dekker and Van der Krogt 1993, 68–83). The first terrestrial globe based on the new data was published by Guillaume Delisle in 1700 (Dahl and Gauvin 2000, 154–59). Delisle removed all hypothetical features from his globe, left unexplored areas blank, and added the tracks followed by famous navigators, from Ferdinand Magellan in 1520 to William Dampier in 1686 (Dekker 1999, 325–27). Voyages of exploration became a popular feature on globes. In particular, the journeys made by Captain James Cook in 1768–79 to the great South Seas were never lacking on globes produced during the last quarter of the eighteenth century (Dekker 1999, 585–86).

Distinct national styles developed for terrestrial globes during the eighteenth century. French and British globemakers preferred to use the vernacular for labeling their



FIG. 331. TERRESTRIAL GLOBE BY GUILLAUME DELISLE, 1700; REISSUED AFTER 1708. Diameter of the original: 32.5 cm. © National Maritime Museum, Greenwich, London (GLB0146). The Image Works.

works, whereas Dutch and German globemakers continued to use Latin. In Italy, Vincenzo Coronelli declared his international ambitions by using Latin in addition to his native tongue.

The choice of the prime meridian, initially a matter of convention, was another point of differentiation. French geographers and globemakers had to use the most westerly point of the Canary Islands for a prime meridian—with Paris at precisely 20° east longitude—as Louis XIII had decreed in 1634. The prestige of French scientific geography induced other continental globemakers to follow suit. Most eighteenth-century British globemakers, however, ran the prime meridian through either London or Greenwich. They also counted longitude 180° east and west from London, a convention that reflected the impact of the techniques proposed for finding the longitude at sea, which determined longitudinal distance east or west of a zero point. By contrast, continental globemakers generally counted a full 360° of longitude in an easterly direction (Dekker 1999, 36–37).

Another feature of navigational interest seen exclusively on British (pocket) globes is the pattern of the trade winds and the monsoons, indicated by arrows

and shading, which Edmond Halley had first presented in 1686 (Dekker 1999, 35–36). The trade winds disappeared from globes around 1800. British globes further distinguished themselves from continental ones by adding an analemma, to show the sun's declination and place in the zodiac for each day of the year, and by using a new type of hour circle placed below the meridian ring instead of on top of it (Dekker 1999, 411–12; Edney 2019). French makers, on the other hand, preferred to mark antique features, such as the correspondence between declinations and climates on the meridian ring and the points of the rising and setting sun in summer and winter on the horizon ring.

The debate over the size and figure of the earth concluded when the French expeditions to Peru and Lapland in the 1730s successfully showed that the earth was flattened at its poles. Louis XV ordered Didier Robert de Vaugondy to construct a model of the flattened earth. The model could only have been symbolic: for a 180-centimeter-diameter globe, the polar axis would be just 12 millimeters shorter than the equatorial axis. Because of lack of money this flattened globe was never built (Pedley 1992, 43–44).

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SEE ALSO: Geographical Mapping

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Celestial Globe. The standard celestial globe produced during the Enlightenment was a sphere onto whose convex, outer surface were pasted printed gores to show the stars and constellations; like the matching terrestrial globes with which they were paired, celestial globes were usually mounted in a meridian ring with an hour circle on top or below and rested in a stand supporting a horizon ring. Such globes show the sky from an external or convex perspective; they accordingly require that the orientation of the stars with respect to each other is the mirror image of their configuration when seen in the sky and that each constellation is shown from the rear. Although it does not correspond to the real sky, the convex presentation maintains the overall properties of the real

world in the sense that—when the globe is properly oriented—the stars move from true east to true west. This makes it possible to demonstrate the daily and annual celestial phenomena reliably.

A properly geocentric mapping of the celestial vault, as if viewed from inside the sphere, was provided on the concave inner surfaces of the cases of some (but not all) pocket globes. Similarly, Vincenzo Coronelli designed gores for the insides of larger globes that could be opened up for instructional purposes. If made, such globes do not survive; the concave gores were pasted onto the convex, outer side of spheres to make improperly oriented celestial globes (Dekker 2004, 61–62, 179). A much larger concave presentation was achieved on the interior surface of the huge Gottorp (Gottorf) globe (311 cm diameter; see fig. 163), whose outer convex surface forms a terrestrial globe; one sat inside the sphere while it rotated to show the daily motion of the stars (Lühning 1997).

Enlightenment astronomers charted the many stars made visible by increasingly powerful telescopes. The major star catalogs by Johannes Hevelius (1,888 stars visible to the naked eye for the epoch 1661) and John Flamsteed (2,934 stars to 7^m for the epoch 1690), and the new data of the southern sky collected by abbé Nicolas-Louis de La Caille (1,930 stars to 6^m and nebulas for the epoch 1750) provided globemakers with ample material. They only had to correct those data by a simple adjustment for precession, the phenomenon by which the position of the vernal equinox shifts—as Tycho Brahe had shown—at a constant rate of about one degree of longitude over seventy-two years.

In the new heliocentric worldview, precession was seen as the reflection of the motion of the equatorial polar axis of the earth. This was certainly one of the incentives for European globemakers to start making "precession globes," or globes mounted in such a way that one could set them for any desired epoch (Dekker 2003). For example, Erhard Weigel mounted his heraldic globes with new constellations in addition to the classical ones in a kind of armillary sphere that made it possible to set the globe for a desired epoch. In France the astronomer Jean-Dominique Cassini (I) designed a precession globe in 1708 very similar to Weigel's. Cassini left it to the globe- and instrumentmaker Nicolas Bion to realize such a globe but no copy is known to survive; a description of Cassini's precession globe was included in later editions of Bion's globe manual, *L'usage des globes celestes et terrestres, et des spheres*.

Subsequently, precession globes were constructed to solve historical problems. This trend started as a response to the posthumous publication of Isaac Newton's *Chronology of Ancient Kingdoms Amended* (1728). By comparing ancient accounts of the colures with the positions of specific stars for the epoch 1689, Newton

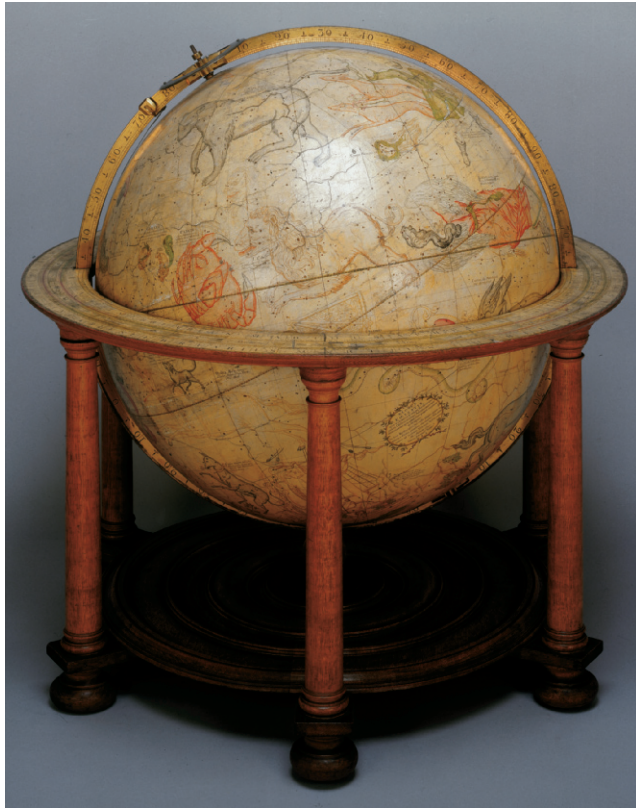


FIG. 332. CELESTIAL GLOBE BY JOHN SENEX, CA. 1730. Diameter of the original: 68 cm. © National Maritime Museum, Greenwich, London (GLB0139). The Image Works.

derived a date of 939 B.C. for those accounts. The ancient colures were subsequently marked on the 68-centimeter celestial globes issued by John Senex after 1730 (fig. 332) (Dekker 1999, 493–95). In 1738 Senex published a description of a precession globe of which at least one copy survives. Around 1800, the Dutch professor Jacob de Gelder suggested a new construction for a precession globe that was produced by Cornelis Covens (De Gelder 1819).

ELLY DEKKER

SEE ALSO: Astronomical Models; Celestial Mapping; Constellations, Representation of

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Instructional Texts for the Use of Globes. Manuals explaining the manifold uses of globes were first produced in the Renaissance. They explained how to adjust the globe for local conditions, to align the globe's meridian ring to the local meridian, to direct the globe's polar axis to the North Pole, and to adjust the pointer of the hour circle to local time. After that, many interesting properties of the heavens and the earth could be demonstrated by using the globes as analog computers. For example, one could determine the time difference between one's location and an arbitrary place elsewhere or the visibility of a star throughout the year.

Globe manuals generally embedded the use of globes within short treatises on cosmography. In early manuals, the relations between heaven and earth were explained from a geocentric or Ptolemaic perspective. In the seventeenth century, the heliocentric Copernican worldview increasingly became a topic of discussion and inevitably affected the contents of globe manuals. The first treatise of interest in this respect is Willem Jansz. Blaeu's instruction in the use of celestial and terrestrial globes, *Tweevoudigh onderwijs van de hemelsche en aerdsche globen* (1634). Six editions of this work appeared in Dutch, ten in Latin, and three in French (Van der Krogt 1993, 627–28). The first part of the treatise teaches the use of globes in keeping with the Ptolemaic worldview and follows the tradition established in the sixteenth century. An English translation of this first part was published by Joseph Moxon in 1654 (Moxon 1978, xxii–xxiii), and Gerard Valk published a reworked version as *'t Werkstellige der sterre-konst* in ca. 1700 (Van der Krogt 1993, 308–12).

The second part of Blaeu's globe book was devoted to explaining two astronomical models based on the Copernican worldview: the Copernican sphere and the tellurian. This part had little to offer for the use of the common pair of globes. However, because of the growing interest in England in Copernican spheres, Moxon published an adaptation of the second part of Blaeu's manual in 1665 (Moxon 1978, xxiv).

