# T

***Tatishchev, Vasiliy Nikitich.*** Russian statesman, historian, geographer, and cartographer Vasiliy Nikitich Tatishchev was born in 1686 near Pskov to a family of royal descent. After graduating from the engineering school in Moscow, Moskovskaya inzhenernaya shkola, Tatishchev participated in the early stages of the Great Northern War (1700–1721), taking part in the capture of Narva, the Battle of Poltava, and the Prut Campaign of Peter I. In 1713–14 he took his education abroad—in Berlin, Wrocław, and Dresden. After his return, Tatishchev worked under Yakov Vilimovich Bryus, a close associate and friend of Peter I and the president of the Berg-manufaktur kollegiya for mining and industry. In 1719, Bryus advised Peter I to begin a detailed description of Russia, appointing Tatishchev as the officer for the work. In the same year, Tatishchev advised Peter I on how maps or drawings of the lands should be made (Pekarskiy 1864, 9–11).

In the 1730s and 1740s, Tatishchev was in the state's employ and responsible for organizing the exploration of the natural resources of the Urals and Siberia as well as for supervising the mining industry there. He wrote several influential reports arguing for improved cartographic standards across the Russian Empire. After Ivan Kirilovich Kirilov's death in 1737, Tatishchev took over the Orenburg Expedition (1734–44) and quickly enacted a new set of field instructions for topographical surveys, one of the most detailed in eighteenth-century Russia (Goldenberg and Postnikov 1985, 65).

These instructions had the effect of improving the geodetic control of surveying. Tatishchev curtailed the use of verbal inquiries, and scientific instrumentation rose to new prominence. His predecessors had called for one instrument course plotted in each district. Tatishchev called for plotting three or four courses through landmarks or along major rivers, with a survey station in each city. The reliability of maps thus grew out of a network of precisely located population centers.

Tatishchev asked surveyors to "write down what can be seen of the terrain from any distance on a rhumb line" (Rossiyskiy gosudarstvennyy arkhiv drevnikh aktov [RGADA], f. 248, op. 14, # 772, ch. 442). Mountains, forests, houses, cemeteries, and fortresses were all to be indicated. Rivers especially were to be charted in great detail: geographical coordinates, depth, width, speed, and bottom features. In their reports, surveyors were to make alphabetized indexes to their maps to serve as glossaries to local features. Tatishchev's detailed questionnaire, which included 192 items, asked surveyors to note geographical and historical details never before recorded (Tatishchev 1950, 77–78).

Tatishchev's management style, although exacting, seems to have been tempered with a kind of optimistic realism. Unlike Joseph-Nicolas Delisle, who assumed that a map of Russia would be impossible to produce until its entire territory was covered by triangulation, Tatishchev understood that mapmakers should begin with accurate degree measurements in the more densely settled, European parts of the country. Traditional reconnaissance route survey methods would have to be employed in Siberia until triangulation caught up (Tatishchev 1950, 98–103). The *Atlas Rossiyskoy,* published in 1745 by the Akademiya nauk under Delisle's supervision, was critiqued by Tatishchev for failing to use new materials such as those that Tatishchev himself had obtained during his term as the Orenburg Expedition's supervisor (Gnucheva 1946, 185).

After his retirement from civil service, Tatishchev dedicated himself to scholarly pursuits. He wrote an encyclopedic dictionary and a five-volume history of Russia, posthumously published. He died in 1750 at the Boldino estate near Moscow.

ALEXEY V. POSTNIKOV

SEE ALSO: Administrative Cartography: Russia; Russia

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***Taxation and Cartography.*** Maps were used widely across Europe in the seventeenth and eighteenth centuries to assess and to record the tax liability of particular pieces of land. Such taxes might be for specific purposes, such as to pay for the upkeep of dikes that protected reclaimed polders or as tithes for the upkeep of the church. Additionally, maps were used by states to raise taxation revenues for general purposes, and the development of physiocracy provided further incentive to taxation reform and land survey in the later part of the eighteenth century. To François Quesnay and fellow physiocrats, the source of all value was land, rather than labor or some other factor of production. The very idea of using a map base to assess the land tax more accurately and levy it more equitably in the late eighteenth century was quintessentially physiocratic (Kain and Baigent 1992, 338; most of this entry draws directly from the much fuller treatment in that work). Physiocrats and other enlightened reformers held that there should be one tax, the *impôt unique*, equally apportioned, due to, and collected by the central state. In France, a physiocratic view of taxation reform directed administrative attention toward a map-based land tax.

In the seventeenth-century Netherlands, there were many instances of a map base being employed to calculate liabilities for dike taxes. In Voorne, for example, an atlas was commissioned from Heyman van Dijck between 1695 and 1701; it consisted of four general maps (at 1:19,000–1:30,000) (fig. 772) and twenty-nine detailed maps of the polder properties (at ca. 1:3,000–1:11,000). The regula-

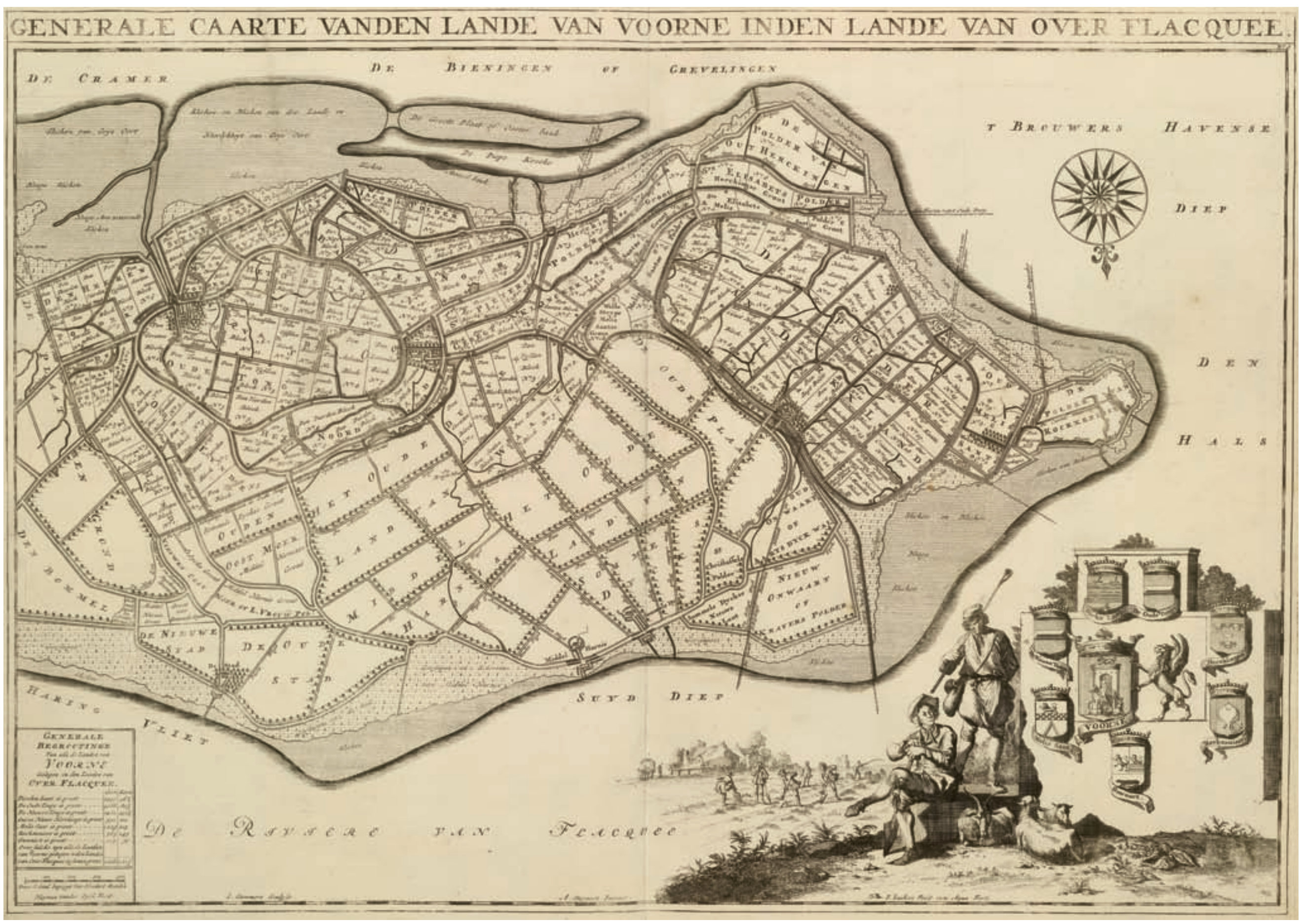


FIG. 772. MAP OF VOORNE BY HEYMAN VAN DIJCK. The *Generale caarte vanden lande van Voorne inden lande van Over Flacquee* at 1:20,000 was one of the general maps in the *Voorne: Caart-boeck* atlas (1701), which contained thirty-three maps. Etched copperplate.

Licentie CC-BY, Kaartcollectie Binnenland Hingman, Nationaal Archief, The Hague (4.VTH E).


FIG. 773. MANUSCRIPT TITHE MAP OF NIEDERZWEHREN COMPILED BY WILHELM DILICH, 1625, 1:6,500. Size of the original: 54.9 × 64.8 cm. Image courtesy of the Hessisches Landesarchiv beim Staatsarchiv Marburg (Best. 304 Karte R III 1).

tion and efficient collection of such taxes were also important in the adjoining low-lying areas of Germany. In coastal areas of Friesland, responsibility for maintaining dikes lay with the owners of adjoining plots of land. This system was managed very carefully from an early date, as dike maintenance was both very expensive and vital to the survival of the community. *Deichkataster*, *Deichregister*, or *Deichrollen*, often accompanied by maps from the mid-eighteenth century onward, show the ownership and extent of each plot of land on the dike bank and the amount of labor or money to be spent on dike upkeep.

Tithe maps were also used for specific, as distinct from general, taxation purposes. A German example is a map of Niederzwehren by one of Hessen's most celebrated early mapmakers, Wilhelm Dilich (fig. 773), depicting the extent of all cultivated titheable plots. Originally tithes were due to the church, but by the seventeenth and eighteenth centuries they had been appropriated in many places by secular entities. One such secular authority was the Elector of Hanover, and in 1744 the Hanoverian treasury ordered a complete survey, mapping, and description of areas liable for tithes so that they could be collected more efficiently (Leerhoff 1985, 154–55). Tithes formed a considerable part of the revenues of many institutions and rulers, who found it worthwhile to commission maps to resolve disputes over tithes and to clarify or revise tithe liability. Thus, tithe mapping increased awareness of the map as a potential instrument of fiscal control and administration.

The Thirty Years' War (1618–48) brought financial as well as political dislocation to much of Europe, and its legacy cast a shadow over state finances well into the eighteenth century. After the war, the practice of maintaining standing armies increased the burden of state expenditure, and at the same time the complexity of government was increasing, as were its costs. As the need for money increased, so states became ever more interested in accurately surveyed and mapped taxation cadastres as instruments for increasing state revenues.

Some of the earliest instances of the management of state revenues with maps occurred in the Netherlands. Here, state revenues were derived in a number of ways, but the two most important sources were rents and taxes, both of which were collected with the aid of maps. Before the Code Napoléon was introduced in the Netherlands in 1811, tax on immovable property was administered differently in each local area. Although comprehensive reform in many areas had to wait for the arrival of the French, mapping, and particularly comprehensive parcel-by-parcel surveying, was gradually accepted as the best means of apportioning tax liabilities fairly.

Germany in the seventeenth and eighteenth centuries was a patchwork of states, many of them tiny, ruled by more or less autocratic hereditary princes. Interest in tax reform increased greatly in the late seventeenth and eighteenth centuries again as a consequence of the Thirty Years' War. There was a steady increase in the complexity and hence cost of government in almost all states, once again driving interest in maps as instruments for increasing tax revenues (an interest also paralleled in the Swiss cantons). The land tax was by far the most important tax, not least because the German economy remained dominated by the agricultural sector in this period. By the late eighteenth century the need for reform of the land tax was becoming increasingly apparent, but delay in reform was here, as in Austria and France (see below), a result of the opposition of the politically powerful nobility. The nobility feared that a survey would reveal the ways in which they abused their taxation privileges, ways that might be curtailed or even abolished as a result of the knowledge that a mapped taxation survey would provide.

One of the most important of all early taxation mapping projects in Germany was that carried out in Cleve (Kleve) in the 1730s. Here the Prussian king faced a population ruined by the Thirty Years' War, royal demesnes leased out and largely exempt from taxation, and state revenue that did not even cover the interest on public debts. There were several unsuccessful attempts in the seventeenth century to reform taxes thoroughly. In 1705 some surveying did take place but was not completed. A turning point came in 1730, when the king appointed Friedrich Wilhelm von Borcke to administer all the Prussian territories west of the Weser River. Borcke was committed to taxation reform and in 1731 secured the agreement of the king to a new, thoroughly mapped taxation cadastre. The resulting maps (fig. 774) are accompanied by registers that are organized by map sheet and parcel number and contain the names of the owner of each plot, their place of residence, and the size and description of all land parcels (Aymans 1986).

Implementation of the Cleve taxation mapping illustrates the classic problem of an absolute monarch attempting to reform land taxation and meeting the opposition of a local nobility that had realized how much they stood to lose. It also showed that, though a taxation survey might ultimately be an important instrument of power and control for the monarch, the costs of such a cadastre could be substantial and could jeopardize its completion. The Cleve survey was not completed, as the ruler in the end could no longer afford it; the mapped survey was intended to increase income to the state, not to be a cost burden.