Blaeu's globe book was distributed all over Europe and set the trend for the many manuals published during the Enlightenment. Most of these included a discussion of both the heliocentric and geocentric world systems. An example is Nicolas Bion's *L'usage des globes* (1699), which went through six editions and was translated into German in 1736. Since globes are especially useful for explaining phenomena as seen from a geocentric perspective, the geocentric worldview continued to be discussed in globe manuals. The topics treated in globe manuals continued to change over the course of

the eighteenth century. Sometimes a description of an orrery was added to the use of globes, as, for example, in the English treatise by Joseph Harris (1731), which went through twelve editions by 1783. Other manuals, such as those by George Adams Sr. in 1766 and Cornelis Covens in 1802, addressed the problem of how to construct and use globes in keeping with the Copernican hypothesis (Dekker 1996). The regular discussions of the Copernican system in globe manuals such as these helped significantly in promoting the acceptance of this system outside scientific circles.

The background of authors also changed during the eighteenth century. Initially globe manuals were written by or for globemakers who used them to advertise their products (fig. 333). Gradually the globemakers were replaced by schoolmasters who had very little to do with globe production and who were accordingly less constrained in their treatment of the structure of the universe. In his *New Treatise of the Use of Globes, or A Philosophical View of the Earth and Heavens* (1805),



FIG. 333. FRONTISPIECE OF JOHANN LUDWIG ANDRAE, *MATHEMATISCHE UND HISTORISCHE BESCHREIBUNG DES GANTZEN WELT-GEBÄUDES: ZUM NÜTZLICHEM GEBRAUCH ZWEYER AUF EINE NEUE ART VERFERTIGTEN HIMEL- UND ERD-KUGELN* (NUREMBERG, 1718). Such emblematic frontispieces were commonly used in instructional texts to exemplify the use of celestial and terrestrial globes in astronomy and geography. Size of the original: 19.5 × 16.5 cm. Courtesy of Adler Planetarium & Astronomy Museum, Chicago.

Thomas Keith, a private teacher of mathematics and geography, discussed many earth-related physical phenomena such as earthquakes and the tides in addition to the structure of the solar system and the motion of the earth therein. Although Keith did not diminish the computational role of globes, and described sixty-four problems to be performed by terrestrial globes and thirty-eight by celestial globes, his realignment of topics foreshadowed the decline in the intellectual prominence of globes in the following centuries.

ELLY DEKKER

SEE ALSO: Education and Cartography; Geographical Mapping; Public Sphere, Cartography and the; Science and Cartography

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Pocket Globe. The first mention of a pocket globe was by Joseph Moxon in his single-sheet *Proves of Several Sorts of Letters Cast by Joseph Moxon*, 1669. It is from this description that the definition of the pocket globe is usually derived: "Concave Hemispheres, wherein is depicted all the STARS and CONSTELLATIONS in HEAVEN. And serves as a Case for a Terrestrial GLOBE. Made portable for the Pocket. By Joseph Moxon, Hydr." Moxon reported in 1672 that he himself had made such a pocket globe (Wallis and Robinson 1987, 32). Some scholars believe that the small terrestrial globe of 2 inch (5.3 cm) diameter from ca. 1625, attributed to Willem Jansz. Blaeu, was the precursor of Moxon's pocket globe; this terrestrial globe, in a case, is related to the pocket globe of the same size published by Abraham van Ceulen in 1697 (Van der Krogt 1993, 367–70, 524, 545).

Pocket globes express in a very elementary way the spherical shape of the world. These cheap globes were within reach of many and quickly found a place in the marketplace next to the common globe. The success of the pocket globe lies in its symbolic value. To carry the whole world in your pocket expressed an intellectual commitment to the new Newtonian experimental philosophy. In this respect, it did not really matter that in many English pocket globes, including Moxon's (fig. 334), the celestial vault was actually presented by convex instead of the proper concave gores. This was because the globemakers used the same set of (convex)



FIG. 334. POCKET GLOBE OF JOSEPH MOXON, GORES DESIGNED CA. 1680; GLOBE MADE AFTER 1706–7.

Diameter of the original: ca. 7.5 cm. Image courtesy of the Bildarchiv Preußischer Kulturbesitz (Inventar-Nr.: K 4706)/ Art Resource, New York.

gores for both pairs of miniature globes and pocket globes; however, a few makers of pocket globes did take the trouble to design concave gores to represent a correct view of the heavens.

Although the production of pocket globes as the gentleman's toy par excellence was predominantly a British affair, a few continental globemakers produced them as well. In Amsterdam, in addition to Van Ceulen, Johannes Deur and Gerard Valk each published a pocket globe in the first quarter of the eighteenth century (Van der Krogt 1993, 569–72). In the same period, Johann Baptist Homann in Nuremberg produced a variant pocket globe with an armillary sphere added inside the terrestrial globe (Mokre 2002, 138–39). Nevertheless, total continental output was negligible compared to that in Britain.

The manufacture of pocket globes in Great Britain has a complex history (Dekker 1999, 128–32; Edell 1985; Van der Krogt 1985). Among the first after Moxon to

produce such a globe in England were Charles Price and John Senex, who cooperated to publish a pocket globe in the first decade of the eighteenth century. When their collaboration ended in 1710, and they divided their copperplates between them, Price retained those for the terrestrial part of the pocket globe and Senex those for the celestial part; both then had new plates engraved to replace the missing ones.

The new Senex pocket globe was acquired in 1755 by George Adams Sr., who further adapted it and published it under his own name. Herman Moll issued a pocket globe in 1719, an updated version of which appeared in ca. 1775 as *A Correct Globe with the New Discoveries*. The plates of the concave celestial gores of the pocket globe published in 1731 by Richard Cushee were reused by Nicolas Lane in 1776, with newly engraved plates for the terrestrial globe.

In the beginning of the second half of the eighteenth

century, Nathaniel Hill and James Ferguson further increased the number of pocket globes that were for sale. Their pocket globes also appeared in various updated states under different names: the one by Hill is known in two editions of 1783, one by William Palmer and John Newton, and another by Newton alone. Ferguson was the first, in about 1757, to make globes with a diameter of exactly three inches. His copperplates were subsequently used in the last quarter of the eighteenth century by Dudley Adams and in the early nineteenth century by the Lane firm; these Ferguson-Adams-Lane pocket globes were often sold by retailers who pasted their own labels on them. After 1800, globemakers continued to produce miniature globes, especially terrestrial ones, primarily for children's education, but the pocket globe boom was over.

ELLY DEKKER

SEE ALSO: Consumption of Maps

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Lunar Globe. Mapping the moon is complicated by its libration, an oscillating motion that causes small changes in its orientation and subsequently in the angle at which the sun's light strikes its surface. Thus, the moon continually shows a slightly different face and the shadows cast by its mountains vary constantly; no two full moons ever look exactly the same. In this context, a lunar map offered astronomers the potential of a constant and unchanging image of the moon, but a lunar globe has the additional potential of demonstrating the changing surface of the moon under the influence of libration. In the 1640s, the authors of the first substantial lunar maps—

Michael Florent van Langren and Johannes Hevelius—separately discussed the desirability of publishing a lunar globe, but neither of them succeeded in constructing one (Whitaker 1999, 37–46, 50–60).

The first lunar globe to be constructed was made for Charles II in 1661 by Christopher Wren, newly appointed Savilian professor of astronomy at Oxford. The globe is known only from archival records; it is said to have been made in relief and, when turned to the light, showed the phases of the moon and the shadows of the craters and mountains as well. Wren's globe was part of the king's cabinet and is reported to have been sold in 1749 (Whitaker 1999, 72–73). Joseph-Jérôme Lefrançais de Lalande (1792, 3:310, no. 3291) mentioned that at the turn of the seventeenth century Philippe de La Hire had another lunar globe made according to Hevelius's proposal. Now lost, La Hire's globe was still part of the collection of the Académie des sciences in 1745.

In the 1740s, Tobias Mayer developed a method to create a lunar map for mean libration; he finished the map in about 1750. He worked in parallel on a lunar globe (41 cm diameter), to be published by the Kosmographische Gesellschaft in Nuremberg founded by the Homann Heirs, as a more exact image of the moon. However, professional distractions after 1751 meant that he could complete only eight of twelve gores. Six gores were engraved in mezzotint in Nuremberg (Oestmann 1999).

The earliest lunar globes still surviving were designed by the English artist and astronomer John Russell (Ryan 1966). As a painter of miniature portraits, Russell was attracted by the varying lights and shades cast by the mountains and valleys of the moon, making his first drawing of the moon in 1764. Russell did not underestimate the work involved in the astronomical project of mapping and modeling the moon. He completed a large map, drawn in pastels and constructed according to Mayer's method, in 1795. He carefully shaded the mountains and valleys both to indicate their elevations and to express the picturesque sentiments he had experienced when first observing the gibbous moon through a telescope. Russell stipple-engraved the derivative twelve-inch (30 cm) globe gores himself. It was Russell's ambition to do better than making a simple lunar globe. His *Selenographia* was not just a three-dimensional map; it was, according to the subtitle of his *Description of the Selenographia* (1797), "an Apparatus for Exhibiting the Phenomena of the Moon" (fig. 335). Russell's lunar globe stands out for the mechanical construction by which all possible states of libration can be reproduced. In this respect, Russell's mechanical lunar globe is unique; no comparable model of the moon was ever made, and only twelve copies are known to survive. In addition to his *Selenographia*, Russell constructed a globe in relief. Russell's brother-in-law, the geographer William Faden—whose portrait by Russell, now in the



FIG. 335. JOHN RUSSELL'S *SELENOGRAPHIA*, 1797. The gores of this lunar globe were printed from stipple-engraved plates and hand-colored. Not shown in this image is the unseen far side of the moon, which Russell of course left blank. Russell placed a small terrestrial globe on a separate gear in

order to demonstrate the various relative motions of the moon and the earth.

Diameter of the original: 30 cm. © National Maritime Museum, Greenwich, London (GLB0140). The Image Works.

British Library, shows him with a lunar globe—reported that he made one for his friend Sir Henry Englefield, but this relief globe does not survive (Ryan 1966, 39).

ELLY DEKKER

SEE ALSO: Astronomical Models; Celestial Mapping

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Relief Globe. A relief globe shows raised and indented features to present variations in elevation of the surface of earth, the moon, or other heavenly bodies. Three lunar globes are known to have been made in relief in the later seventeenth and eighteenth centuries, but none are known to survive. A celestial globe with constellations in relief was produced at the turn of the seventeenth century by Erhard Weigel (Dekker 1999, 220–21).