With the exception of the Cleve cadastre, large-scale, centrally organized mapped taxation surveys in Germany had to wait until the nineteenth century. It was rather different in the Austrian Habsburg territory, where the Milanese *censimento* was the first surveyed and mapped taxation cadastre that actually worked. The *censimento* was begun by Charles VI and continued by his successor Maria Theresa, both of whom saw the principle of equal taxation as crucial to their wider political and military reforms. It was the earliest and, for more than a century, the only fully surveyed and mapped cadastre in Austrian Habsburg territory. Conducting the *censimento* marked the climax of the struggle of the Milanese authorities against the autonomy and privileges of particular groups, notably the nobility and the church. Its impact was felt far beyond Lombardy (Zangheri 1980, 107).

The need for reform of taxation in Milan had been apparent from the early eighteenth century. When Prince Eugene of Savoy was governor of Milan, he attempted to raise money to support his troops and found the taxation system in disarray. The Giunta di Nuovo Censimento Milanese was set up in 1718 to undertake a survey that was to set taxation on a more equitable footing in the Duchies of Milan and Mantua. In 1735, this was extended to cover the Duchy of Parma after it fell to Austria under the terms of the Treaty of Vienna (1738) (Kretschmer 1968, 63).

The Giunta began its work by gathering information from all landholders about the nature and extent of holdings and buildings and of sovereign rights over their land. The court mathematician and astronomer, Johann Jakob Marinoni, argued that mapping was the key

FIG. 774. MANUSCRIPT MAP FROM THE CLEVE CADASTRE, 1738. At a scale of ca. 1:2,000. Size of the original: ca. 65.5 × 99.0 cm. Image courtesy of the Landesarchiv Nordrhein-Westfalen Abteilung Rheinland, Duisburg (Kleve, Kataster Nr. 61, Gahlen, 9r–10v).

to an improved taxation system, and that this should be conducted using his own improved plane table, that standard chains and poles should be issued, and that maps should be at a scale of 1:2,000 and should show property boundaries, boundaries of cultivation, communications, drainage, and settlements (Lego [1968], 2, 7). Assessors appointed by the Giunta visited each village and divided the land according to its quality (good, average, or poor), land use, and cost of production. The War of the Polish Succession (1733–38) brought about a temporary halt, and the death of Charles VI in 1740 and the Silesian Wars (1740–48) further delayed the work. When Maria Theresa took up the project in 1749, the assessments had to be completely redone, but by 1759 every parish in the duchy had been surveyed and had information about it recorded in maps, in *Grundparzellenprotokoll* (land registers) and in *Bauparzellenprotokoll* (building plot registers).

The Milan taxation cadastre was widely recognized by contemporaries as a pioneering taxation survey. Adam Smith said: “It is esteemed one of the most accurate that has ever been made” (Smith 1976, 2:835). As a surveying and mapping exercise, the *censimento* was an unequivocal success, but as a piece of taxation reform, it was not wholly satisfactory. The new cadastre left the overall tax burden, and hence the income of the sovereign, unchanged, although the burden was now borne by more people and, in particular, the bulk of the contributions was now paid by the rich rather than the poor (Zangheri 1980, 109). The Milanese cadastre provided a model for tax reform in Europe, its greatest influence being felt not within Habsburg territories but elsewhere, as in the Principality of Piedmont, the Duchy of Savoy, and Spain. In the last, Zenón de Somodevilla y Bengoechea, marqués de la Ensenada, finance minister to Fernando VI (r. 1746–59), instituted a general taxation reform. Ensenada had spent time in Italy, and his Spanish reforms were explicitly modeled on Maria Theresa’s reforms in Lombardy. The problems in Spain closely resembled those of Milan and Piedmont, namely the existence of a powerful nobility and clergy whose exemption from taxation the central state was determined to break. A new cadastre in the province of Castille was begun in 1749 and completed five years later. However, in 1754

Ensenada was ousted and the tax reform foundered in the face of insurmountable noble and clerical opposition (Durán Boo and Camarero Bullón 2002).

In France the nobility, with their jealously guarded privileges of tax reductions and exemptions, opposed general taxation reform until they themselves were "reformed" by the 1789 Revolution. What early attempts at nationwide taxation reform in seventeenth-century France underline is that some necessary political conditions had to be fulfilled before a government could succeed in this area of policy. First, the political and administrative unification of the country had to be agreed on; second, the equality of each citizen in law had to be recognized; and third, equality of each individual in the realm of taxation had to be achieved. These political conditions were not fulfilled until after the Revolution of 1789 and even then perhaps more in rhetoric than in reality. However, some advances were made before this in the Duchy of Savoy (1728–38) and in three *généralités* (separately governed areas) of France.

Savoy was divided into *départements* (administrative districts), corresponding in the main to natural regions, each headed by a *délégué* who controlled a group of surveyors and their assistants. The survey work was carried out by a relatively small number of surveyors and valuers (perhaps a hundred), most of whom had gained experience of such work in mountain areas in the Lombardy tax reforms. Men who knew the limits of a parish were nominated *indicateurs,* and the community provided two *estimateurs* to value each parcel of land and assign it to one of three categories: good, average, or poor. Parcels were delimited in the presence of their proprietors or their representatives, who had to bring evidence of ownership and any rights to tax exemption. Thus, the mapping served three purposes for government administration: it provided a fair and rational basis for assessing tax liability, it provided a precise record of that liability, and it also served as a record of landownership. It was "the product of enlightened despotism . . . instituted primarily to identify the number of minor aristocrats who were avoiding dues, but also to extract fair taxes from all land owning peasants" (Jones and Siddle 1982, 32).

The survey, also known as the *cadastre sarde,* was important in a context much wider than that of the tiny Duchy of Savoy. The imagination and effort expended in the cadastral survey of Savoy were much admired by contemporaries, especially by physiocrats and political writers in France. In the second half of the eighteenth century, in the three *généralités* of Limoges, Riom, and Paris that were characterized by liability to personal taxes, attempts were made to convert these to taxes related to landed property. The role that maps played in each of these regions is different, but between them they provided models for almost all the components of the later revolutionary and Napoleonic cadastres. They are known collectively as *plans d'intendance*, named after their advocacy by the *intendants*, or Crown representatives, who governed them. Each system was based on a detailed survey of the extent and quality of the land to determine tax liability, and large-scale maps were instruments that served as a record of that liability for all time (fig. 775).

The *plans d'intendance* illustrate the ways in which some local administrators were thinking about and using maps as part of taxation reform programs in the decades immediately preceding the Revolution. Each contains elements recognizable in the nineteenth-century general taxation cadastre of France. One man who put together all the elements of this system during the eighteenth century and so has been dubbed the "father of the French cadaster" was Jean-François Henry de Richeprey, a political economist, advocate of social reform, and a prolific topographical writer (Kain and Baigent 1992, 224–25). In his youth, he had worked on the *plan parcellaire* of Corsica and the Milanese cadastre. In the 1780s he was employed as a member of the Haute-Guyenne assembly brought together to direct fiscal reform in the province. By that time there was, of course, nothing novel about using mapped surveys as a means of evaluating or recording land tax liabilities in France. What Richeprey contributed was the development of a rigorous and definitive formula, one that underpinned the nineteenth-century cadastre of France.

The closing years of the Ancien Régime in France had seen both practical examples of tax reform by cadastral survey and a plethora of didactic works advocating wholesale reform, such as that of Richeprey. Though proposals differed in detail, all agreed that a general, mapped cadastre was the only practical solution to the problem of inequality of taxation burdens that had festered for so long. The law of 1 December 1790 abolished all the old taxes and replaced them by a single property tax that had to be divided equally among all properties on the basis of net productivity (Direction générale des Impôts 1987).

This law thus set down the first foundations of a national cadastre, and Gaspard Marie Riche de Prony, director of the Ecole des Ponts et Chaussées, was appointed director of the cadastral department in 1791. As he conceived it, according to Josef W. Konvitz (1987, 49–50), the cadastre was "a highly centralized, rigorously scientific operation designed to permit the piecing together of maps of local areas and comparisons between them." There were two distinct components to the compilation of the cadastre as Prony saw it: first, the geodetic survey; second, the local field surveys to assess land valuations. Mounting costs, reduced budgets, political uncertainties, and delays in reforming systems of measurement and training personnel meant that little


FIG. 775. MANUSCRIPT *PLAN D'INTENDANCE* OF NOISY-LE-ROI, JEAN NICOLAS DEVERT, 1787. Size of the original: 41.2 × 67.0 cm. Image courtesy of the Archives départementales des Yvelines, Montigny-le-Bretonneux (C97/43).

progress toward taxation reform—for which the cadastre was to be an instrument—was made in the 1790s. Really effective reform awaited the series of nineteenth-century taxation surveys beginning with Napoleon's *cadastre parcellaire* begun in 1807.

The land taxes in England and Wales differed in two respects from the land taxes of continental Europe. First, the political context in which they were levied was radically different, and second, they were collected as a part of a general income tax without the use of surveying, mapping, or even a comprehensive written register. These taxes contrasted sharply with those in, for example, Austrian Habsburg lands, Denmark, and the Duchy of Cleve, as the tax was levied on landed classes who in England did not enjoy the tax privileges of their continental neighbors. In England the propertied classes themselves decided in Parliament that they should be subject to taxation. This explains why the English land tax stands as a notable exception to the general European trend of levying land taxes on the basis of taxation surveys during the eighteenth century. No evasion meant no need to reform and thus no need to invoke instruments such as taxation mapping.

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SEE ALSO: Administrative Cartography; Cadastral Surveying; Property Map: Cadastral Map; Property Mapping

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***Telescope.*** See Instruments, Astronomical

## *Thematic Map.*

CLIMATE MAP
GEOLOGICAL MAP

***Climate Map.*** Insofar as the term *climate* connotes the annual mean and seasonal variation of temperature, precipitation, and other atmospheric properties, climate maps were rare before 1800 because coordinated observations and scientific imagination were largely lacking. Evangelista Torricelli invented the mercury barometer in 1643, and Daniel Gabriel Fahrenheit introduced the mercury thermometer in 1714, but systematic observations over meaningfully large areas were not available until the latter part of the eighteenth century. The Societas Meteorologica Palatina, founded at Mannheim in 1780, organized a geographically extensive network of systematic weather observers, but even though the group compiled thrice-daily records for fifteen to thirty-three places over the period 1781 to 1792, the resulting data remained unmapped until 1819, when German physicist Heinrich Wilhelm Brandes produced the first synchronous weather map, for 6 March 1783, using measurements collected over thirty years earlier (Monmonier 1999, 18–22).

Claudius Ptolemy's use of parallels to divide the world into *climata* with similar weather is occasionally considered a climate map, as are later maps of vegetation and other phenomena affected by climate. For instance, Eberhard August Wilhelm von Zimmermann's 1777 and 1783 zoological maps are cited as providing examples of "isothermal-like climatic lines [that] appeared on maps before true isotherms were devised" (Wallis and Robinson 1987, 228). Even so, the symbols and content of modern climatic maps are largely nineteenth-century innovations. Astronomer Edmond Halley's 1701 map of magnetic deviations over the Atlantic Ocean pioneered the use of isolines to portray statistical surfaces (see fig. 348), but the technique was not used for atmospheric cartography until 1817, when Alexander von Humboldt presented a map centered on Europe, on which highly generalized isotherms describe average temperatures between eastern North America and China. Brandes applied the isoline to barometric pressure in 1819—his lines of equal deviation from normal pressure were not true isobars, which typically portray sea-level pressure—and a rainfall map of Europe in the 1841 edition of Heinrich Berghaus's *Physikalischer Atlas* is perhaps the earliest use of the isohyet.

Halley's 1686 map of trade winds was a significant milestone (fig. 776). Based largely on reports acquired from mariners a decade earlier, during a year of astronomical work on St. Helena, the map illustrated his paper "An Historical Account of the Trade Winds, and Monsoons," published in *Philosophical Transactions*,


FIG. 776. HALLEY'S 1686 MAP OF THE TRADE WINDS. Bound into Halley 1686. Size of the original: 15.0 × 49.5 cm. Image courtesy of the Science Museum/Science & Society Picture Library, London.

which he edited at the time. Centered on the Greenwich meridian, the map shows prevailing wind direction over water for an oblong area between 32°N and 32°S and extending from 90°W to 150°E. To symbolize wind direction, Halley used "rows of stroaks in the same line that a Ship would move going alwaies before it; [with] the sharp end of each little stroak pointing out that part of the Horizon, from whence the Wind continually comes." For monsoon winds, which reverse direction, additional "rows of the stroaks run alternatively backwards and forwards" to create a greater density of symbols in the Gulf of Bengal and the waters between Cambodia and New Guinea (Halley 1686, 163). Dashed lines separate regions with disparate wind patterns, and "Calms and Tornado's" identifies an area off west Africa that astute sailors diligently avoided. Hailed by Norman J. W. Thrower and others as "the earliest meteorological chart" (1969, 657), Halley's map is more accurately labeled a climate map. Cast appropriately on a Mercator projection's conformal framework, it was a source for the wind symbols occasionally added to eighteenth-century nautical charts.

Halley's winds chart underscores his discovery that seasonal shifts in wind direction were related to the intensity of solar heating, in particular, the upward movement of air warmed from the below during the summer over land and the consequent movement of moisture-laden air onto the land from the ocean (Frisinger 1977, 123–25; Thrower 1969, 659). This explanation of the trade winds remained dominant well after 1735, when George Hadley, in a short paper published in *Philosophical Transactions* without cartographic illustration, added the earth's rotation as a key element in a more general theory of atmospheric circulation (Lorenz 1983). Similarly obscure is Jean Astruc's "Carte des vents qui sont propres à la province de Languedoc" (1737; noted in Wallis and Robinson 1987, 158), which describes wind patterns over land for a comparatively small area at a larger scale. Aside from Halley's chart, climate maps were largely insignificant until the mid-nineteenth century, when systematically collected atmospheric data made thematic mapping an important tool of climate science.