The production of terrestrial globes in relief started in the eighteenth century. Marcel Destombes (1978) explained in detail that it was a predominantly French enterprise. It seems to have started with a marble globe decorating the garden of the Parc de Meudon in Paris early in the century; still known in 1777, it is now lost. In 1753, Philippe Buache announced to the Académie des sciences that the construction of a relief globe nine feet (2.75 m) in diameter was under way in the dome de Luxembourg, the observatory of Joseph-Nicolas Delisle (Buache 1757). The purpose of the globe was to demonstrate Buache's theory of the structure of the earth, in which mountain chains continued between continents under the oceans. This large globe was never finished, but Buache did present a reduced version (32 cm diameter) to the Académie des sciences on 12 November 1757 (Buache 1762). This globe has not survived.

Another attempt to build relief globes was undertaken by Buache's pupil Pierre Lartigue. Lartigue concentrated especially on the techniques involved in making relief globes and experimented with various materials. The first globe that came out of these trials was made of plaster, had a diameter of forty-four centimeters, and took three years to complete; it was presented on 16 July 1777 to the Académie des sciences. Unfortunately, Lartigue's works are now lost. Lartigue was inspired by the ideas of Valentin Haüy, a well-known member of the Académie des sciences who after 1771 sought mecha-

nisms to teach the blind. When he opened the Institution Royale des Jeunes Aveugles de Paris in 1784, Lartigue made a relief map of Europe for its students; this was perhaps the earliest tactile map. Relief globes appeared to be a perfect means to teach geography to blind pupils, and relief globes would be made in Germany and Britain early in the nineteenth century to benefit the blind (Wallis and Robinson 1987, 70–71; Zögner 2003).

Destombes mentioned that Lartigue made a relief globe for the king and another one for the director of the Imprimerie royale (later nationale) au Louvre. This last globe is possibly the relief globe that is attributed to Lartigue (Duprat 1973, 208, no. 131). Another relief globe, of nearly eighty centimeters diameter, is part of a double globe made in 1786–88 for Louis XVI by Edme Mentelle, professor at the École royale militaire (fig. 336) (Duprat 1973, 208, no. 137). This globe consists of two hemispheres that can be opened to reveal a second relief globe inside. A depiction of the ces-



FIG. 336. TERRESTRIAL RELIEF GLOBE BY EDMENTELLE, 1786–88. The globe is part of a complex apparatus created for Louis XVI. Size of the original: 2.4 m × 1.3 m. Château de Versailles, France/Bridgeman Images.

tial sphere, with figures of the constellations and signs of the zodiac, is drawn on the inside of the two outer hemispheres.

Although relief globes were made outside France after 1800, such globes have always remained rare items in globemaking, not only because of the technical problems involved in relief molding, but also because by definition such globes are huge exaggerations of the true variations in depth.

ELLY DEKKER

SEE ALSO: Heights and Depths, Mapping of: (1) Relief Depiction, (2) Relief Map

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Cultural and Social Significance of Globes. In 1683 Vincenzo Coronelli, the Franciscan cosmographer from Venice, crafted a large pair of terrestrial and celestial globes in Paris for the French cardinal César d'Estrées as a gift to impress Louis XIV, the so-called Marly globes (see figs. 175 and 182). Each globe measured almost four meters in diameter and was elaborately engineered. By owning such large globes and elaborate mechanisms, a ruler displayed prestige and power. Since antiquity and throughout the Renaissance a globe had been a symbol of both universal knowledge and worldly dominion, evoking the perfection of the cosmos, the knowledge of the learned, and the power of the mighty. Lavishly decorated globes allowed viewers to see the magnitude of the whole planet and enabled princes and rulers to gaze upon the world they wished to master. Globes imposed visions of spatial order across lands and seas, peoples and environments.

The symbolism of the globe in the visual arts has a long and varied history, continuing into the period of the Enlightenment. In Western visual culture a globe in the hand of a ruler has marked the monarch's sovereignty over the world. In many works of European art, Christ, as the Savior of the world, holds a globe in his hand or God the Father has his feet on a globe. A globe can be found as the attribute of mythological and allegorical figures including Apollo, Cybele, Cupid, Truth, Astronomy, Urania, Fame, Abundance, Justice, Philosophy, and Fortune. In Cesare Ripa's *Iconologia*, the widely used collection of personifications first published in 1593 and translated into English in 1709, Geography has a terrestrial globe at her foot. A globe could indicate the profession of philosophers, theologians, astronomers, geographers, and explorers.

In the Enlightenment, the image of the globe kept the complexity of its symbolism, its several meanings, and the variety of roles it played in the artistic domain. A globe could represent the whole universe or just the planet earth, and its image carried ambivalent messages. Celestial globes offered visions of the eternal but were also reminders of the passing of time. In the hands of God a terrestrial globe evoked the order of creation: it was a perfect geometric figure, offering an image of harmony and completeness, beyond the scale of perspective and human experience. Associated with the devil, the globe was a symbol of evil and chaos. For instance, in the first engraving in a very popular Jesuit text, Antoine Sucquet's *Via vitae aeternae iconibus illustrata per Boëtium a Bolswert* (1620, with many editions and translations), a burning globe (with a cross on top) laying on its side stands for the pointless desire of worldly things and the inversion of values. Since the world is both mankind's home and a temporary dwelling where people die, a terrestrial globe could indicate both the perfection and the corruptibility of man. Globes often feature in allegorical still-life paintings suggesting the vanity of human life, as in the *vanitas* pictures by the Dutch Baroque artists Adam Bernaert (ca. 1665, Walters Art Museum, Baltimore) and Maria van Oosterwijk (1668, Kunsthistorisches Museum, Vienna).

A globe was above all a symbol of wealth, power, and imperial ambitions. In Andrea Pozzo's allegory of the Jesuit missionary work throughout the world, Ignatius of Loyola is raised to Christ and receives light from him at the center of the four continents. The personification of Europe holds a globe in her left hand and a scepter in her right hand to signify the superiority of Europe and her right to rule over Asia, Africa, and the Americas (fig. 337). Europe as a queen with a terrestrial globe appears also in the fresco painted in the middle of the eighteenth century by Giovanni Battista Tiepolo in the Würzburg Residence.



FIG. 337. DETAIL FROM ANDREA POZZO, *APOTHEOSIS OF SAINT IGNATIUS*. Painted fresco on the ceiling in the church of Sant'Ignazio, Rome, ca. 1685–94. Detail shows Europe holding the globe.

Scala/Art Resource, New York.

As a cartographic document, a globe is a sphere on which a map of the world or the heavens is represented. The cultural and social context in the Enlightenment, however, was fundamentally different from earlier ages that produced globes. The transition from a Ptolemaic to a Copernican worldview, the invention of increasingly sophisticated mechanical devices to show the structure of the solar system, a renewed interest in science (in its widest sense) that was spreading through all levels of society, and the emphasis on the need of exact geographical and astronomical observations all had a significant impact on globemaking and encouraged a widespread educational use of globes. Once a mere cartographic document, by the seventeenth and eighteenth centuries the globe became an instrument for scientific demonstration. No longer seen as just an attribute of historical, allegorical, and mythological figures, the globe increasingly assumed the appearance of a distinct three-dimensional object, important in its own right. Significant in this context is the renewed interest in the only extant

globe from antiquity, the large celestial globe held on the shoulders of a second-century Roman statue of Atlas, acquired in the sixteenth century by Cardinal Alessandro Farnese, the so-called Farnese Atlas, essential to the Grand Tour and an object of study and replication (Lippincott 2011). Globes appeared in all sizes and functioned not only as decorative objects and pointers to social and cultural status but as scientific instruments.

In 1788 architect Etienne-Louis Boullée submitted to Louis XVI a plan to renovate the Bibliothèque du Roi. Above the main portal on the building's facade Boullée designed a giant globe, reminiscent of Coronelli's work (Coronelli's grand globes were meant to be displayed in the royal library). Large globes also decorated the exterior of the 1726 building of the Viennese Kaiserliche Hofbibliothek (1726), which housed some Coronelli globes. Globes also featured in libraries of religious institutions. Other exemplars of Coronelli's artifacts were kept for instance in the Benedictine Melk Abbey in Lower Austria and in the Camaldolese Classe Abbey in

Ravenna. Both globes and books were seen as playing a crucial role in the learning and educational process.

Images of the world have always played a significant role in the visual arts, but after the seventeenth century, pictures of globes multiplied in all artistic media (including architecture and book illustration), reflecting the boom of globe production and marketing in Northern Europe and the role of the globe in contemporary scientific enquiry. When, in 1741, the German traveler Johann Georg Keyssler visited Paris, he read on the pedestal of the celestial globe made for Louis XIV a Latin inscription engraved to celebrate the power of “the French monarch, who with his finger moves both heaven and earth.” For Keyssler, the inscription was “gross and fulsome” flattery (Keyssler 1756–57, 3:312; Lee 1998, 406). He commented that, in fact, anyone could easily turn the Marly globes on their axes without effort, not only the Sun King. His amusement, however, can be seen as having wider implications. By Keyssler’s time, miniature globes, which began to be produced in England in the late seventeenth century, came into vogue and were available on the European market. These globes, invented by the English polymath Joseph Moxon, allowed seventeenth- and eighteenth-century users to hold the world in their hands, as Christian rulers were seen to do in works of art designed to celebrate their authority. The portable globe often reproduced not only the ordering of the lands on the outer surface of the sphere representing the earth, but, as happened with the much larger globes, also the entire expanse of the starry sky on its inner, concave surface. The universe itself, heaven and earth, could be in anyone’s pocket. The pocket globe, a fashionable gadget attractive for its cheaper price, showed the whole cosmos on a very small scale. Originally luxury items individually commissioned for royalty or collected by wealthy patrons, in the course of the seventeenth and eighteenth centuries globes of any size became mass-produced and available as fashionable items to a wider public. Commercial globemaking boomed as part of the wider consumer revolution, with its increasing demand for high quality goods. In 1783, for example, Antoine de Rivarol wrote that “women style their hair with globes, small societies form around globes, small theaters perform [plays] about globes” (Rivarol 1783, 19).

Moreover, globes were meant to make the new Copernican and Newtonian world system understandable to the public. As demonstration models, globes served not only as depictions of the surface of the earth and a map of the heavens but as explanations of the principles of geography and astronomy. Globes could still be seen as pieces of furniture stored in special rooms devoted to valuable items and intended to present the owner as a learned and refined individual. But globes attracted a wide market and brought natural science to popular culture. By the eighteenth century, an educated European

member of the bourgeoisie was expected to be familiar with the outline of the heavens and the distribution of land and sea on earth.