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SEE ALSO: Thematic Mapping

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***Geological Map.*** Geological features were first mapped extensively in eighteenth-century Europe. The few earlier maps include Dud Dudley's map of coal and iron deposits encircling Dudley, England, in *Mettallum martis*, his 1665 book promoting coal for iron smelting. Its practical basis in mining knowledge contrasts with Athanasius Kircher's fanciful map reviving an ancient theory that Europe's rivers rise from subterranean ocean-fed springs, published in 1665 in his *Mundus subterraneus* (Taylor 1985, 16–17) (see fig. 782).

Various terms for the earth sciences appear in eighteenth-century book or map titles: "geologia," "mineralogy," "subterraneous geography," "histoire naturelle des roches," "mineralogische Geographie," and "Geognosie." By the 1790s "geology" and "geognosy" had edged out rival terms. Geognostical theory ascribed the ordered deposition of rocks to the biblical Flood but would later yield to geology as sedimentary, igneous, and metamorphic processes were increasingly understood.

By the early eighteenth century, mapping minerals and rocks was a recognized route to theoretical understanding. As early as 1683, Martin Lister had suggested to the Royal Society in London that "to judge of the make of the *Earth*, and of many *Phænomena* belonging thereto. . . . for this purpose it were advisable, that a *Soil* or *Mineral Map*, as I may call it, were devised" (Lister 1684, 739). Similar proposals appeared in England, Sweden, Germany, and France (Ellenberger 1983, 5–15).

Across eighteenth-century Europe individuals began investigating minerals, rocks, and fossils. Often working alone, they disseminated ideas by teaching, meeting, and circulating manuscript and published tracts. A few maps appeared before 1750 and more afterward (Eyles 1971, 363–64). Detailed observation and mapping remained local activities, focusing on small areas like mineral-rich Saxony or the volcanic Auvergne. William Smith's first geological map in 1799 showed only the environs of Bath, the English city where he lived (Boud 1975, 87).

The few maps showing larger regions, such as the several *cartes minéralogiques* by Jean-Étienne Guettard published in the *Mémoires de l'Académie Royale des Sciences*—of France and England, 1746 (published 1751), the Middle East, 1751 (1755), Switzerland, 1752 (1756), North America, 1752 (1756), and Poland, 1762


FIG. 777. *MAPPA MINERALOGRAPHICA FODINAS IN HUNGARIÂ,* 1726. Copper engraving; ca. 1:1,435,000. This is an early mineralogical map of Hungary with point symbols taken from metallurgy. From Luigi Ferdinando Marsigli, *Danubius Pannonico-Mysicus, observationibus geographicis, astronomicis, hydrographicis, historicis, physicis perlustratus*, 6 vols. (The Hague: P. Gosse, R. Chr. Alberts, P. de Hondt, 1726), vol. 3, pl. 8.
Size of the original: 46 × 66 cm. Courtesy of Special Collections, Kenneth Spencer Research Library, University of Kansas Libraries, Lawrence.

(1764)—were small-scale, speculative, and for the most part based on secondhand information. So daunting was the sole national geological mapping project, the *Atlas et description minéralogiques de la France* begun in 1766 by Guettard with the assistance of Antoine-Laurent de Lavoisier, that Antoine-Grimoald Monnet, who took over in 1777, published it incomplete in 1780 (see fig. 345), with some additional maps published later (Ellenberger 1983, 15–24).

As well as maps, eighteenth-century books about the earth sciences began to include fossil and mineral drawings, topographical views, vertical (columnar) sections, and horizontal sections. They presage the proliferation and integration of modes of geological illustration during the nineteenth century into the "visual language of geology" still used (Rudwick 1976, 149–52). For example, eighteenth-century mining engineers combined mine plans with projected sections or topographical views to show dual aspects simultaneously (Taylor 1985, 28–31). Similarly, and hardly coincidentally, technical drawings combining plans, elevations, and sections appeared in eighteenth-century architecture, shipbuilding, and civil and military engineering, all applied sciences sharing with mining engineering the need to represent three-dimensional shapes.

On other eighteenth-century maps, geological content appears against a backdrop of terrain representation, each map different but all emphasizing the three-dimensional form of the landscape. In 1743 English physician Christopher Packe surveyed and mapped East Kent to illustrate theories about water flowing through networks of valleys akin to blood vessels (see figs. 350 and 622). Dense lines of rivulets and rivers articulate the terrain, while elevation numbers and symbols for chalk and gravel pits are graphically subordinate. Although the legend lists "deep green" meadows, "light green" downs, and "brown" arable land, known copies of the map are uncolored (Boud 1975, 75–80). Georg Christian Füchsel's 1761 map of Thuringia sculpts hills with light and shade, but numbers identifying rock types are codes decipherable only in the text. Nicolas Desmarest published a map of the volcanic Auvergne landscape in 1774 using rock sketching and hachuring to depict landforms impressionistically (Ellenberger 1983, 26–29). Lettering and mineralogical symbols are embedded in those linear textures, less obvious to the searching eye. These examples demonstrate that copper engraving's linear techniques can visualize topography effectively but take up space, leaving little room for other information.

One solution to image crowding was to depict geology on sparser base maps. In 1726, Luigi Ferdinando Marsigli, an Italian nobleman, soldier, geographer, and naturalist, published a six-volume book about the Danube Valley illustrated with several maps, one of them mineralogical (fig. 777). Scattered across this map of mines and minerals in Hungary are small conventional shaded hill symbols. Hills with mines are darker, while fourteen types of mineralogical point symbols identify the minerals they yield (Ellenberger 1983, 14–15). The Guettard *Atlas* shares the pragmatic aim of inventorying mineral resources by employing narrow bands of hachures as plateau-like backdrops for the mineralogical symbols. On these maps, mineralogical information preempts topographic realism.

Other map authors began to indicate lithology between outcrops, a change that presented different design challenges. Some experimented with area patterns. Guettard outlined three rock types on several small-scale maps, most notably his map linking the geology of France and England (1751). More advanced in content than design, the map's only area pattern, faint wavy lines, barely distinguishes the *bande* of marly rocks. John Whitehurst used more elaborate area patterns on cross-sections illustrating his 1778 book about Derbyshire, explaining: "I have endeavoured to represent the different qualities of the *strata* by hatched lines, &c. as colours are represented by the engravers of coats of arms" (Whitehurst 1778, 145). On William George Maton's 1797 mineralogical map, the area patterns are lithologically meaningful although less graphically distinct (fig. 778). Patterns

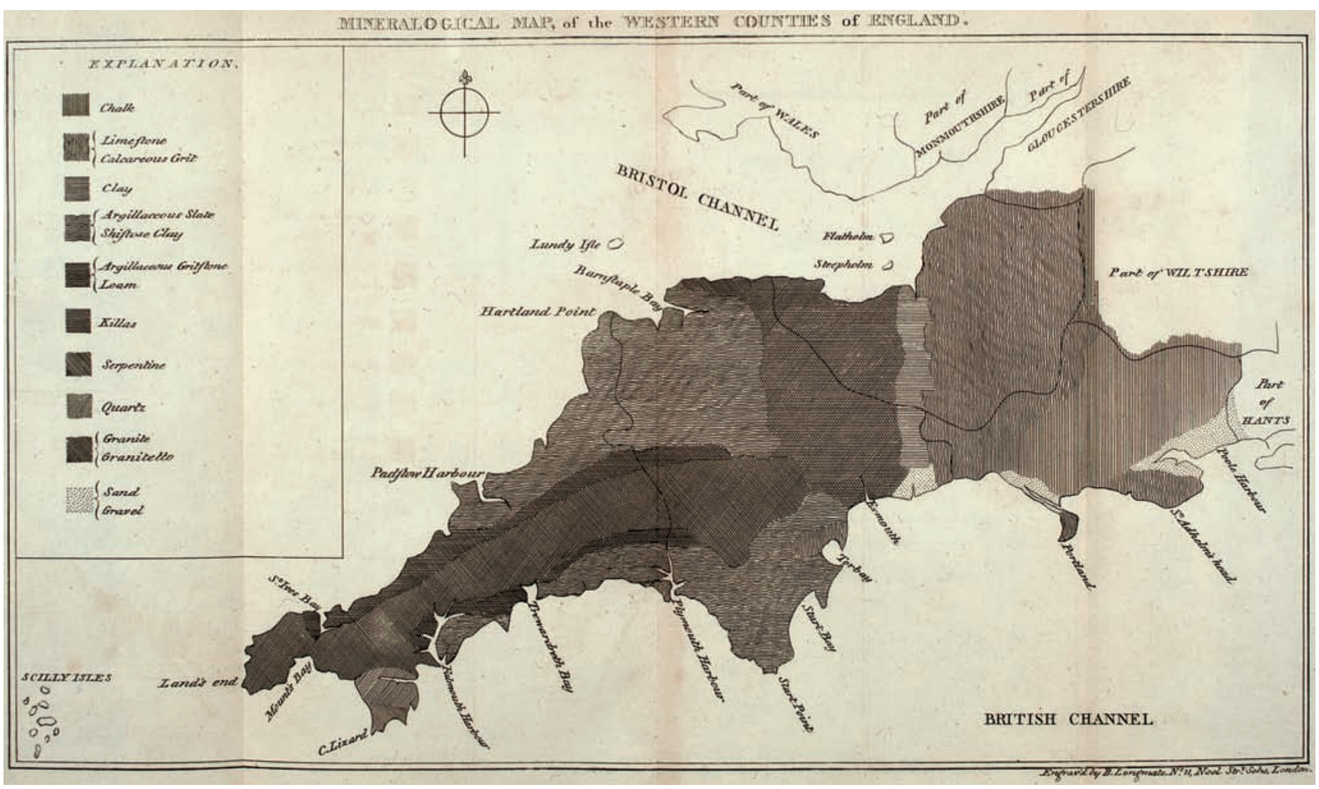


FIG. 778. *MINERALOGICAL MAP, OF THE WESTERN COUNTIES OF ENGLAND*, 1797. Copper engraving; ca. 1:1,150,000. The area patterns on this map represent rock components and sometimes overlap to indicate composite rocks. From William George Maton, *Observations Relative Chiefly to the Natural History, Picturesque Scenery, and Antiquities, of the Western Counties of England, Made in the Years 1794 and 1796*, 2 vols. (Salisbury: J. Easton, 1797), vol. 2, following 208.
Size of the original: 19 × 32 cm. Courtesy of Special Collections, Kenneth Spencer Research Library, University of Kansas Libraries, Lawrence.


FIG. 779. DETAIL FROM *PETROGRAPHISCHE KARTE DES CHURFURSTENTHUMS SACHSEN*, 1778. Hand-colored copper engraving; scale unknown. The extent of eight major rock types is indicated by pastel area coloring, while letters (e.g., B for basalt) and mineralogical point symbols add more detailed information about rock and mineral occurrences. From Johann Friedrich Wilhelm von Charpentier, *Mineralogische Geographie der chursächsischen Lande* (Leipzig: S. L. Crusius, 1778).
Size of the entire original: 38.0 × 55.5 cm; size of detail: ca. 15.5 × 15.5 cm. Image courtesy of the Linda Hall Library of Science, Engineering & Technology, Kansas City.

representing rock components sometimes overlap, such as horizontal lines for clay overlying diagonal lines for quartz to represent argillaceous gritstone and loam (Boud 1975, 80–82).

In the 1770s mapmakers, often associated with the mining academy (Bergakademie) in Freiberg, Saxony, took another approach, indicating different lithologies by area coloring (Eyles 1971, 363). Typical of the period, maps were printed in black from engraved copperplates and sometimes colored by hand. Darker colors accented point and line symbols, while paler watercolor washes highlighted areas without obscuring printed information. One of the earliest examples, Johann Friedrich Wilhelm von Charpentier's 1778 petrographic map of Saxony (fig. 779), distinguishes eight rock types with area coloring but also includes mineralogical symbols (Taylor 1985, 18–20). Similar late eighteenth-century maps of areas in Central Europe included ones by Friedrich Gottlob Gläser, 1774; Johann Philipp Becher, 1789; Georg Sigismund Otto Lasius, 1789; Mathias Flurl, 1792; Franz Ambrosius Reuss, 1793; and Leopold von Buch, 1797. Color schemes, still experimental, varied. Abraham Gottlob Werner, influential as a teacher after 1775 at the Bergakademie in Freiberg, favored indicating the bottom of each stratum with a darker colored line (Taylor 1985, 20–22). William Smith, beginning to study the succession of strata in the 1790s, introduced washes graded darker toward the base of each stratum on his historic 1815 geological map of England and Wales. Even though this particular coloring technique did not catch on, it was innovative (Taylor 1985, 24–26).

Collectively these cartographic forerunners were successful in passing on characteristics that still enrich graphic expression in geology. Within subdivisions of the international geological timetable, hues progress from light-colored young rocks to dark-colored old rocks, reminiscent of Werner's and Smith's darker coloring at the base of strata. On large maps, abbreviated unit labels (descended from eighteenth-century mineralogical symbols) aid map readers to identify geological units too small for area symbols to be distinguishable. Stratigraphic columns and cross-sections printed with maps enhance three-dimensionality and the interpretation of subsurface structures. The eighteenth-century effort to balance geology and topography on maps developed into area colors and patterns that make geology visually prominent backed by subtler topographic contours, commensurable but readable by the trained eye. Picking up where the unfinished Guettard *Atlas* left off, the national geological surveys established during the nineteenth century would expand coverage beyond local mapping until, by the end of that century, the pieces of the geological map of the world had fallen into place.

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SEE ALSO: Guettard, Jean-Étienne; Marsigli, Luigi Ferdinando; Signs, Cartographic; Thematic Mapping

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## *Thematic Mapping.*

ENLIGHTENMENT
AUSTRIAN MONARCHY
FRANCE
GERMAN STATES
GREAT BRITAIN
ITALIAN STATES
NETHERLANDS
POLAND
RUSSIA
SPAIN
SWEDEN-FINLAND
SWITZERLAND

***Thematic Mapping in the Enlightenment.*** The concept of "thematic mapping" is a creation of twentieth-century academic cartographers. Following Max Eckert's epochal work (1921–25), they defined thematic maps as cartographic displays of variations in the distribution from place to place of a single phenomenon, or of a set of related phenomena, as opposed to general maps that locate and depict an assemblage of geographical features. A thematic map is thus a tool of analysis and comprehension. In practice, the functional definition of thematic maps does not clearly differentiate between general and thematic maps, and they collapse into a supposed continuum from the display of a variety of data, to more selective or "special purpose" maps, to the portrayal of a single data set on a base map that serves as a spatial reference (Robinson 1982, 15–17). It is perhaps inevitable that map historians have interpreted special purpose maps solely as precursors of "true" thematic maps (e.g., Castner 1980).