Since knowledge of geography and astronomy was recognized as an essential part of a gentleman’s education, globes became classroom objects, as Pietro Longhi’s painting *The Geography Lesson* (1752; see fig. 224) testifies. Terrestrial and celestial globes were used as models to aid popular understanding not only at home, but also in schools and universities, in academies and learned societies, and during public lectures, providing evidence of both the growth of popular interest in scientific matters and the rise of geography as an integral part of Enlightenment inquiry. Not by chance, globes, as well as other prestigious objects that had been stored in royal collections of curiosities, became part of the newly established national museums and libraries during the Enlightenment.

Globes became the most widely used educational instruments, and manuals were published on their use. Joseph Harris, in *The Description and Use of the Globes and the Orrery* (first ed., 1703), one of the most popular textbooks of the eighteenth century, explained the use of globes as teaching devices and models for scientific speculation: “The principal Uses of these Globes, (besides their serving as *Maps* to distinguish the outward Parts of the Earth, and the Situations of the Fixed Stars) is to explain and resolve the Phænomena arising from the diurnal Motion of the Earth round its Axis” (1738, 37).

Manuals on the use of globes also included advertisements that bear witness to the increased interest in globemaking and globe production for the general public. Harris’s book has a frontispiece showing an engraving of the great orrery (four feet in diameter) made by the instrumentmaker Thomas Wright to advertise “Orreries of different sorts” sold at Wright’s shop. On the verso of the title page in the 1738 edition, a text praises Wright’s skill and craftsmanship in making these devices. As may be gathered from Harris’s text, the workshop produced large orreries on commission (for King George II, the Watts Academy, the Royal Academy at Portsmouth, and “Noblemen and Gentlemen”) and small orreries for teaching purposes. But Wright, as the text on the verso of the title page reads, also had “some ready made by him, of different Prices.” Preceding Harris’s chapter on “The Description and Use of the Celestial and Terrestrial Globes” is an engraving featuring a pair of terrestrial and celestial globes, “Made and Sold by Richard Cushee” (fig. 338).

Wright published his own manual, *The Use of the Globes* (1740), to promote (on the end page, for example) other books, instruments, and even private tuition offered to “Gentlemen and Ladies.” The book also included advertisements for globes, maps, and books sold at the shop of John Senex, fellow of the Royal Society,

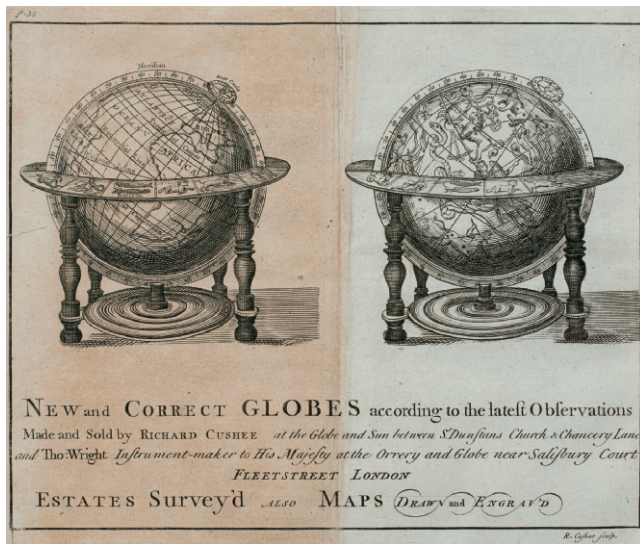


FIG. 338. “NEW AND CORRECT GLOBES ACCORDING TO THE LATEST OBSERVATIONS.” Advertisement of globes sold by Richard Cushee and Thomas Wright. From Harris 1738, facing 35. Image courtesy of the Warburg Institute Library, London; photography by Ian Jones, London.

a most successful cartographer and engraver who specialized in making globes and published Wright’s handbook. On the frontispiece the globes sold at Senex’s shop are advertised with their prices (fig. 339). Senex charged ten shillings for a pocket globe in a case (three-inch diameter). Obviously, the price increased with the size: a basic pair of nine-inch diameter terrestrial and celestial globes on stands cost two pounds; twelve-inch diameter, three pounds; seventeen-inch diameter, six pounds. Senex would charge twenty-five guineas (twenty-six pounds and five shillings) for a pair of larger globes, featuring—as advertised—all the discoveries on earth and the observations in the sky, thus “fit to adorn the Libraries of the Curious.” This pricing shows that pocket globes were aimed at the popular market, whereas the high prices of larger globes indicate a business targeted toward the elites.

New markets opened as society changed. A strong and highly competitive globemaking industry flourished in Northern Europe. Globemakers were often part of a family firm (the Blaeu, Valk, and Adams families, for instance). There were, of course, differences between European nations. In England, for example, the manufacture of globes developed within the context of the instrumentmaking trade, whereas in continental Europe the globemaking industry was part of the cartographic tradition. Throughout Europe, however, globes attracted a diversity of groups, not only royals or specialists. Spectacular globes were still exhibited in royal palaces and libraries, but globes also appeared in the meeting rooms

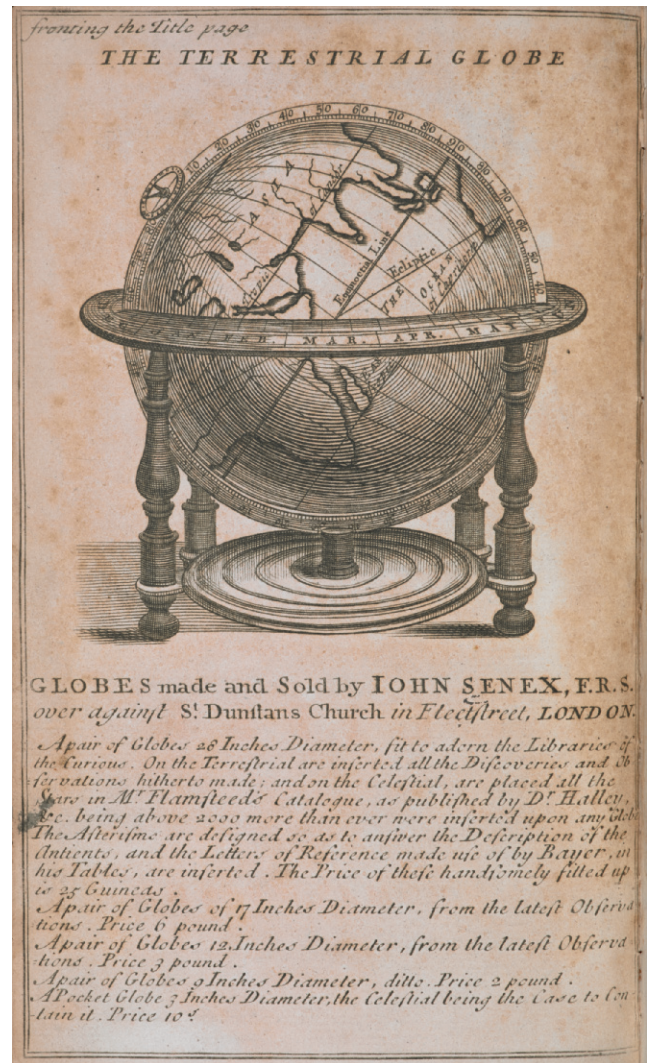


FIG. 339. “THE TERRESTRIAL GLOBE.” Advertisement of globes sold at John Senex’s shop. From Wright 1740, frontispiece. © The British Library Board, London.

of learned societies and in private studies, playing various and more common roles in European culture.

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SEE ALSO: Consumption of Maps; Cosmographical Map; Education and Cartography; Geographical Mapping; Medals, Maps on; Public Sphere, Cartography and the

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Grand Tour. See Travel and Cartography

Graphomètre. See Instruments for Angle Measuring; Theodolite, Graphomètre, and Similar Instruments

Great Britain. The commonality of cartographic institutions and practices across the British Isles belies the region's lack of political and administrative unity throughout the period 1650–1800. Oliver Cromwell united the kingdoms of England (including Wales), Scotland, and Ireland within the Commonwealth after Charles I's execution in 1649; Charles II's restoration in 1660 also restored the three kingdoms' official independence from each other. The 1707 Act of Union combined England and Scotland to create Great Britain per se. Ireland remained distinct until the creation of the United Kingdom under the 1801 Act of Union. The other territories of the English and British monarchs remained distinct and are treated separately in this volume: the several colonies that comprised British America; the South Asian terri-

tories of the East India Company; and, after 1714 when the elector of Hanover also became George I, parts of northern Germany.

With its greater population and economy, England's social institutions dominated those of Scotland and Ireland. That dominance was maintained physically by large standing armies garrisoned in Ireland and Scotland and morally by the extension of English culture, including mapping practices, from London to the peripheries. Yet political power was highly fractured, with Parliament progressively undermining the Crown's powers and with local officials wielding significant authority. Territorial responsibility was so decentralized that there was little governmental capacity for statewide surveys (Pedley 2005, 81–83).

British cartography was thus overwhelmingly the result of private enterprise and its development was in large part regulated by the economy. The small economy at the time of the Restoration could not easily support the era's enthusiasm for ambitious cartographic projects. The post-1690 era of steady economic growth led to early efforts in internal improvements, overseas trade, and industrialization that in turn fueled the post-1750 era of economic expansion, global power, and domestic affluence. The "general mediocrity" of British cartography before 1750 was thus alleviated by only a few exceptional "highlights" (Woodward 1978, 192; Barber 1989). But after 1750, mapmakers' ambitions could increasingly be sustained, both by a stable marketplace and an increasingly active government, and British cartography became ever more sophisticated.

This periodization can be seen first in the history of Britain's map trade. Until the early eighteenth century, the map trade suffered from a lack of skilled manpower, was undercapitalized, had a very limited client base (albeit one that already appreciated the instrumental and symbolic functions of maps) (Barber 1990), had scant access to new surveys and fresh source material, and was heavily indebted to older Dutch models. With the notable exception of John Ogilby's famous atlas of road maps, *Britannia* (1675) (see figs. 614 and 866), and James and John Knapton's *Atlas maritimus & commercialis* (1728), early projects for folio atlases and large globes generally proved overly ambitious and bankrupted their publishers. Despite the financial risk, the map trade gradually developed a skilled labor pool, with an apprenticeship system supported by the guild system, augmented by the immigration of Huguenots experienced in the print trades. In order to limit costs and exposure, mapsellers created new schemes to raise money through subscriptions, published atlases serially, entered into partnerships with Dutch mapsellers, and plagiarized continental mapmakers extensively.

Mapsellers benefited from the liberalization of the book trade in 1695, when official censorship and re-



FIG. 340. AN IRISH COPY OF AN ENGLISH MAP. James Barlow engraved *A New and Correct Chart of the Sea Coast of England Scotland & Ireland* [1746], copied from Samuel Thornton's 1708 map of the same name, for the second of

two pirated editions of *The English Pilot, the Second Part* that George Grierson published in Dublin in 1746.

Size of the original: 45.3 × 53.2 cm. © The British Library Board, London (Cartographic Items Maps 177.d.1 [22.]).

restrictions on presses were ended; however, the map trade did not receive the copyright privileges that were extended to letterpress works in 1710 until 1733. The growth of the public sphere supported the publication of ever larger atlases addressing political interests (Harley 1997), national atlases organized by county (Hodson 1984–97), and the proliferation of maps within a wide variety of books and, after 1730, in the new monthly journals (Jolly 1990–91). By century's end, London's map trade was varied and sophisticated, and the small, guild-based firms were transforming into institutionalized companies. Moreover, after 1750 provincial markets for printed works grew sufficiently to support local map publication and to offset the dominance of the London map trade; in particular, because British copy-

right law did not extend to Ireland, Dublin booksellers plagiarized many London publications, including maps (fig. 340).

At first sight, British marine charting appears not to have followed this periodization. The central government was strongly interested in improving the Royal Navy and navigation generally. Thus, Charles II founded the Royal Observatory at Greenwich in 1675 to undertake celestial observations that would serve as the basis for determining longitude at sea and also directed the Admiralty to undertake the first entire survey of Britain's coasts, begun by Captain Greenville Collins in 1681. Yet these innovations were poorly implemented. Lacking consistent institutional support and funding, Collins worked intermittently until 1688 and then was

able to have fewer than half of his charts published in his *Great Britain's Coasting-Pilot* (1693) (see fig. 515). John Adair's surveys of the Scottish coasts in the 1680s, supported in part by the Scottish Parliament, remained unpublished until 1703. With no means or will to train hydrographers, the Admiralty encouraged mariners to undertake new surveys, mostly after 1750, by holding out the prospect of promotion and lucrative appointments. Great strides were made independently by Scottish schoolteacher Murdoch Mackenzie the Elder, who undertook a triangulation survey of the Orkney Islands, which was published in 1750 (see figs. 80 and 759); his later *Treatise of Maritim Surveying* (1774) determined new standards for maritime surveying. But only in 1795 did the Admiralty establish the Hydrographical Office (Robinson 1962, 40–46, 71–86, 102).

As for the Royal Observatory, it too developed slowly (the first astronomer royal had to provide his own instruments) and only attained a firm institutional footing over the course of the early eighteenth century. Here too, the government encouraged private efforts to determine longitude at sea through the prospect of a huge reward offered under the 1714 Longitude Act.

Production of marine charts was dominated by commercial enterprise. The growth of the merchant marine led to the slow eclipse of the so-called Thames School of manuscript chartmakers. Initial collections of charts, starting with Joseph Moxon's *A Book of Sea-Plats* (1657), simply reprinted Dutch charts. Only after 1700 did the publishing dynasty of Mount and Page find a ready market for larger works, such as the various volumes of *The English Pilot* begun by John Seller in 1671. Commercial mapsellers also produced and disseminated the results of hydrographic surveys so that by 1800 London was the European center of chart production.

The detailed mapping of Britain was largely a commercial and civil affair. Organized by the basic territorial unit of the county, regional mapping before 1750 has been characterized as a "century of re-publishing" earlier maps based ultimately on surveys of England and Scotland from the period 1570–1620 (Delano-Smith and Kain 1999, 75–81; Fleet, Wilkes, and Withers 2012, 66–69). The growing interest in agricultural improvements, all privately capitalized, spurred new topographical surveys in support, first, of draining the extensive fenlands of eastern England and then within established county boundaries, starting with Joel Gascoyne's *A Map of the County of Cornwall* (1699) on a scale of 1 inch to 1 mile (1:63,360). County surveys were greatly stimulated by the premiums offered by the Society of Arts after 1759 to reward the production of detailed base maps of each county, leading to the remapping not only of England but Scotland as well (Delano-Smith and Kain 1999, 81–97; Fleet, Wilkes, and Withers 2012, 128–33).

By contrast, military mapping before 1750 was almost completely limited to the topographical and architectural mapping of fortifications. William Roy and David Watson's famous military survey of the Scottish highlands after the Jacobite rebellion in 1745 offered a general view of the military situation of roads and forts. The recurring threat of French invasion after 1756 led to a number of detailed regional military surveys, notably the map of southeastern England by Roy, Watson, and David Dundas (1765) and Charles Vallancey's intermittent surveys of southern Ireland (after 1776). As master general of the Ordnance, Charles Lennox, third duke of Richmond, promoted a further round of such surveys after 1782, using civilian surveyors. Recognizing the public need for such information, he reorganized the surveys in 1791 with the goal of publishing the resultant maps, giving rise to what would eventually be called the Ordnance Survey.

Large-scale property and infrastructure mapping also experienced a significant upsurge in activity after 1750, as landowners became more accustomed to maps and as the landscapes of England and Scotland were significantly transformed by enclosures, forest management, reclamation of marshes and heaths, the growth of rural industries, the creation of planned villages, and the construction of new roads, canals, and harbors (fig. 341). Intended for only small groups of users, large-scale maps remained almost entirely in manuscript. As ever, Parliament was disinclined to fund large infrastructure programs and consequently devolved administrative and financial responsibility for such enterprises to private corporations (Delano-Smith and Kain 1999, 112–32; Fleet, Wilkes, and Withers 2012, 134–43). The acute shortage by 1780 in the domestic supply of ship timbers for the Royal Navy did prompt governmental intervention; the Crown Land Revenues Act of 1786 ordered the systematic mapping and inventorying of the royal woods as an aid to scientific methods of silviculture and conservation, leading to the production of seventeen land revenue reports (1787–93) that included the first comprehensive forestry maps made in Britain. Finally, the age of improvement was reflected in an upsurge in detailed urban mapping (Delano-Smith and Kain 1999, 200–214; Fleet, Wilkes, and Withers 2012, 107–11; Kain and Oliver 2015).

The British government supported mapping activities by its expansion of overseas empire, colonies, and trade. The repeated wars with Catholic France, from the Nine Years' War (also known as the War of the League of Augsburg, 1688–97) to the Napoleonic Wars (1803–15), led to an ever-increasing appreciation of the value of maps for strategic, tactical, and logistical planning. Indirectly, the increasingly global scope and cost of the wars fueled an ever-increasing public debt, which in

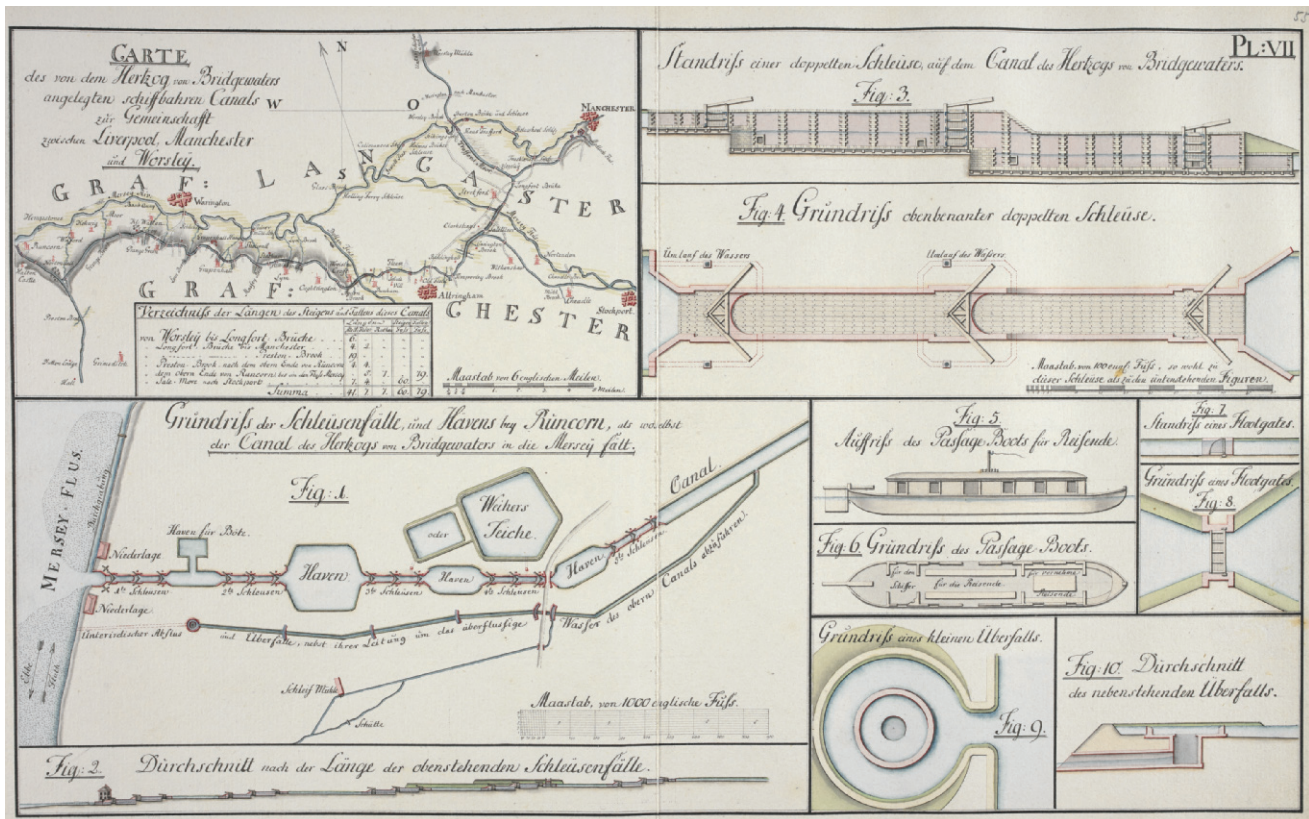


FIG. 341. CANAL SYSTEM BY JOHANN LUDEWIG HOGREWE, 1778. Although the electors of Hanover were also kings of England, in 1714–37 there were very few cartographic connections between the two territories. One was the engineer Hogrewe, whom George III brought to Britain in the 1770s. Hogrewe investigated Britain's burgeoning canal system and

published an account, *Beschreibung der in England seit 1759. angelegten, und jetzt grösten theils vollendeten schiffbaren Kanäle* (1780); the king's collections contain many manuscript canal maps by Hogrewe.