The history of thematic mapping has largely been written as the development of the modern concept (Wallis and Robinson 1987, 72–73), told especially in terms of innovations in printing technologies and symbolization strategies. From this perspective, and especially by comparison to the rapid proliferation and supposed "golden age" of statistical mapping in the nineteenth century, thematic mapping in the eighteenth century appears sporadic, comparatively primitive, and focused primarily on physical phenomena (Robinson 1982; Friendly and Palsky 2007).

The development of recognizable thematic maps in the long Enlightenment was a function of interrelated practices by which a range of individuals sought to investigate, visualize, and map specific aspects of the world. In the process, they applied established mapping practices in new ways to create what Eberhard David Hauber (1724, 65) called *curiose Vorstellungen* (curious representations). For Hauber, such curious maps (generally called "special" maps by contemporaries) were maps that did not match the contemporary standard for regional and provincial maps. He listed maps of Europe that depicted languages, religions, eclipses, and especially post-route and other roads for the aid of travelers; under particular regions, he further identified historical maps, regional maps of river systems, ecclesiastical provinces, natural history, theaters of war, and overseas colonies; and also moralistic and allegorical maps (e.g., *Leo Belgicus*), geographical games, and celestial maps (Hauber 1724, 65, 67, 69, 73–74, 93, 96, 98, 107, 116–17, 152–53, 164–73). A similar range of imagery was described in the introduction to the entry on maps in Johann Georg Krünitz's famous encyclopedia (Anonymous 1793), probably written by the geographer Anton Friedrich Büsching. This variety of map forms, which is borne out in the following entries on thematic mapping within particular national or regional contexts, stems from the interaction of the key processes of data gathering and data visualization with individual interests and efforts.

Early modern data gathering featured the ever-increasing enumeration and measurement of phenomena in support of intellectual inquiry and public administration; thus, it was integral to the development of the Enlightenment public sphere (McCormick 2014). The Enlightenment's *esprit géométrique*, or quantifying spirit, defined in 1757 in the *Encyclopédie* as "a spirit of computation and of slow and careful arrangement, which examines all parts of an object one after another and compares them among themselves, taking care to omit none," was materially aided by quantification and calculation (d'Alembert 1757, 628; quoted in Heilbron 1990, 2). In other words, as Europe's states grew progressively more bureaucratic in order to marshal, control, and tax their populations and resources, in order to sustain ever-larger standing armies and navies, their officials relied on more detailed and systematic enumerations and statistical surveys. Much of the quest to order, systematize, and compare aspects of the world addressed the land itself, not only in the form of mapping practices generally but also in a variety of organized spatial practices ranging from the standardization of house addresses, in order to regulate and control growing urban populations (Tantner 2009), to the assessment and collection of excise fees by itinerant tax inspectors (Brewer 1988, 101–14). More generally, political economists, *économistes*, and *Statistiker* studied trade, public finances, and populations (McCormick 2014; Behrisch 2016). For J. L. Heilbron (1990, 15), the work of the "mathematical landscapers" was exemplified by German forest managers who, after 1763, prepared inventories of the numbers and types of trees, plans for harvesting to maximize yield, and assessments of the potential value of cut timber even before harvest. Overall, Heilbron argued that 1760 stands as an approximate tipping point between early sporadic and more concerted efforts to quantify the world.

Thomas L. Hankins (1999, 52) argued that 1770 marks a similar threshold in data visualization: there-

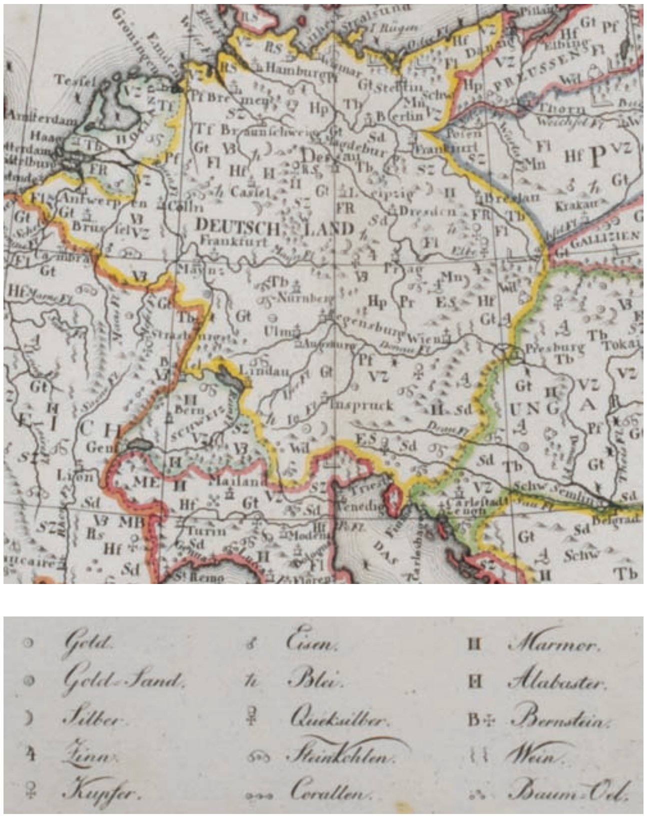


FIG. 780. MAP OF NOMINAL DATA: ECONOMIC PRODUCTS. Details from August Friedrich Wilhelm Crome, *Neue Carte von Europa* (Hamburg, 1782), which shows, according to the title, "the most remarkable and most prestigious products of the trading centers" of Europe using multiple signs together with lists of products by country in the margins. Crome's symbols would be used in later economic maps, such as Johann Matthias Korabinsky's pioneer thematic country map (1791), followed by Joseph Marx von Liechtenstern's maps of five Hungarian counties (1793–94) for a planned but never completed atlas and by Heinrich Wilhelm von Blum von Kempen, of whose economic atlas only thirteen sheets were published (1796).
Size of the entire original: ca. 53 × 70 cm; size of map detail: ca. 10 × 11 cm; size of legend detail: 3.5 × 10.5 cm.
© British Library Board, London (Cartographic Items Maps K.Top.4 [94]).

after, William Playfair, James Watt, and Johann Heinrich Lambert each began to use graphs to simplify and identify trends in large amounts of economic or scientific data. Even so, in terms of mapping data, there was little variation in approaches to visualization across the period, and strategies always depended on data type. Nominal data—identifications of particular phenomena by name or category—were visualized in simplified geographical maps, some of which were created with special administrative purposes in mind. Qualitative nominal data identified by particular locations gave rise to maps of the locations of different kinds of minerals (e.g., see fig. 777), or of different economic activities (fig. 780), together with maps of post-routes and river systems. Data identified by areas led to world and regional maps of animals; of human diseases, in the particular case of Leonhard Ludwig Finke's now lost map from 1792 (Barrett 2000); and of languages (fig. 781). The innovative maps of Heinrich Scherer represented the spread of Catholic religion by light areas, against darker shades of other religions (see fig. 755).

By contrast, interval and ratio data—the measured magnitudes of a phenomenon—permitted the presentation of statistical surfaces through the use of isolines or form lines. This was undertaken most famously with Edmond Halley's map of magnetic variation across the Atlantic, first published in 1701 (see fig. 348); Halley's use of isogones drew on already established practice and would be emulated throughout the eighteenth century. More subtle uses of isolines, combined with flow lines, occurred later in the century with the mapping of the path and the degrees of shadow caused by solar eclipses (see figs. 211, 793, 802, and 950) and with the efforts to delimit the extent of the Gulf Stream by water temperature (see fig. 347). Streamlines were used by Halley in his 1686 map of tropical wind patterns, a dynamic phenomenon (see fig. 776). This map was updated by William Dampier in 1699 (Peterson, Stramma, and Kortum 1996, 33–38) and thereafter widely copied.

The use of these representational strategies throughout the seventeenth and eighteenth centuries suggests that Arthur H. Robinson (1982, 33) was wrong to distinguish, for this era, between thematic maps and noncartographic graphs and diagrams, which he called "premaps." Michael Friendly and Gilles Palsky (2007, 213), who also suggested "para-thematic" works as transitional hybrid forms, demonstrated that statistical and cartographic visualizations played off each other across the entire eighteenth century. In part this was conceptual, as several scholars at the end of the era metaphorically likened their visualizations to maps. In the 1780s, August Friedrich Wilhelm Crome made large comparative diagrams, or maps, of the character of European states (see fig. 767). In 1797, Joseph de Maimieux constructed an artificial language in two-dimensional matrixes that he called a *mappemonde intellectual*; the matrices, organized by linguistic "latitude" and "longitude" would, he argued, provide a "common scale" for translation (Edney 1994, 105).

But the interconnection of maps and diagrams was also pragmatic. Johann Georg Hagelgans broke with established traditions of listing events in dense chronologies by plotting each event, by date and region, in a geographical manner in his *Atlas historicus* (1718), with eight chronological tables. Each event was located, like a town on a map, by one of eighty symbols that described its nature, such as the manner in which kings died or by which they acquired their Crowns (Rosenberg and Grafton 2010, 103, 106–7). At the end of the century,


FIG. 781. MAP OF NOMINAL DATA: DISTRIBUTION OF SPOKEN LANGUAGES. One of Gottfried Hensel's philological maps of the four continents, *Evropa poly glotta*, from his *Synopsis vniversæ philologiæ* (Nuremberg: Homann, 1741). Hensel proposed a standard coloring to indicate the descent of language from Noah's three sons (red, from Japheth; yellow, from Shem; and green, from Ham). Each national language region in Europe is represented by the first line of the prayer "Pater Noster" in the corresponding language, written with the particular characters of the kind of writing listed alphabetically around the map. For the Americas, Hensel supposed miraculous ancient migrations from Asia and Africa.
Size of the original: 15.4 × 19.4 cm. Image courtesy of the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland (OS-1741-4).

Paul Dietrich Giseke created a schematic map—*Tabula genealogico-geographica*—of the affinities of plants according to the classification of Carl von Linné (Linnæus), building on the contemporary understanding of "map" as a metaphor for organization by which information could be structured (Edney 1994, 105–6). Profiles and linear diagrams drew explicitly on topographical mapping practices, whether in 1770, when Philippe Buache's linear diagram of high and low water in the Seine was based on the longitudinal cross-sections of rivers and canals (Friendly and Palsky 2007, 228–29), or in 1783, when Jean-Louis Giraud-Soulavie mapped the vertical cross-section of zones of vegetation and cultivation up the side of the Pyrenees (Bourget 2002, 108–11).

Ultimately, the limiting factor in thematic mapping in the Enlightenment was the general satisfaction of the great majority of natural philosophers and officials with the presentation of the data they had collected and analyzed in lists and tables. Maps might have been praised as a device with which to see the world and its structure, such that Gottfried Wilhelm Leibniz could suggest late in the seventeenth century that his proposed handy tables and compact summaries of European states were akin to maps: the prince could "look [them] over in a moment" to see "the connections of things" (quoted in Daston 2011, 91). Yet, in harmony with the era's baroque aesthetic, the contemporary fashion was for access to the data, in all their complexity, not for abstracted summaries. This preference is evident in the persistence in England, well into the nineteenth century, of the written rent-roll, or terrier, in lieu of an estate map (Fletcher 1998); in the preference shown by *Statistiker* in the German states for verbal and tabular accounts (Van der Zande 2010); and in the general sense among naturalists that complex illustrations were unnecessary (Rudwick 1976). This attitude changed sharply by the end of the century, when Alexander von Humboldt turned to geovisualization techniques as research tools of spatial interconnections of natural phenomena (Godlewska 1999, 252–53). Some historians have suggested that by the end of the eighteenth century, state officials had come to appreciate the effectiveness of abstracted data visualizations, at least in the German states (Nikolow 2001; Van der Zande 2010, 419), but the general rule was that each instance of data visualization, whether graphic or cartographic, manifested personal interest. There is a reason, after all, that Hauber called such maps "curious."

The key factor in promoting visualization, and mapping, seems to have been access to data. In some instances, data were already widely available. Athanasius Kircher used maps of the patterns of major rivers in each part of the world to support his argument, in his *Mundus subterraneus* (1664–65), that rivers were fed by large subterranean reservoirs (fig. 782). By contrast, in the same work, Kircher used Aristotelian concepts of the motion of air and water to deduce a model of ocean circulation, which


FIG. 782. EXAMPLE OF CARTOGRAPHIC VISUALIZATION AND REASONING. *Typus hydrophylacy intra Alpes Rheticas* in Athanasius Kircher, *Mundus subterraneus,* 2 vols. (Amsterdam: Joannem Janssonium & Elizeum Weyerstraten, 1664–65), 2:71, purporting to demonstrate that the major rivers of Europe were all fed from the same underground reservoir beneath the Alps.
Size of the original: 15 × 20 cm. Image courtesy of the Linda Hall Library of Science, Engineering & Technology, Kansas City.

he then mapped out (Peterson, Stramma, and Kortum 1996, 26–32). Kircher's model of the earth's geophysical structure significantly influenced Buache's search for regularity and order in the distribution of mountain chains, presented in *Cartes et tables de la géographie physique ou naturelle* of 1757 (Debarbieux 2009) (see fig. 5). Ethnographic data supported visualizations of the distributions of different peoples, as in world maps in the *Nouvel atlas portatif* (1762) by Didier Robert de Vaugondy that used color for skin types, facial shapes, and religions, and by Marie Le Masson Le Golft, whose *Esquisse d'un tableau général du genre humain* [1786] employed shading and symbols to distinguish between religions, mores, physical color, and physical shape (see fig. 234).