Size of the original: ca. 25.5 × 41.5 cm. © The British Library Board, London (Western Manuscripts, Kings MS 46, plan VII).

turn encouraged public political debate and the public consumption of maps (Edney 2008); the growth of the public sphere also entailed a geographical discourse that emphasized Scotland's distinctive national identity, especially in light of the union with England (Withers 2001). After 1750, the acquisition of extensive overseas territories prompted major surveys in British America and in India, by the East India Company; increased support for scientific inquiry prompted a series of oceanic explorations by James Cook and others. As a result, London became a major clearinghouse for new geographical information.

Map historians have understandably emphasized the ambitious projects of the Restoration, the post-1750 cartographic achievements of an industrial and imperial Britain, and the engravers and publishers who made up the map trade throughout the period. Given the dominance of the English economy, such histories have focused on the production of maps in London or as directed by London-based institutions. However, overviews of how the British Isles were mapped have

been written according to national territorial divisions (Delano-Smith and Kain 1999; Andrews 1997; Fleet, Wilkes, and Withers 2012) with little consideration of the commonalities of cartographic practice.

ALEXANDER JAMES COOK JOHNSON

SEE ALSO: Academies of Science; Administrative Cartography; British America; Celestial Mapping; East India Company (Great Britain); Geodetic Surveying; Geographical Mapping; Hudson's Bay Company (Great Britain); Map Collecting; Map Trade; Marine Charting; Military Cartography; Property Mapping; Thematic Mapping; Topographical Surveying; Trade and Plantations, Board of (Great Britain); Urban Mapping

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Green, John. John Green was the leading British proponent of critical geography in the early eighteenth century. His work has an intellectual unity that stands in marked contrast to the work of his contemporaries (Crone 1949); even French geographers approved of his pioneering cartographic memoirs (Robert de Vaugondy 1755, 179–80). Yet his notorious character meant he was only ever a geographer-for-hire. The sparse evidence indicates a womanizer, probable bigamist, and gambler (Crone 1951). He was actually born Bradock Mead, before 1688, to a respectable Dublin family; he perhaps attended Trinity College but, if so, he did not graduate. Moving to London before 1717 and adopting the name "Rogers," he worked as a researcher and writer, notably for Ephraim Chambers's *Cyclopædia* (1728). Soon thereafter, his role in the kidnapping of an Irish heiress sent him to jail. By 1735 he was free and, as "John Green," editing geographical texts and maps for a series of London booksellers, falling out with each in turn, and rarely signing his work. He committed suicide in 1757.

Green's interest in maps stemmed from his editing of geographical texts, for which carefully constructed maps were essential. His first known publication—the anonymous *The Construction of Maps and Globes* (1717)—

was originally the preface for a putative collection of geographical voyages. His textual sensibilities permeated this monograph on map projections: if British geography was ever going to advance beyond its hackneyed state, in which derivative works were routinely passed off as new, maps and texts should be subjected to the same critical practices, and geographers should explain that criticism in detailed memoirs. Thus, for the English translation of Jean-Baptiste Du Halde's 1735 account of China, published as *Description of the Empire of China and Chinese-Tartary* (1738–41), Green recom-piled Jean-Baptiste Bourguignon d'Anville's associated maps according to revised values for longitude; his explanation of his geographical editing was appended to the translators' preface (Foss 1985, 366–73). This explanation was probably the first critical statement prepared by a British geographer. When finally permitted full rein by Thomas Jefferys, Green wrote a volume of *Remarks* in conjunction with his six-sheet *Chart of North and South America* (1753) and an *Explanation* of his *New Map of Nova Scotia, and Cape Britain* (1755). Yet his self-conscious pursuit of geographical truth is marred by his four-sheet *Map of the Most Inhabited Part of New England* (1755), whose statement of sources is quite fraudulent and obscures how the map was in fact copied from others (Edney 2003, 158–59).

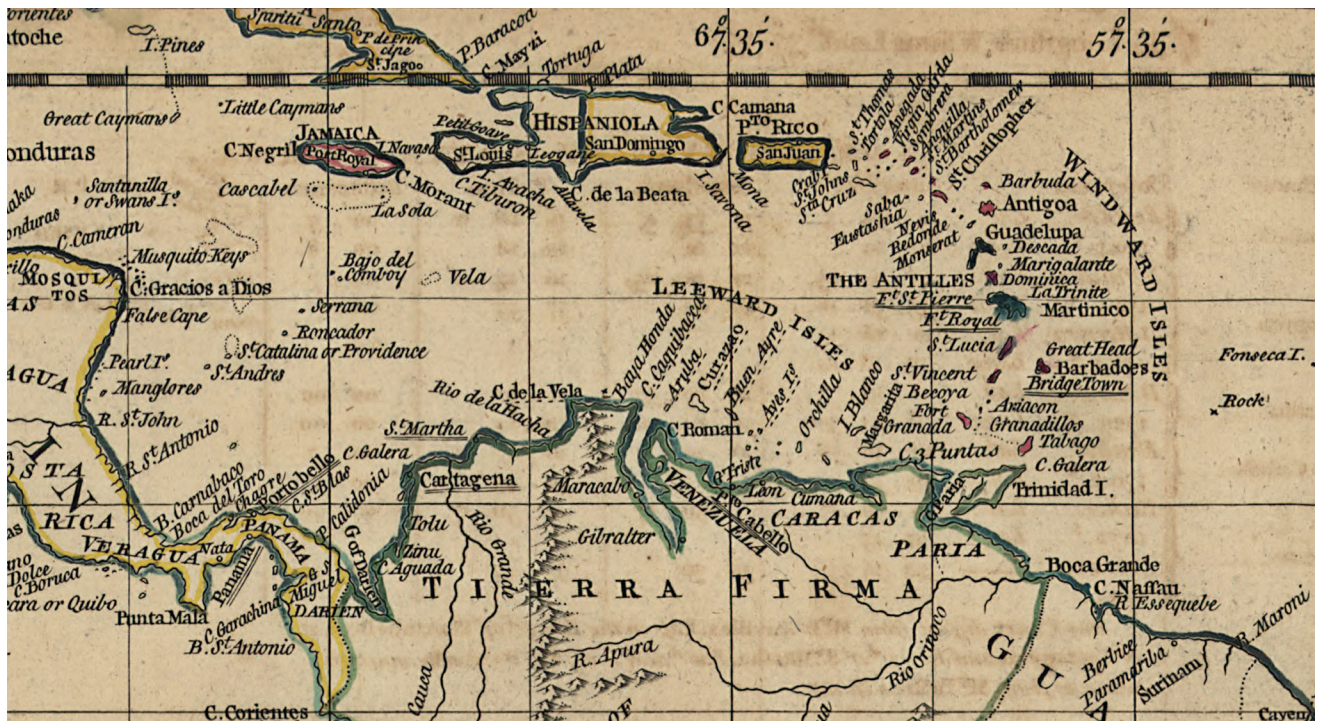
Green's maps were quite unlike contemporary British work. He advertised the quality of his work by listing his source materials and underlining the key locations to which he had fitted them (one line if only latitude was known, two for longitude). He favorably compared his own work to that of the leading French mapmakers (fig. 342). This critical style, together with some contemporary references to his authorship, has permitted the reliable attribution of some sixteen books and separate maps to him (Edney 1998). Those contemporary references suggest, no matter how obscure he has become, that Green's scholarship was then well regarded. In this respect, his mapping practices seem to have set a standard to be emulated as British geography grew increasingly rigorous after 1763 in the service of a burgeoning empire.

MATTHEW H. EDNEY

SEE ALSO: Geographical Mapping; (1) Enlightenment, (2) Great Britain; History of Cartography; Memoirs, Cartographic

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47° 35' Longitude W. from Londⁿ. 37° 35' 27° 35'

Places.	Observers.	Situation.	NORTH COAST OF SOUTH AMERICA.		
			this Chart.	Bellins.	Difference.
Puertobello	Feuillee, Lat.	9 . 33 . 5 .	9 . 33 . 5 .	9 . 28 . 0 .	00 . 5 .
	1704.* Long.	62 . 10 .	62 . 10 .	62 . 18 .	00 . 8 .
Cartagena	P. Feuillee, Lat.	10 . 30 . 25 .	10 . 30 . 25 .	10 . 23 . 0 .	00 . 7 .
	1704.* Long.	57 . 50 . 0 .	58 . 00 .	57 . 55 .	00 . 5 .
St. Martha	D. Herrera, Lat.	10 . 26 . 35 .	11 . 19 . 53 .	11 . 19 .	00 . 00 .
	1724.* Long.	57 . 46 . 15 .	56 . 24 . 30 .	56 . 24 . 30 .	00 . 00 .
Porto Cabello	D. Herrera, Lat.	11 . 19 . 53 .	10 . 10 . 0 .	10 . 17 . 0 .	00 . 7 .
	Feuillee, Lat.	10 . 30 . 50 .	50 .	50 . 43 .	00 . 43 .
Cayenne	1704.* Long.	49 . 52 .	4 . 56 . 17 .	4 . 56 . 17 .	00 . 00 .
	Richer, Lat.	4 . 56 . 17 .	34 . 45 .	35 . 30 .	00 . 15 .
	1672. ^d Long.	34 . 45 .	1744.*	35 . 45 .	
	Condamme, —	34 . 35 .			

Our Chart differs from M^r. D'Anville's Map, in the Long^d of Puertobello, Lat^d of Cartagena, and Long^d of St. Martha, Lat^d and Long^d of P. Cabello, much the same as from M^r. Bellins Chart.

FIG. 342. DETAILS OF THE NORTH COAST OF SOUTH AMERICA AND THE WEST INDIES FROM SHEET SIX OF JOHN GREEN'S A CHART OF NORTH AND SOUTH AMERICA. From Thomas Jefferys, A General Topography of North America and the West Indies (London: Robert Sayer, 1768). Originally published in 1753, this map shows Green's practice (above) of using underlining to identify places of known latitude (one line) and latitude and longitude (two

lines). Green also supplied tables (below) of the key locations as used on "this chart" as compared with the works of major French and Spanish mapmakers. Size of the entire sheet: ca. 54.5 × 61.5 cm; size of each detail: ca. 9.5 × 17.5 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C. (G1105 .J4 1768).

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Robert de Vaugondy, Didier. 1755. *Essai sur l’histoire de la géographie, ou sur son origine, ses progrès & son état actuel*. Paris: Antoine Boudet.

Greenwich Observatory (Great Britain). One of the great unsolved problems in the seventeenth century was finding longitude at sea so that ships could be navigated when out of sight of land. A theoretical solution was the method of lunar distances, in which the moon’s position among the stars could be used to determine time at a fixed meridian. When compared with local time, this would give the longitude. But it required more accurate moon and star positions than were then available. For this reason the Royal Observatory at Greenwich was founded by King Charles II in 1675, with John Flamsteed as its first astronomical observator. The choice of Greenwich as the site was dictated by convenience and economics, rather than by science. The foundations of a derelict building already existed in the Royal Park, which was close to London and with suitable building materials nearby at the Tower of London and Tilbury Fort (fig. 343) (Forbes 1975, 19–24).

Most of Flamsteed’s time as astronomer royal (the title to which astronomical observator was later changed) was spent in making the observations required to compile an accurate new catalog of star positions to replace that of Tycho Brahe, which had been made without telescopic aid. It was not until 1725, over five years after Flamsteed’s death, that the catalog was completed by his assistant Joseph Crosthwait and published as *Historia coelestis Britannica*. Meanwhile, a pirate copy had been published in 1712 by Isaac Newton, based on data loaned him for his private use by Flamsteed. After winning a court case, Flamsteed was given all the unsold pirate copies, which he destroyed—after removing those sections that might be useful to him. The star positions were also plotted on charts in the 1729 *Atlas coelestis*, on a projection devised by Flamsteed and now known as the Sanson-Flamsteed projection (Nicolas Sanson was a prolific French cartographer).

The second astronomer royal was Edmond Halley. Despite their earlier friendship and collaboration, Flamsteed would not have favored Halley because of his close association with Newton. Nevertheless, Halley came to the post in 1720 at the age of sixty-four,

having already distinguished himself as one of England’s greatest scientists. Among his many achievements were important cartographic contributions including charts of the southern stars, trade winds, and magnetic declination, but, of these, only his chart of the observed path in England of the 1724 total eclipse was made during his time at Greenwich. Halley’s work as astronomer royal was chiefly concerned with measuring the position of the moon to complete the second requirement of the method of lunar distances. After replacing the astronomical instruments (those of Flamsteed had been removed by his widow), Halley lived to observe the moon over a full nineteen-year Metonic cycle (Cook 1998, 377–404).

The urgency of the longitude problem had been emphasized by the British government’s offer in 1714 of a huge prize for its solution. Despite this, the lunar distance method was not ready for implementation at sea until the publication in 1766 of the first *Nautical Almanac* by Nevil Maskelyne, the fifth astronomer royal, which gave predictions of the moon’s position among the stars for the year 1767. Updated predictions would be published in each new annual edition of the *Almanac*. Equipped with a sextant, to measure the angular distances between the moon and certain stars, and after some heavy calculations drawing on values provided by the *Almanac*, the mariner could determine longitude at sea, east or west of Greenwich. But Maskelyne failed to win the prize, which was awarded in 1773 after considerable prevarication, to John Harrison for the alternative technology of the marine chronometer. Though vastly more expensive and less widely available than the *Nautical Almanac*, the chronometer method was popular with mariners because of its relative simplicity of application and its endorsement by James Cook.

In 1784, Major General William Roy undertook the measurement of the distance between the Greenwich and the Paris observatories. He started from a baseline on Hounslow Heath and triangulated from there to the transit circle at Greenwich, then on to Dover and the French coast. César-François Cassini (III) de Thury, director of the Paris Observatory, had already supervised the triangulation from there to the French coast (Roy 1790).

The Greenwich Observatory continued to publish the *Nautical Almanac* and contribute to astronomy, but it was never in the business of producing charts. The meridian of the Greenwich Observatory was adopted for defining standard global time by an international conference in 1884, which led to its adoption as a prime meridian for official mapping by many countries in the twentieth century.

STUART MALIN



FIG. 343. THE OCTAGON ROOM OF THE ROYAL OBSERVATORY AT GREENWICH, CA. 1676. Etching by Francis Place after Robert Thacker.

Size of the original: 46 × 61 cm. © National Maritime Museum, Greenwich, London. The Image Works.

SEE ALSO: Academies of Science; Flamsteed, John; Greenwich-Paris Triangulation; Halley, Edmond; Longitude and Latitude; Meridians, Local and Prime

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Greenwich-Paris Triangulation. In a *mémoire* sent to the British government in 1783, César-François Cassini (III) de Thury proposed extending to England the triangulation of France in order to determine the difference in longitude between Europe's two famous ob-

servatories, both producers of astronomical data (Cassini, Méchain, and Legendre [1791], xii–xiii). The Royal Society (William Roy in particular) was interested in measuring the difference between the prime meridians of London and Paris (Widmalm 1990, 188). French navigators and astronomers were equally interested because of their need to use and compare data from Greenwich to establish the longitudes of observed locations (Chapuis 1999, 271), even though the *Connaissance des temps* used the Paris meridian as reference for lunar distances from 1786 (the edition for the year 1789) (Chapuis 1999, 70).

In the summer of 1784, Roy measured an initial baseline on Hounslow Heath, southwest of London, for a chain of triangles running from the British capital to Dover. From there, the chain extended across the Channel to the French coast to join a similar chain of triangles based on the Paris meridian (Cassini, Méchain, and Legendre [1791], xii–xiii). Thus, these two coun-

tries began an exemplary cooperative venture characterized by an exactitude unprecedented in the history of geodesy. Such accuracy was possible because of improvements in instrumentation made during the 1780s, notably the increased quality of the steel for surveyor's chains and of platinum and brass for rods used to measure baselines. At the end of the eighteenth century, these standards were verified by a comparator of length measures, created by Étienne Lenoir, which was precise to within about twenty microns. This same margin of error was achieved by Jean-Charles Borda; his rods made of a brass-platinum alloy had a variation in dilation of nearly just twenty microns with a variation of one degree in temperature (Chapuis 1999, 272).

In England, the theodolite benefited from several technical advances, including the division of circles, which made it possible to obtain high-quality results from instruments of moderate radius. Between 1784 and 1787, Jesse Ramsden worked to produce his remarkable theodolite, whose scope was mounted on a horizontal axis and equipped with a micrometer and a source of light for use at night (Taylor 1966, 244) (see fig. 412). On the zenithal circle graduated in half-degrees, it was possible to read the angular displacement of the scope to within three seconds (Daumas 1953, 247). Once the theodolite was ready and paid for by George III, the English government invited French commissioners to collaborate in joining the triangles between Dover and Calais during the summer of 1787 (Cassini, Méchain, and Legendre [1791], xiv).

For the French, this undertaking provided an opportunity for Jean-Dominique Cassini (IV), Pierre-François-André Méchain, and Adrien-Marie Legendre to test Borda's new astronomic circle, which was produced by Lenoir and had just been used on the border between France and Spain (Daumas 1953, 243) (see fig. 541). Cassini IV described the instrument, which had been paid for by Louis XVI, as "just a whole circle, a foot in diameter, and thus of a very portable and very convenient size, which can be placed anywhere, set up without difficulty on the smallest support, in the narrowest space and which, in spite of its small size, provides more exactitude than one could expect from large quarter circles [i.e., quadrants]" (Cassini, Méchain, and Legendre [1791], 23).

The French mission also carried a quadrant of 2.5-foot radius. Méchain used both instruments, but all the measurements confirmed the clear superiority of Borda's smaller circle (Mascart 1919, 489). The astronomical circle (also called repeating circle or *cercle répétiteur*; not to be confused with Borda's similar "reflecting circle") was a little less exact than the English theodolite, but it had the enormous advantage of being one-third the size, therefore less cumbersome, with its

32-centimeter diameter and weighing only 20 pounds compared to the theodolite's 200 pounds (Cassini, Méchain, and Legendre [1791], xvi, 57; Widmalm 1990, 194). The progress for geodesy was considerable: "One evaluated at about ten toises [19.49 meters] the error that geodesic measurements might yield over a distance of sixty lieues [266,700 meters]. . . . It will be possible to reduce this error by more than half" (Cassini, Méchain, and Legendre [1791], xi). The triangulation also supported Roy's ambition to initiate a national survey for Great Britain (Widmalm 1990, 188, 195).

In the autumn of 1787, the junction of the two triangulations took place with great precision (fig. 344). "The Paris meridian found itself rejoined to the Greenwich meridian by a continuous chain of forty-two triangles, which, extended to a base historically measured to the north of Dunkirk, gave its [the base's] length to within a foot [pied = 324.84 mm] of what had been determined earlier using the chain of triangles from the Paris meridian, an agreement as surprising as it was satisfactory between two operations departing from two points as widely separated as London and Paris" (Cassini, Méchain, and Legendre [1791], xvi).

The astronomers thus established a difference in longitude of about 2°20' between the Paris and Greenwich observatories. On the French side, the first result obtained was 2°19'29.2" and the second measured was 2°20'9.4". Across the Channel, Roy obtained 2°19'42". These results were very good, since the value later accepted was 2°20'14" (Chapuis 1999, 273). In the long term, these results influenced a growing rhetoric of accuracy and exactness that distinguished discussions of surveying and cartography (Widmalm 1990, 195–200). The Greenwich-Paris triangulation was a remarkable instance of two countries, competitive on commercial and military fronts, cooperating in the name of science.

OLIVIER CHAPUIS

SEE ALSO: Geodesy and the Size and Shape of the Earth; Geodetic Surveying: (1) Enlightenment, (2) France, (3) Great Britain; Instruments for Angle Measuring

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FIG. 344. PLAN OF THE TRIANGLES WHEREBY THE DISTANCE BETWEEN THE ROYAL OBSERVATORIES OF GREENWICH AND PARIS HAS BEEN DETERMINED. From William Roy, "An Account of the Trigonometrical Operation, Whereby the Distance between the Meridians of the Royal Observatories of Greenwich and Paris Has Been

Determined," *Philosophical Transactions* 80 (1790): 111–270, pl. IX.