More generally, data visualization depended on the particular positions held by certain individuals: Dampier's privateering gave him extensive experience with winds and currents (Hasty 2011); Halley's Atlantic voyages, supplemented by correspondence (Török 2006, 409), allowed him to gather comprehensive data on magnetism; the steady increase in the publication of official data permitted Playfair and Crome to assemble and graph their information about long-term economic trends and Europe's populations (McCormick 2014).

Thematic mapping was often carried on in manuscript. Indeed, Hauber (1724, 63 note h) extended instructions to map owners on how to apply decorative color. He suggested that interested persons could color or add special symbols to their own printed geographical maps to show curious information, whether the distribution of languages and religions, regions in certain historical periods, or journeys. Historians have inevitably focused on printed thematic maps, whether published in works of natural science or as commercial curiosities, but many more maps remained in manuscript. For example, the soldier, surveyor, and military engineer Luigi Ferdinando Marsigli prepared several thematic maps for his six-volume *Danubius Pannonico-Mysicus* (1726), including detailed hydrographic maps of the river, a map of Roman antiquities, a set of detailed mineralogical maps (see fig. 777), and cross-sections of mines, but his other thematic work remained unpublished. When serving as a commissioner for the Habsburg-Ottoman boundary delineation, he prepared a report on commercial routes across the Balkans, which included a map for Emperor Leopold I. Shortly thereafter, Marsigli created a manuscript post-route map for newly acquired territories in Croatia and Slovenia, as well as a map outlining a frontier quarantine zone to prevent the plague from entering Habsburg territories (Török 2006). Myriem Foncin (1965) reconstructed the legend of another such work, a large manuscript map of France made after 1771, that provided a detailed graphic index to about fifty-five different economic productions and features (fig. 783); the map's production was perhaps influenced by the

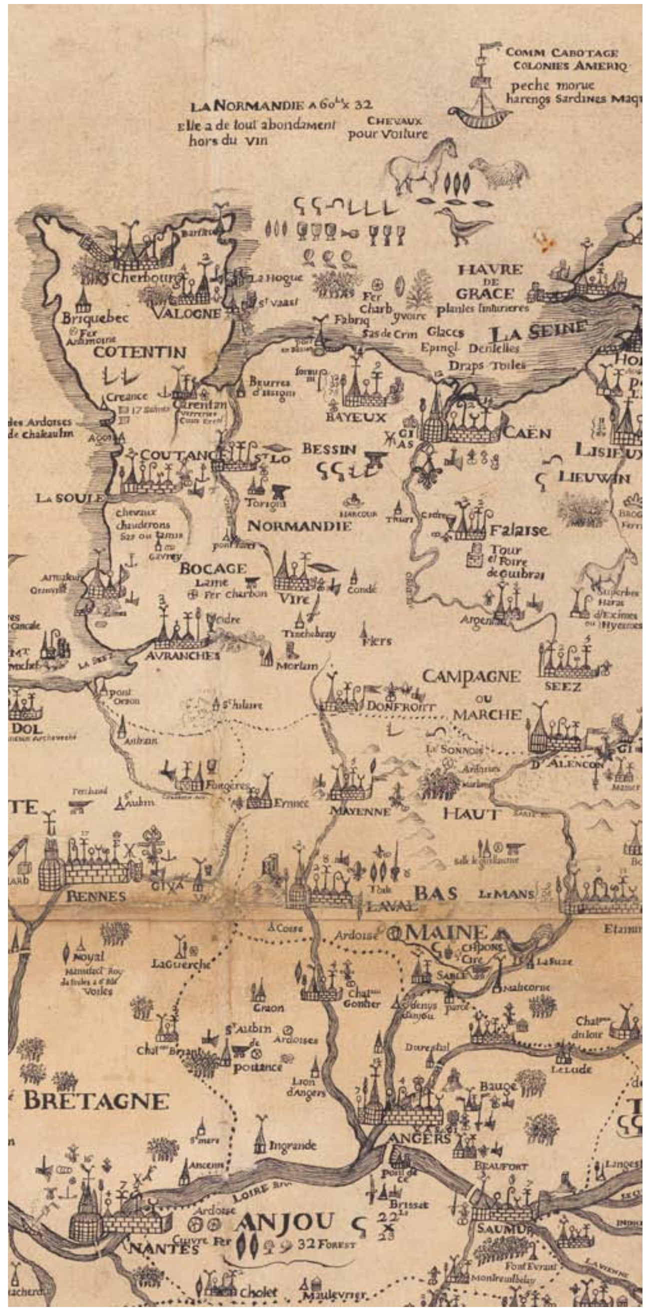


FIG. 783. DETAIL FROM AN UNPUBLISHED ECONOMIC MAP. Detail of northwestern France, from the Normandy coast south, from a large anonymous, untitled, and undated manuscript map apparently made as a graphic index to Mathias Robert de Hesseln's six-volume *Dictionnaire universel de la France* (1771). The towns were represented in a conventional manner, according to the kinds of ecclesiastical establishments present, but were surrounded by additional signs—as many as fourteen at some locations—indicating civil institutions. Between towns, signs indicate the products of agriculture (arable and pastoral), mines and quarries, manufacturing, forestry, and fishing. Drawn in six sheets, of which five are extant (the sixth sheet is missing).
Size of the entire original: 133 × 133 cm; size of detail: ca. 46.5 × 22.5 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge A 1106 RÉS).


FIG. 784. MODIFIED THEMATIC MAP. Robert Townson based his petrographic map on a 1791 economic map by Johann Matthias Korabinsky, adding hand-colored information about thirteen types of rocks, as well as post routes and peoples. *A New Map of Hungary, Particularly of Its Rivers and Natural Productions* was folded into Townson's *Travels in Hungary* (London, 1797), which was quickly translated into French and Dutch.
Size of the original: 46.5 × 60.5 cm. © The British Library Board, London (Cartographic Items Maps *28195[59]).

*philosophe* Étienne Bonnot de Condillac, who pursued economic interests in the 1770s.

Finally, in one instance at least, the publication of a thematic map prompted a further act of visualization. Johann Matthias Korabinsky, a teacher and journalist, graphically summarized the findings of his *Geographisch-historisches und Produkten Lexikon* (1786) in a 1791 economic map of Hungary, *Novissima Regni Hungariæ potamographica et telluris productorum tabula*. Within just a few years, Robert Townson, an English traveler to Hungary, used Korabinsky's map as the basis for his own petrographic map of the country (Török 2007) (fig. 784).

Highly focused and influential early thematic maps are still scattered across archives. A more complete history of thematic mapping in the Enlightenment requires the sustained consideration of these manuscript works as well as the better-known published maps.

ZSOLT G. TÖRÖK

SEE ALSO: Antiquarianism and Cartography; Customs Administration Map; Eclipse Map, Solar; Historical Map; Isoline; Modes of Cartographic Practice; Religion and Cartography; Signs, Cartographic; Statistics and Cartography; Thematic Map; Transportation and Cartography: Road Map

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***Thematic Mapping in the Austrian Monarchy.*** The origins of thematic cartography in Austria are closely linked to the work of the Viennese physician and historian Wolfgang Lazius, who compiled several historical maps during the 1540s and 1550s (Svatek 2008; Wawrik 2003, 200–12; Meurer 2007, 1242–43). After the death of Lazius in 1565, thematic cartography in Austria underwent a decline. In the seventeenth and early eighteenth centuries, only some thematic information, mainly of an economic nature, was integrated into topographic maps. It was only toward the end of the eighteenth century that thematic cartography began to recover as a result of the emergence of commercial cartography and the foundation of several map publishing houses (e.g., Artaria). From this point, Vienna evolved into a leading center of mapmaking in Central Europe, a development that may be ascribed to: the establishment of the Vienna copperplate engraving school (Wiener Kupferstecherschule) in 1766 by Empress Maria Theresa; a rising demand for printed material due to higher educational standards and the upward social mobility of a larger section of the population; a growing interest in geography; and the decline of the map publishing houses in southern Germany.

Through the eighteenth century, the majority of thematic maps produced in Austria were post-route maps detailing post lines and stations; however, there were also some geological, economic, language, and battle maps. Topographic maps, too, contained thematic information. The first such instance is a map of Tyrol (*Tyrolis* *sub felici regimine Mariæ Theresiæ Rom. Imper. Avg. chorographice delineata*; see figs. 57 and 84) compiled by two farmer-surveyors from the Innsbruck area, Peter Anich and Blasius Hueber, and published in 1774. Internationally, it was probably the best-known Austrian map of the eighteenth century due to the excellent quality of its content, which include post stations, mines, and bathhouses (Kinzl 1976). The maps created by Joseph Karl Kindermann likewise contain numerous thematic details, such as his map of Marburg district (Maribor, in Slovenia) featuring mines, marble quarries, coal pits, and factories (Dörflinger 2004, 123).

The mid-eighteenth century saw a significant improvement of road networks in the Austrian part of the Habsburg monarchy. The 1748 *Postordnung* definitively established regular passenger coach service, which enabled an increasing number of people to travel by mail coach. This provided the incentive for the compilation of the first post-route maps, which were initially produced by publishing houses in southern Germany and, with the rise of Austrian commercial cartography, in Austria as well (Dörflinger 1984, 81–82). The most important examples include the *Post Charte der Kaiserl. Königl. Erblanden* by Georg Ignaz von Metzburg of 1782 (see fig. 85) and the *Atlas universae rei vederariae bilinguis . . . Allgemeiner Post Atlas von der ganzen Welt* of 1799 (forty maps) by Viennese publisher and geographer Franz Johann Joseph von Reilly. The Court Chamber requested Metzburg to design a post map of the entire Habsburg Empire with an overview of post stations and trading posts. Like most eighteenth-century maps, the Metzburg map displays a decoratively rich and symbolically intricate title cartouche, incorporating a large monument crowned by the Austrian coat of arms, an eagle with a post-horn, and a landscape scene with post traffic displayed to the right and below the title (Dörflinger 2004, 90–91, 132–33, 142–43).

The *Allgemeiner Post Atlas* by Reilly contains forty post-route maps covering the whole of Europe. For sources, Reilly used the latest post maps of other European countries, place indexes, and other information furnished by post-station personnel who had responded to the more than one thousand letters sent by Reilly all over Europe. Like other maps of this type, the post routes are represented as straight lines between individual post stations, with the distances between stations provided (fig. 785). The final section of the atlas comprises an index of over 7,600 post stations. While Reilly was originally a civil servant, he began to devote himself increasingly to geography and cartography, publishing a number of atlases and individual maps, ultimately setting up his own publishing house in 1792 (Dörflinger 1984, 205–7, 250–60; 2004, 143). Other post-route maps were produced in Innsbruck and Graz, e.g., the *Postkarte von Tirol und Vorarlberg* (1799, ca. 1:1,000,000) by Franz Carl Zoller and the *Postkarte Saemtlicher K.K. deutschen und hungarschen Erblande* (1792, ca. 1:2,500,000) by Johann Michael Kauperz (Dörflinger 1984, 136–37).

Economic maps were similarly drafted to reflect the growing number of newly established factories and the resulting boost of interest in economic issues, including the *Comitatus Soproniensis ungarice Soprony varmegye et germ: Oedenburger Gespanschaft* (1793, ca. 1:250,000) by Joseph Marx von Liechtenstern and the *Natur und Kunst Producten Atlas der oestreichischen deutschen Staaten* (1796, ca. 1:1,000,000) by Heinrich Wilhelm von Blum von Kempen. Liechtenstern's economic map of Ödenburg (Sopron, in Hungary) would have been published in the "Ungarischen Produkten-Atlas," the first (but never completed) economic-geographic atlas of Central Europe, for which only a few sheets were published, including the maps of the counties of Pressburg (Bratislava, in Slovakia), Komorn (Komárom), Tolna, and Bács. The economic map of Ödenburg is especially remarkable for its panoply of over sixty signs denoting natural resources, crops, livestock, and commercial enterprises, with additional symbols for Catholic churches, Lutheran churches, and synagogues. Liechtenstern was one of the most productive Austrian cartographers of the late eighteenth century (Bernleithner 1972; Dörflinger 2004, 127, 139). After studies in mathematics and natural sciences under renowned professors such as Ignaz von Born, Maximilian Hell, and Metzburg, Liechtenstern studied law and entered the administrative civil service. In 1790, he founded the Cosmographische Gesellschaft of Vienna. After the society's dissolution in 1797, he set up a Cosmographische Institut, where he produced much-respected maps and atlases over the following years. In 1815, he was appointed professor of statistics at the University of Vienna (Bernleithner 1972).

Blum von Kempen, a native of the Speyer area in Germany, began work on the *Natur und Kunst Producten Atlas* in 1794, with plans for the atlas to include thirty-seven map sheets and be completed by 1797. However, his death in early 1797 meant the atlas remained unfinished. Viennese art dealer Johann Otto adapted the extant map sketches into an atlas comprising thirteen map sheets, twelve of which were economic maps, such as the *Natur und Kunst Producten Karte von Kærnten.* A typical feature of these maps is their decorative design, which primarily focuses on the characteristic products of the areas covered. Thus, the map of Styria shows products of the ironworking industry, while that of Anterior Austria features clocks and textiles. Conversely, the map of Carinthia depicts the formidable rocky landscape dominated by Grossglockner Peak (Dörflinger 2004, 140–41).

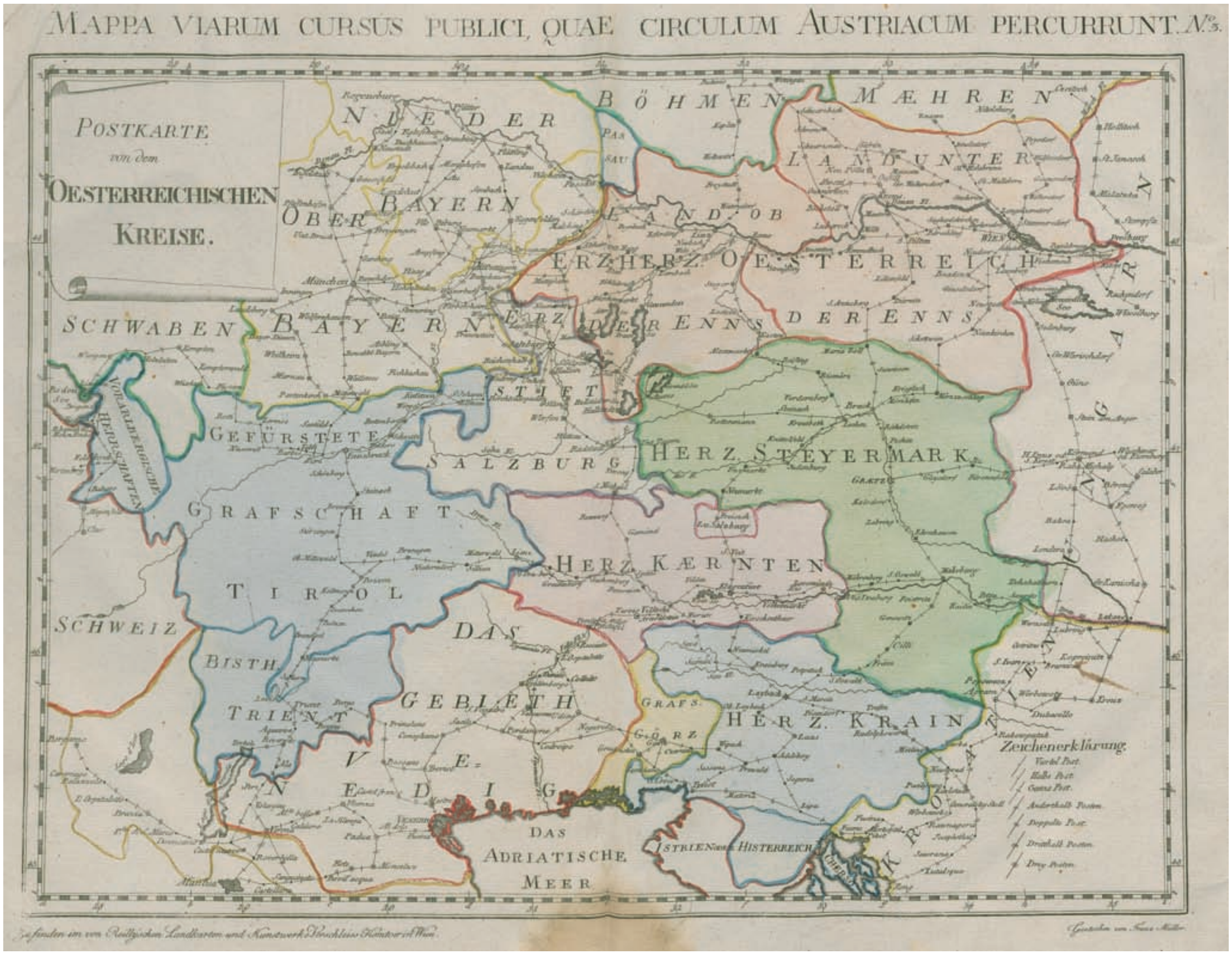


FIG. 785. *POSTKARTE VON DEM OESTERREICHISCHEN KREISE* (VIENNA 1799), BY FRANZ JOHANN JOSEPH VON REILLY. Copper engraving by Franz Xaver Müller, 1:1,300,000. One of the maps in Reilly's *Allgemeiner Post Atlas,* this map displays post routes as straight lines without reference to their true course. The slash marks across the route lines signify the distances between different post stations.
Size of the original: 39 × 48 cm. Image courtesy of the Universitätsbibliothek, Vienna (III-273083, map no. 3).

By the end of the eighteenth century, thematic cartography in the multiethnic Habsburg state gradually had begun to include maps detailing languages, ethnicities, and religions. For example, the map of economic products and peoples, *Novissima Regni Hungariæ potamographica et telluris productorum tabula* (1791, ca. 1:1,000,000) by Johann Matthias Korabinsky, uses ninety-one different symbols to convey economic information, but the spatial distribution of ethnicities and languages is visualized with colored lines outlining borders (red for Germans, light blue for Magyars, green for Slovaks, etc.) (Dörflinger 1984, 130–31).

Geological maps also used the combination of color and symbol to represent rock formations, such as the topographic-mineralogic-geologic map of Carniola (1788) by Belsazar Hacquet (fig. 786). Born in France, Hacquet studied medicine in Vienna and in 1766 obtained work as a physician at the mercury mine of Idrija (Carniola). During the following years, he undertook numerous journeys to research the geology, mineralogy, and botany of Carniola (Dörflinger 1984, 80–81; 2004, 134–35).

From the early eighteenth century in Austria, the increased construction of waterways for navigation inspired the creation of maps and plans. The Lorraine-born hydraulic engineer and geographer François Joseph Maire developed several projects in the 1770s to improve the navigability of Austria's rivers. In 1785–86, he published a four-sheet survey map (*Carte hydrographique de etats de la maison d'Autriche en deça du Rhin / Hydrographische Karte der oestreichischen Erbstaaten*

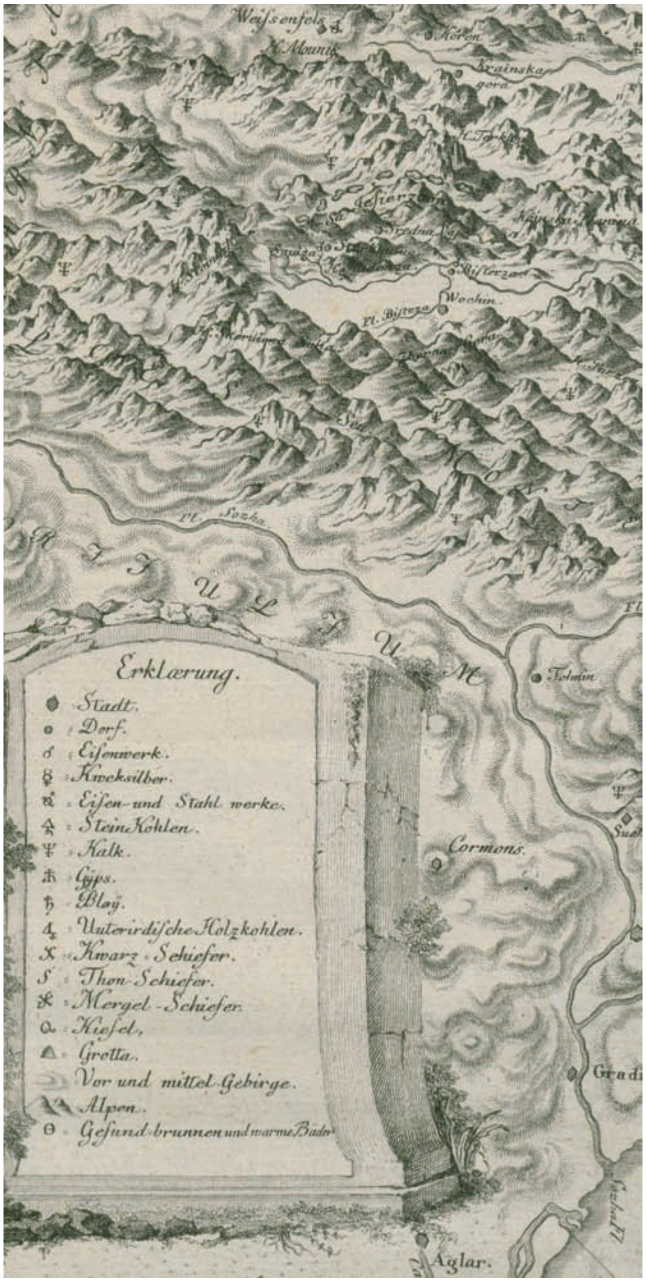


FIG. 786. DETAIL FROM THE TOPOGRAPHIC-MINERALOGIC-GEOLOGIC MAP OF CARNIOLA AND NEIGHBORING AREAS (LEIPZIG, 1778), BY BELSAZAR HACQUET. Copper engraving, ca. 1:460,000. The map, which accompanies volume 1 of Hacquet's four-volume travel account, *Oryctographia Carniolica* (Leipzig, 1778–89), employs signs for both natural resources and rock formations. High mountain ranges are shown in bird's-eye view, while uplands are visualized with hachures. This map also uses many Slovene toponyms.
Size of the entire original: 66 × 44 cm; size of detail: ca. 23.5 × 11.0 cm. Image courtesy of the Universitätsbibliothek, Vienna (I-247396/1-2).

*diesseits des Rheins*, 1:1,000,000) as well as five detailed maps and a sluice plan in Vienna (Dörflinger 2004, 136–37). However, some of these maps and plans were highly utopian, as for example that of the proposed waterways between Vienna and Rijeka or between the Drau River and Lake Como. Maire also produced a map of the environs of Vienna in 1788. The Wiener Neustadt Canal, extending from Vienna to the town of Wiener Neustadt about fifty kilometers to the south, was built between 1797 and 1803, the only waterway suggested by Maire that was completed, and some sections still exist. Other cartographers, such as Sebastian von Maillard and Franz Xaver Müller, designed waterway maps (Dörflinger 1984, 92–94, 147–48; 1977, pl. 63 [190–91]).

Political maps were also produced by cartographers, such as the *Diplomatischer Atlas* (1791–98) by Reilly, compiled after the end of a war that joined Russia and Austria as allies against the Ottoman Empire. Various peace treaties (Sistova, 1791; Basel, 1795; Campo Formio, 1797) with their proposed boundaries provided material for the seven maps of the atlas (Dörflinger 1984, 261–63).

Thematic cartography reached an apogee in the first half of the nineteenth century. This was mainly due to the establishment of a bevy of institutions that ensured the systematic and comprehensive collection of data (e.g., Direktion der administrativen Statistik in 1840, Kaiserliche Akademie der Wissenschaften in 1847, Geologische Reichsanstalt in 1849, Zentralanstalt für Meteorologie und Erdmagnetismus in 1851, and Geographische Gesellschaft [Vienna] in 1856), the development of modern statistics, and the new reproduction technique of lithography (Kretschmer 1989, 11, 13).

PETRA SVATEK

SEE ALSO: Austrian Monarchy; Transportation and Cartography: Post-Route Map

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***Thematic Mapping in France.*** Thematic maps have a specific purpose and in most cases use topographical content to represent phenomena that may be qualitative or quantitative, concrete or abstract. Less frequently, geographical maps are used to represent the distribution of physical, social, or cultural phenomena and can be considered thematic. Examples include Didier Robert de Vaugondy's three world maps, published in his *Nouvel atlas portatif* (1762), on which he represented the distribution of populations according to religion, skin color, or facial type (Pedley 1992, 96, 136), and the *Esquisse d'un tableau general du genre humain* (see fig. 234), a type of anthropological map by Marie Le Masson Le Golft [1786] (O'Connor 2005, 70–72, 250–53). While this cartographic approach became widespread during the nineteenth century, its early manifestations may be seen in the second half of the eighteenth century with the development of statistics in France. Gilles Palsky characterizes this period as one of "thematic additions" (1996, 32), during which the refinement of descriptive techniques spread to new fields. This refinement does not, however, suggest the dawn of a truly analytical approach. Nevertheless, before the development of thematic maps, these "enriched" geographic maps were part of a fundamental shift in the field of cartography: maps were no longer simply a means of describing the surface of the earth; they now could be designed to represent knowledge gained in other fields of natural and human science. Maps thus became a means of demonstration—as Philippe Buache notably proved with his earthquake map of 1756 (Lagarde 1990)—or a tool used by administrators and engineers, as, for example, maps of land use. Detailed maps like these first appeared at the same time as the physiocratic theory of economics, and they attempted to describe types of terrain. The most common categories were garden, forest, vineyard, pasture, swamp, fallow, and cultivated land. Forestry maps were constructed according to the same principles. However, the most emblematic example certainly remains the work of the engineers of the Ponts et Chaussées. From 1744, the Bureau des dessinateurs de Paris was effectively charged with centralizing information from the entire kingdom and producing road maps designed to help coordinate road-planning policy. The École des Ponts et Chaussées grew in response to this development, and cartography courses were taught there throughout the second half of the eighteenth century. Antoine Picon has shown that maps produced by École students did not always focus on the school's operational goals. For their final exams, students had to demonstrate their graphic virtuosity and would sometimes map imaginary spaces in a variety of styles (see fig. 631). These productions nevertheless suggest a "certain vision of nature and how it could be transformed by man" (Picon 1995, 113).

Maps also played a role in efforts to create comprehensive inventories in keeping with the encyclopedic spirit of the times. One example accompanied the anonymous "Projet d'une carte de France" (fig. 787), which proposed to map the towns, roads, mountains, canals, rivers, and locations of mines and smelting works, in addition to providing import and export figures for every province of the kingdom (Konvitz 1987, 114–15). This *esprit d'inventaire* equally informed the map production planned by Gaspard Marie Riche de Prony from 1791 at the Bureau du cadastre (Picon 1995, 119–20).

Administrators and engineers could always use large-scale maps specially adapted to their needs. But in order to represent any specialized subject matter on smaller-scale geographical maps, icons or shading had to be added to a previously printed background. The idea had not yet developed that the map itself could incorporate its own graphic language and rely only on the graphic elements of sign, shading, color, and linework, without resort to an accompanying memoir or long descriptive legends. On the contrary, it was a period of hybrid maps, as Palsky (1996, 34) has explained:

> In fact—and this was a fundamental feature of certain specialized maps before 1800—new, non-topographical information appeared most often as additions to ordinary maps. . . . Hence, it is unnecessary to debate the distinctions between topographical details and thematic additions: maps born out of the new spirit of geographical exploration of the seventeenth and eighteenth centuries were hybrid maps, with much more sophisticated content than earlier maps, but whose design had not yet abandoned traditional description.