Size of the original: 31.6 × 64.6 cm. Image courtesy of the Department of Special Collections, Memorial Library, University of Wisconsin–Madison.

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Guettard, Jean-Étienne. Jean-Étienne Guettard (1715–86) was a prolific naturalist whose efforts to map the surface configuration of land established his reputation as a pioneer of geological cartography. Thanks to the support of Bernard de Jussieu, the young Guettard from Estampes was introduced to the world of Parisian naturalists during the 1740s. Guettard benefited from the protection first of René Antoine Ferchault de Réaumur, becoming his assistant in 1741, and then from the Orléans family in 1747. The quality of Guettard's early work won him an appointment to the Académie royale des sciences as an assistant botanist on 3 July 1743. Three years later, he presented his "Mémoire et carte minéralogique" to colleagues at the Académie; it was later published with two maps (*Carte minéralogique sur la nature du terrain d'une portion de l'Europe* and the larger-scale *Carte minéralogique, Où l'on voit la nature et la situation des terrains qui traversent la France et*

l'Angleterre) as an abridged version of the whole work (Guettard 1751, 364, 384). The maps displayed data collected from various excursions showing the nature and location of the terrain at a glance. The work demonstrated Guettard's emphasis on patterns in the distribution of substances across the earth's surface. Drawn by Philippe Buache, the maps employed two types of graphic representations: point symbols for locating mineral beds and three wide bands (*bandes*) that identified schists and metallic ores, marl, and sand deposits. This cartographic method, which depicted general landforms and evoked stratification, generated new perspectives; Guettard used the technique again to present mineralogical data that he had collected on North America, Switzerland, Poland, the Middle East, and France to the Académie royale des sciences in 1763 (Rappaport 1969, 278).

From the early 1760s, Guettard deliberated over what scale would allow the most precise depiction of land detail. He finally chose 1:180,000 and began field trips accompanied by his assistant, the young Antoine-Laurent de Lavoisier. The *contrôleur general*, Henri-Léonard-Jean-Baptiste Bertin, took an interest in this detailed atlas project in which mines could be depicted, and he decided to finance an undertaking to map all



FIG. 345. JEAN-ÉTIENNE GUETTARD, *CARTE MINÉRALOGIQUE DE PRESQUE TOUTE LA BRIE ET PAYS ADJACENTS*, 1767. Prepared and executed by Jean-Louis Dupain Triel père. Two columns frame each map: the left column displays the key to symbols used by Guettard to represent mineralogical resources; the right column presents a cross-section

based on barometric measurements performed by Lavoisier. From Jean-Étienne Guettard and Antoine-Grimoald Monnet, *Atlas et description minéralogiques de la France* (Paris: Didot, Desnos, Jombert, 1780), F. 41. Image courtesy of the Newberry Library, Chicago (Case folio G1838.G84 1780).

of France in this way. However, the 1:180,000 scale slowed the project's pace. In 1770, only sixteen maps were printed, which barely covered the northwest portion of the territory (fig. 345). The maps combined the point symbols favored by Guettard with the verticality of the sections defended by Lavoisier. They perpetuated thematic methods that had become traditional in eighteenth-century mineralogical maps, but they also attempted to depict stratification using a technique other than the *bandes* devised in 1746. The *Atlas et description minéralogiques de la France*, by Guettard and Antoine-Grimoald Monnet (1780), included these sixteen maps plus twenty-nine others drawn by Monnet. Other volumes were announced but never published. Though not completed, the project showed how the map was progressively thought of as an administrative tool and how the localization of resources and the configuration of terrain were intertwined deeply with mineralogical cartography in the second half of the eighteenth century.

ISABELLE LABOULAIS

SEE ALSO: Thematic Map; Geological Map; Thematic Mapping; France

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Gulf Stream. The Gulf Stream is the best-known portion of the North Atlantic current gyre; it is the most studied, for reasons of navigation, and was mapped during the Enlightenment as an object of scientific investi-

gation (Withers 2006). Transatlantic voyagers from Columbus onward were aware of subtle surface currents affecting their navigation. Their accounts of the North Atlantic revealed two of the most easily perceived qualities of the Gulf Stream—its velocity and its relatively warm temperature.

Although sailors like Nantucket's whalers used the current and passed the knowledge on locally without the need of descriptive maps, it is remarkable that over two-and-a-half centuries passed before any comprehensive charts showing the current were published in the late eighteenth century. Some writers have suggested that seventeenth-century charts by Athanasius Kircher (1665) and Eberhard Werner Happel (1685) show the Gulf Stream, but their arguments and the maps are unconvincing (De Vorse 1976, 118n4).

Early in the eighteenth-century, mariners began to mention the current and eventually depict it on their charts. In 1705, in his *Voyages and Descriptions*, William Dampier commented on the current that ran always to the north through the Gulf of Florida (Withers 2006, 63). In 1735, a chart of Chesapeake Bay by Walter Hoxton noted a strong northeast flowing current offshore that was recommended to speed northbound navigators, but it was too limited in size to include any graphic depiction of the Gulf Stream.

The first chart to show the Gulf Stream clearly as a major feature of the North Atlantic was prepared at Benjamin Franklin's request by his cousin, Timothy Folger, a Nantucket whaling captain (De Vorse 1976). In London in his role as deputy postmaster for the American colonies, Franklin had been asked why the mail packets often spent longer crossing the Atlantic than did merchantmen. Folger told Franklin that the packet skippers were often seen sailing against the Gulf Stream, while the merchantmen steered to avoid it. Franklin had Folger draw the current, which was then engraved on a copperplate of an old Atlantic chart. These in-house copies were sent to the packet commanders in Falmouth, who appear to have ignored them. Printed in a limited number, probably in early 1769 (Cohn 2000, 128–32), this first Folger-Franklin chart was never published, and only three copies are known to exist.

Much later Franklin went on to publish the Folger view of the Gulf Stream. The first was a French version, prepared and engraved by Paris map publisher Georges-Louis Le Rouge probably in 1783 (fig. 346) (Cohn 2000). An English version, *A Chart of the Gulf Stream*, appeared in 1786 with Franklin's letter to Alphonsus le Roy (Franklin 1786). This chart, engraved by James Poupard, was enormously influential and frequently copied and reprinted. It is largely responsible for the incorrect although widely held opinion that

Franklin was author of the first published Gulf Stream chart.

The first published and widely circulated chart of the Gulf Stream, however, was prepared by William Gerard De Brahm, Britain's German-born surveyor general of the Southern District of North America (De Brahm 1974). In a 1771 Atlantic crossing he had studied the current's course and speed by means of a chronometer and, in 1772, published the first map to show the Gulf Stream as a major feature of the North Atlantic Ocean. De Brahm's *Hydrographical Map of the Atlantic Ocean, . . . Shewing the differ.^t Variations of the Compass, the Setting and Changes of the Currents in the Ocean, . . . Perform'd in 1771*, appeared in his book of sailing directions, *The Atlantic Pilot* (1772), some sixteen years before Benjamin Franklin published his own better-known *A Chart of the Gulf Stream*.

When the Franklin and De Brahm depictions of the Gulf Stream are compared they show considerable differences in style and content largely due to their dissimilar genesis; Franklin's chart was based on Folger's knowledge of the width of the current by cruising along its edges looking for whales and observing its velocity from the speed of whaling boats in the current while his ship was outside its flow. Franklin's chart indicates the Gulf Stream's velocity in several places from the Carolina coast to the Newfoundland Banks. Mail packet navigators bound for American ports were most liable to be impeded by the northeasterly current, which Franklin painstakingly determined to be warmer than the waters through which it flowed. Thus, the Folger-Franklin charts and their derivatives portray a broad, river-like, warm current with distinct edges. De Brahm, on the other hand, was familiar with the Gulf Stream through his experiences while carrying out detailed hydrographic surveys along the Florida coast. Significantly, the only coastlines sketched on his chart are those of southern Florida north to Charleston and the southwestern approaches to his destination, the English Channel. While Franklin's motivation centered on aiding ships bound for America in avoiding the Gulf Stream's impeding flow, De Brahm's ambition was to aid ships bound for Europe by employing the current's easterly flow to accelerate their crossing time. Through accurate celestial navigation and inference, De Brahm determined the Gulf Stream's location and velocity. On his innovative chart he symbolized the Gulf Stream as a dark ribbon of flow lines of constant width indicating the course of the current from the Gulf of Mexico to the north and northeast until it joined with a broader current issuing from the Arctic. This combined current is shown to flow south-east around the Azores before beginning to curve south-westwardly to complete a North Atlantic current gyre.



FIG. 346. THE UNTITLED FOLGER-FRANKLIN MAP OF THE GULF STREAM, AS PUBLISHED IN PARIS BY GEORGES-LOUIS LE ROUGE CA. 1783.

Image courtesy of the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland (OS-1782-2).

De Brahm's flow lines highlighted what later oceanographers would term the Gulf Stream's centerline, where its maximum reliability and velocity are found.

By the closing decades of the eighteenth century the nature, location, and significance of the Gulf Stream had been made known to the burgeoning maritime science of the Enlightenment thanks to the efforts of De Brahm and Franklin and their maps. Their pioneering endeavors were carried forward by others including Franklin's nephew and shipboard associate Jonathan Williams, who pioneered the use of a thermometer to find the exact edges of the Gulf Stream (fig. 347), American na-

val officer Thomas Truxton, Massachusetts governor Thomas Pownall, British physician and scientist Charles Blagden, British naturalist William Strickland, and British hydrographer James Rennell.

LOUIS DE VORSEY

SEE ALSO: De Brahm, William Gerard; Thematic Mapping

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FIG. 347. JONATHAN WILLIAMS'S MAP OF THE GULF STREAM, 1793. From Jonathan Williams, "Memoir of Jonathan Williams, on the Use of the Thermometer in Discovering Banks, Soundings, &c.," *Transactions of the American Philosophical Society* 3 (1793): 82–100, map between 84

and 85. The map shows the Gulf Stream with the tracks of five ships.

Size of the original: 19.5 × 40.0 cm. Image courtesy of the Special Collections Library, University of Michigan, Ann Arbor (AS 36 A 532 v.3).

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