Mineralogical charts of the period are probably the best examples of this method of enriching small- to medium-scale maps with supplementary information.

Beginning in the mid-eighteenth century, mineralogist Jean-Étienne Guettard presented cartographic

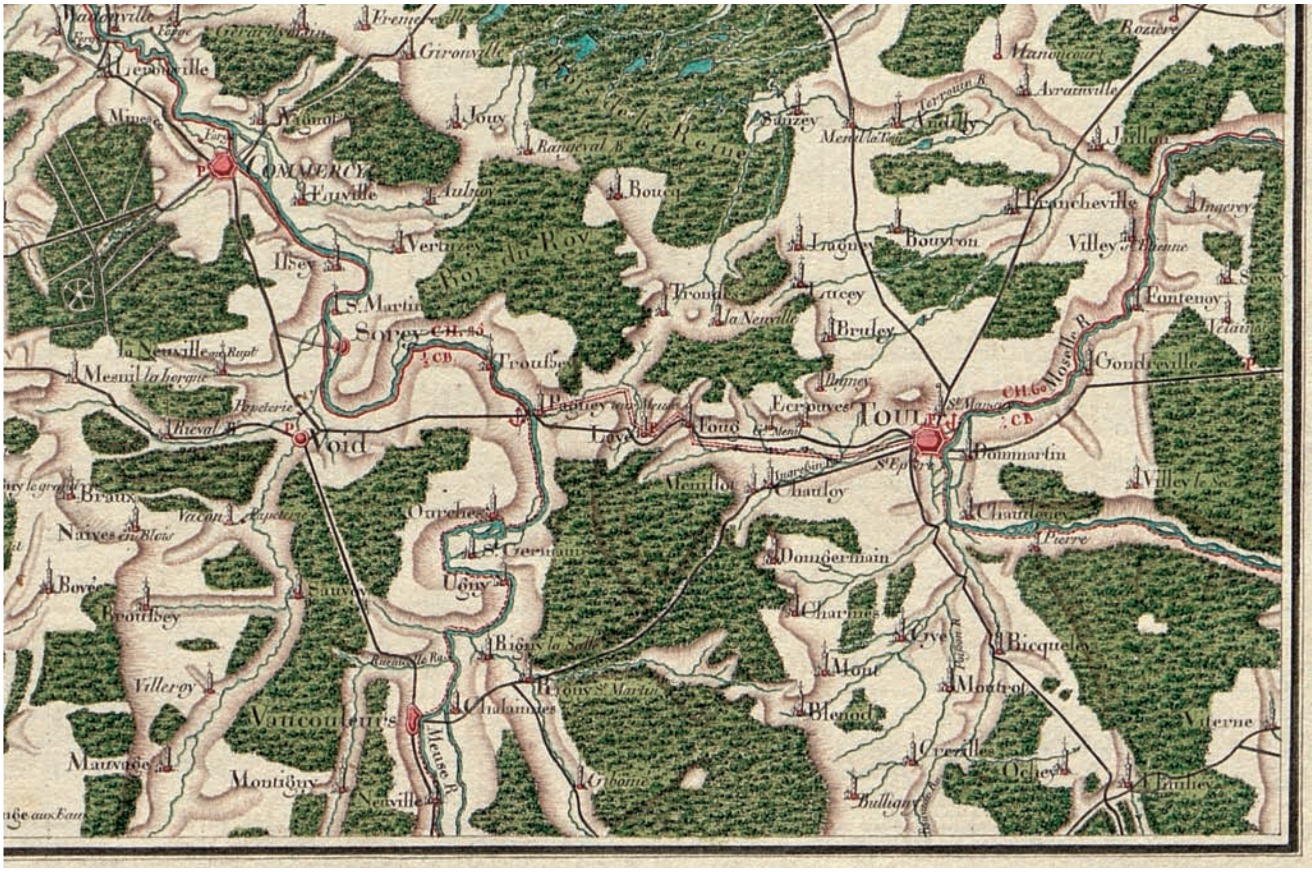


FIG. 787. DETAIL FROM THE "ETUDE D'UNE REDUCTION DE LA CARTE DE FRANCE." This manuscript map accompanied the undated "Projet d'une carte de France, réduite au tiers de l'échelle de celle de l'Académie, destinée pour l'administration des Ponts et Chaussées," ca. 1780s. The anonymous author of this manuscript memoir, dissatisfied with the Cassini *Carte de France* (*celle de l'Académie*) as a tool for planning infrastructure, offered this one-third reduction of a section of the *Carte de France* to show how a map could employ the main features of the Cassini map but also emphasize roads (black), rivers (blue), and proposed canals (red), as well as streams and swamps, with particular attention to navigation.
© École nationale des Ponts et Chaussées, Marne la Vallée (DG 1746).

representations of his analyses in maps at different scales. Based on Guettard's data, Philippe Buache created the *Carte minéralogique, Où l'on voit la nature et la situation des terreins qui traversent la France et l'Angleterre* to accompany Guettard's 1746 "Mémoire et carte minéralogique." This map featured the principal waterways, the names of provinces and counties, plus approximately forty signs indicating the locations of mineral resources; gray shading delineated three concentric bands identifying sand, marl, and schist deposits. This use of signs continued to be common in the second half of the century until the end of the Ancien Régime, notably in Guettard and Antoine-Grimoald Monnet's *Atlas et description minéralogiques de la France* (1780) (see fig. 345), but also on rare economic maps produced before the full development of statistics, such as the anonymous, untitled, hand-drafted map that according to Myriem Foncin (1965) was based on data from Mathias Robert de Hesseln's *Dictionnaire universel de la France* (1771) (see fig. 783). Although colored shading was less often employed, at least on printed maps, the technique was more common when supplementary information was added by hand to printed maps. The map collection of Charles-Étienne Coquebert de Montbret contains numerous such examples that appear to date from the early nineteenth century.

These developments did not end with the Ancien Régime. During the French Revolution, the Agence des mines—and later the Conseil des mines—was given responsibility for regulating and administering natural resources and resuming the program of charting the new Republic's mineralogical reserves using the cartographic techniques described above. The information collected by inspectors and engineers from the Conseil was not only tabulated, but also charted in several series of geographical maps. In year IV (September 1795–September 1796), the Conseil des mines enlisted the geographer Jean-Louis Dupain-Triel *fils* to represent available mineralogical data on another version of his map of roads and inland navigation (fig. 788). Their selection of Dupain-Triel was significant because in 1781 his father (Jean-Louis *père*) had created a mineralogical map based on Guettard's observations (fig. 789), had prepared many maps for Guettard and Monnet's *Atlas et description minéralogiques,* and had published the *Carte géographique de la nature, ou disposition naturelle des minéraux, végétaux, etc. observés en Vavarais . . . d'après les cartes de M. l'Abbé Giraud-Soulavie* (1780). This time, the Conseil des mines commissioned Dupain-Triel *fils* to create a map that should represent "at a single glance, all of the mines and factories in the Republic" and "demonstrate the means of distribution, the connections between different companies and institutions, the economies to be gained, and the resulting increases in trade that should result. It should assist the civil service to apportion monies; and finally it should present perspectives useful to commerce, whether domestic or foreign" (Anonymous 1799). Statements such as this suggest that the economy was as important as technical advances to the engineers of the Conseil des mines. It is apparent that during the Revolution, the Corps des mines was encouraged, with the help of tools like Dupain-Triel's map, to promote more efficient commercialization of mineral resources. While this map is no longer extant, descriptions of it suggest that it was hardly a model of graphic economy. It appears that the addition of icons showed locations of different types of mineral deposits; and the transportation network on the map's printed background suggested possible trade links. The result seems to have achieved its goal as well as possible within its technical limitations, but the use of a previously printed background detracts from the purity of the final result. While such makeshift creations may have fit the needs of the Conseil des mines, they did not reach scientific standards, and the challenge of creating a mineralogical map that would "by its disposition demonstrate the nature of the terrains that made up French soil" remained (Anonymous 1799).

This goal was known to the engineers of the Conseil des mines, who were accustomed to noting mineralogical data on printed maps while making routine inspections in the districts under their supervision. The archives


FIG. 788. DETAIL FROM JEAN-LOUIS DUPAIN-TRIEL *FILS*, *TABLEAU GÉOGRAPHIQUE DE LA NAVIGATION INTÉRIEURE DU TERRITOIRE RÉPUBLICAIN FRANÇAIS,* 1795. The map emphasizes rivers and canals, with connecting roads. It served as a base map for a later, no longer extant, version with mineralogical data. Size of the entire original: 95 × 95 cm; size of detail: ca. 49 × 95 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge C 11330).

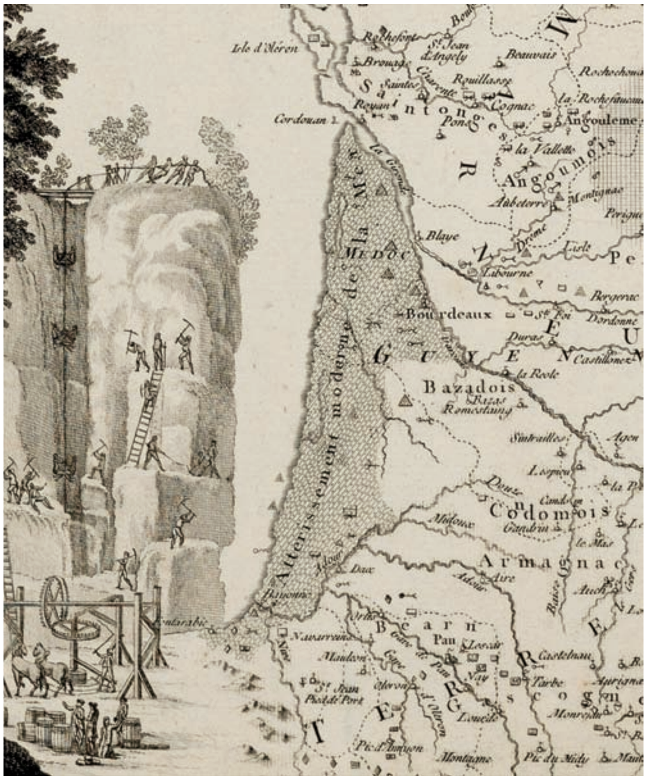


FIG. 789. DETAIL FROM JEAN-LOUIS DUPAIN-TRIEL *PÈRE*, *CARTE MINÉRALOGIQUE DE FRANCE* (PARIS: DUPAIN-TRIEL, 1781). This map emphasizes the type of soil through hatching and the location of different minerals with various symbols; shown is the area between Bordeaux and Bayonne.
Size of the entire original: 41 × 52 cm; size of detail: ca. 14.0 × 11.5 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge D 1812).

of the mapmaking department of the Agence des mines confirm that sheets of the Cassini map were regularly used for this purpose—four series of such maps have been conserved there. Moreover, in year IV, when the engineer Peltier was sent to inspect the second mineralogical region, the Conseil des mines supplied him with nineteen sheets of the Cassini map and two from Pierre de Belleyme's *Carte de la France divisée en 88 départements et subdivisés en districts* (1791, ca. 1:880,000). To synthesize the data collected in the field, the Conseil des mines recommended Louis Capitaine's one-quarter reduction of the Cassini map, the *Carte de la France dédiée au Roi* (1789–90, 1:345,600). From year III (1794–95) on, the Conseil des mines sought multiple copies of Capitaine's map from the Bureau de l'Agence des cartes and from Etienne-Nicolas Calon, who directed the Musée géographique. According to contemporary commentaries, these maps focused on the terrain rather than the locations of mining sites. Again, unfortunately, not a single example of these working documents is known to exist. Nevertheless, according to the descriptions in the engineers' extant correspondence, these maps did not just use location icons, but also tried to identify homogeneous terrain. This practice is repeated some years later in the work of Jean-Baptiste-Julien d'Omalius d'Halloy, who, from 1810, was commissioned by the minister of the interior to travel the whole of France to produce a mineralogical map.

The use of maps by the agents of the Conseil des mines from 1794–95 suggests that these documents had a double function: some were simply used to inventory and pinpoint locations; others were tools for identifying regularities and irregularities in the terrain and making these variations more easily understood. Yet the project of creating a true mineralogical map was constantly deferred. The trend in cartography during this period was toward economic inventory rather than toward encouraging discoveries about the geology of the country. Such cartography led to the same dead end as any inventory of resources: while useful for evaluating the status quo of mining in France, it did not embody a geological thesis or contribute to progress in this field of knowledge.

Although they were small in number, and mostly topographical or hydrographical, eighteenth-century thematic maps are a reminder that beginning in the Enlightenment, cartographic representation was no longer as dependent on the descriptive memoir; maps could reveal the characteristics of territories by their own codes and signs. Furthermore, the map became a way to conceptualize a problem and not merely indicate a location. For this reason, map use increased as one of the administrative practices instituted by Nicolas Louis Francois de Neufchâteau at the Ministère de l'intérieur around year VIII (1799–1800) (Konvitz 1987, 122).

ISABELLE LABOULAIS

SEE ALSO: Buache, Philippe; France; Guettard, Jean-Étienne

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***Thematic Mapping in the German States.*** With the Peace of Westphalia in 1648, the Thirty Years’ War in Germany came to an end. While the war had different effects geographically, the majority of the German states were devastated and millions of lives were lost. Germany’s development took until the eighteenth century to catch up to its neighbors, first with the Enlightenment in the arts and sciences and eventually through political and sectarian fragmentation. Institutions of advanced learning were founded, such as technical colleges and universities—including important ones at Halle (1694) and Göttingen (1737)—as well as scientific academies based on the models of London and Paris—in Berlin (1700), Göttingen (1751), Munich (1759), and Mannheim (1763; later reestablished in Heidelberg). In these institutions, geography was taught as a science. In the southern German free cities of Nuremberg and Augsburg, the map publishers Johann Baptist Homann and Matthäus Seutter flourished and made an impact on a European scale, while yet other publishing houses were founded in Leipzig and Berlin. In addition to topographic maps, purely thematic maps also were produced.

Under official authorization, hand-drawn large-scale maps of districts, forests, boundaries, water resources, and ditches as well as cadastral maps were drafted for reconstruction, internal colonization, settlement of religious refugees, drainage, flood control, sewer construction, and lease and tax collection. Unusual are the maps of herring fences in the Schlei region (Schleswig-Holstein); a printed example with about twenty insets showing the fishing weirs, *Accvratissima Sliæ flvminis descriptio* at 1:18,000, was published by Joan Blaeu in Amsterdam in 1662. For litigation before the *Reichskammergericht* (supreme court) and other high courts, hand-drawn legal inspection maps were submitted as evidence. This practice increased after the Reichstag decided on the reorganization of the *Reichskammergericht* in 1654. Therein, it was determined that plaintiffs and defendants should provide proper maps to better inform the court in cases of boundary disputes. Sometimes these maps were printed for the public to promote a particular view of the law. In sensational criminal cases, maps also were published to satisfy the curiosity of the public (Neumann 2002).

Forest maps were often made for big game hunting, a prerogative of the *Landesherren*, but they were primarily important for designating wood supplies in the mining industry that was widespread throughout the central German uplands after lumber shortages reached their peak in 1700. Regional maps, such as the medium-scale Homann map of 1737 (fig. 790), show the extent of forests and technically advanced mining facilities in the Harz Mountains. Chief mining official Hans Carl von Carlowitz, in charge of Saxony’s mining industry, wrote an early forestry handbook, *Sylvicvltvra Oeconomica* (1713) and championed a “sustainable” economy, for which surveys and maps were required.

Mine surveyors prepared mine plots. Locations and distributions of minerals and natural resources had occasionally appeared as a special feature in topographical maps of all scales. Precursors of mineralogical maps were published, such as Johann Christoph Müller’s medium-scale twenty-five sheet *Mappa geographica regni Bohemiae*, engraved by Michael Kauffer in Augsburg in 1720 with ten different symbols for mines. In 1761, Georg Christian Füchsel designed a printed geological map, *Generalis delineatio montium*, dependent on space and time, for his work on the geology of Thuringia, which also featured geological profiles. In 1765, the Bergakademie was founded at Freiberg in Saxony, and it quickly developed into one of the world’s leading mining academies. Its staff members and students contributed to the mapping of rock strata and minerals. The unpublished 1768 map of southeastern Saxony by Christian Hieronymus Lommer, a surveyor and member of the academy’s staff, showed five main rock formations with color and a sixth formation with colored dots; it was one of the first colored geographical maps of a German region. In 1774, academy graduate Friedrich Gottlob Gläser published a mineralogical description of the county of Henneberg, which was followed by Professor Johann Friedrich Wilhelm von Charpentier’s published


FIG. 790. JOHANN BAPTIST HOMANN, *DELINEATIO AUREAE STERILITATIS HERCINIENSIS I. E. HERCINIÆ METALLIFERÆ ACCURATA CHOROGRAPHIA* (NUREMBERG, 1737–40), CA. 1:76,000.

Size of the original: 50.0 × 56.5 cm. Image courtesy of Bibliothèque nationale de France, Paris (Cartes et plans, Ge BB 565 [3, 82]).

petrographic map of Saxony in 1778 (Hoth, Schmidt, and Thalheim 1996) (see fig. 779). Beginning in 1775, Professor Abraham Gottlob Werner taught geological surveying and mapping at the mining academy for many years and extended his assignment when Saxony began its geological mapping surveys in 1791 in order to investigate comprehensively the coal resources to be included in the larger project. Werner contributed to this effort with his scheme of forty colors, the *Farben Tafel*, which organized rocks by their characteristics and based the colors on the concept of imitation of the rock color, not on the stratigraphic age. His ideas, though unpublished, were communicated in lectures to his students and circulated throughout Europe (Schäfer-Weiss and Versemann 2005). Other geoscientific maps were published by the Bishopric of Fulda, including of the Harz Mountains and elsewhere.

Because of the political and sectarian fragmentation of Germany, it was customary to have related map areas in similar colors instead of using delicately colored ribbon borders. In the early eighteenth century, Homann adopted the color scheme developed by the educator Johann Hübner and explained in Hübner's *Nachricht von den Land-Charten, welche unter seinr Aufsicht in Ham-*

*burg illuminiret werden* (1718). Around 1720, Eberhard David Hauber designed a map of Germany, published by Homann, with colors showing the religious confessions guaranteed by the Peace of Westphalia (*Tabula geographica totius Germaniæ qua differentium imperii trium religionum status et dominia diversis coloribus distincta exhibitur*); Homann's world maps of the distribution of religions featured glued-on slips to explain the colors. Toward the end of the eighteenth century, surface coloring disappeared, probably for aesthetic reasons, only to reappear in the nineteenth century with the introduction of the lithographic political map.

Road maps based on the model of the *Totivs Germaniæ novvm itinerarivs,* designed by the brothers Johann Georg Jung and Georg Conrad Jung in 1641, as well as on English and French exemplars, were used in the individual German states. In his maps of Schleswig-Holstein (1652), Johannes Mejer systematically recorded the major roads. In the wars of Louis XIV, French maps containing the road network on the Rhine for military purposes were reproduced in Germany. With economic recovery, freight traffic increased (especially in the trade and fair cities of Frankfurt and Leipzig) and thus grew a need for road maps. For example, the union of Saxony and Poland led to the production of a strip map from Dresden to Warsaw (*Carte itineraire depuis Dresde à Warsovie / Polnische Reise Karte über die vornehmsten Passagen von Dresden nach Warschau*, 1751). Johann Ulrich Müller published an early all-German distance map, *Tabula geographica totius S. Imperii Romani*, at a scale of 1:2,000,000 in Ulm in 1690.

Post-route maps became more common after 1650 as mail services began to offer regular seats to passengers instead of only occasionally allowing them in the freight compartments. These routes increased with the construction of highways in the eighteenth century. Jeremias Wolff, based in Augsburg, published a German post-route map in 1705 (*Teutschland in seine 10. Kreisse abgetheilt*). More content was offered in the *Neu-vermehrte Post-Charte durch gantz Teutschland*, published by Johann Peter Nell in Brussels in 1711 and by Homann in Nuremberg in 1714 (Elias 1981). In 1765, Homann published a sixteen-sheet post-route map as a pocket atlas (*Neue und vollständige Postkarte durch ganz Deutschland*, by Johann Jacob von Bors and Franz Joseph Heger), and the *Neuer Post- und Reise-Atlas von ganz Deutschland* was published by the printing house of Weigel & Schneider in Nuremberg in 1785. Since there was money to be made from postal services, larger states such as Prussia and Saxony created their own with the help of post-route maps. Postal routes that went beyond German borders were also represented. In 1749 in Augsburg, the *Reise-Carte der Wege durch Dænnemarck und Schweden auch durch Preussen und einen Theil des Russischen Reichs* at a scale of 1:4,000,000 was published by Gottfried Jacob Haupt and featured the postal routes of the countries on the Baltic Sea and even the most important shipping routes between northern Germany and Scandinavia (Ritter 2014, 21 and n28).

Since Germany had little direct involvement in overseas enterprises, the production of nautical charts was sparse and confined to port and coastal maps. Nonetheless, there emerged some mapping focusing on particular aspects of the seas. Athanasius Kircher designed several thematic maps of the seas for his *Mundus subterraneus*, and the world map of ocean currents by the Hamburg author Eberhard Werner Happel displays not only ocean currents but also possible subterranean tunnels and volcanic zones (fig. 791). Hand-drawn large-scale maps of flood damage on the coast and along the inland rivers, particularly along the Rhine, were also produced. These maps were printed for major events, such as the map of the storm surge of 25 December 1717 by Homann (*Geographische Vorstellung der jämerlichen Wasser-Flutt in Nieder-Teutschland*) or the map from a devastating levee breach on the Elbe on 8 July 1771 published by Dalençon (*Denkmahl für die Nachkommenschaft, in einem accuratem Abriss derjenigen Hamburgischen Gegenden, welche durch einen am 8. Juli 1771 vom Ober-Wasser in der Neuen-Gamme erfolgten Durch-Bruch des Elb-Deichs*). Philipp Heinrich Zollmann published his map of the German waters and river basins by 1712 with Homann (Rohde 1999) (see fig. 296). Johann Hermann Dielhelm from Frankfurt described the currents of the Rhine (*Denkwürdiger und nützlicher Rheinischer Antiquarius*, 1739) to the Danube (*Antiquarius des Donau-Stroms*, 1785) and added overview maps.

Important maps featuring terrestrial magnetism came from Johann Heinrich Lambert, who mapped isogones on landmasses in 1777 in Berlin, and Christlieb Benedict Funk von Hartenstein in Leipzig, who in 1781 represented the entire earth's surface with isogones and isoclines on two globes and also on polar azimuthal maps (fig. 792) (Christoph 2014, 24). The Brunswick-based professor Eberhard August Wilhelm von Zimmermann, founder of animal geography, published in Leipzig his *Tabvla mvndi geographico zoologica: Sistens quadrupedes hucusque notos sedibusque suis adscriptos* (1778) in his work on the distribution of mammals.

Historical maps, which are among the earliest thematic maps with humanities content, were published by the Wittenberg professor Johann Matthias Hase in 1743 (*Tabvlae geographicae*, the third part of his *Historiae universalis politicae*; see fig. 83) and in 1750 (*Atlas historicus*, compiled by Hase and published by Homann) that for the first time included the Middle Ages to the modern era. Homann also published language maps of


FIG. 791. EBERHARD WERNER HAPPEL, *DIE EBBE UND FLUTH AUFF EINER FLACHEN LANDT-KARTEN FÜR GESTELT* (ULM, 1675). Size of the original: 20 × 28 cm. Image courtesy of the Rare Book Division, Department of Rare Books and Special Collections, Princeton University Library (HMC01.6422).

the four continents in 1741, for example, *Evropa poly glotta* with the first lines of the "Pater Noster" in various languages. This was included in Gottfried Hensel's *Synopsis vniversæ philologiæ* (see fig. 781). The Giessen-based professor August Friedrich Wilhelm Crome produced an early economic map titled *Neue Carte von Europa* in 1782 while educating a prince in Dessau (Harms 1991) (see fig. 780).

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SEE ALSO: Customs Administration Map; German States; Hase, Johann Matthias; Homann Family; Transportation and Cartography: Post-Route Map; Wiebeking, Carl Friedrich von

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FIG. 792. CHRISTLIEB BENEDICT FUNK VON HARTENSTEIN, *SÜDLICHE ERD-OBERFLAECHE AUF DER AEQUATORFLAECHE ENTWORFEN UND SEINER CHURFÜRSTLICHED DURCHLAUCHTIGKET ZU SACHSEN UNTERTHAENIGST ZUGEEIGNET* (LEIPZIG, 1781). The Southern Hemisphere with isogonic lines for magnetic declination.
Diameter of the original: 60 cm. Image courtesy of the Universität Bern, Zentralbibliothek, Sammlung Ryhiner (MUE Ryh 1106:45).

***Thematic Mapping in Great Britain.*** During the Enlightenment, thematic mapping was an incipient practice in Great Britain. By the mid-seventeenth century, there were virtually no examples of thematic cartography produced in Britain; however, a series of closely interlinked socioeconomic developments occurred that gave rise to this mode of mapping.

First, between 1650 and 1800, Britain's economy was utterly transformed by a dramatic rise in global trade borne by new colonial possessions and the initial industrialization of what had hitherto been a primarily agrarian economy. This transformation led to an unprecedented process of urbanization and infrastructural development, which in turn contributed to a more sophisticated appreciation of the natural environment and how it could best be exploited to support the demands of the new economy.

Second, the period saw the rise of commercial enterprises that could sponsor new and sophisticated forms of mapmaking and could publish and disseminate maps to a wider audience. Increased consumption heightened the practical importance of maps and sustained the future economic viability of thematic mapping. Critically, commercial mapmakers increasingly undertook the production of accurate general or base maps that were often a prerequisite to thematic mapping, filling the void left by the lack of government support for mapmaking in Britain.

And third, the Enlightenment ushered in an intellectual philosophy that highly valued insights generated by empirical observation and scientific experiment. The new natural philosophy created an impetus not only to make more accurate qualitative observations about both natural phenomena and human endeavors, but also to quantify observations and to develop new strategies to express those observations visually. While inextricably linked to the commercial world, the new philosophy also gave rise to intellectual associations, such as the Royal Society of London, and to their periodicals, which played a critical role in fostering thematic cartography.

British thematic mapping can, in this period, be divided into maps that focused on depicting quantified aspects of the natural world and those that concentrated on evaluating aspects of human enterprise or man-made alterations to the natural landscape. Importantly, some of the maps that are cited here can best be termed as "proto-thematic cartography," because while they include features that address specific thematic concepts, they may also have been intended to serve broader purposes.

Thematic mapping relating to how various elements of the natural world might be quantified and understood concerned three main areas: maritime navigation, astronomical phenomena, and geology. Britain pioneered the mapping of the natural workings of maritime environments and their effect on navigation as part of its ascendency to become the undisputed global maritime power and as part of London's gradual rise as a preeminent center of the publication of sea charts and pilot books.

Edmond Halley was, as Arthur H. Robinson noted, "the first versatile thematic cartographer" (Robinson 1982, 49). A towering figure of the English intelligentsia, serving as the editor of the Royal Society's *Philosophical Transactions* and later as the astronomer royal, Halley was also a sometime captain in the Royal Navy and based his maps, in part, on empirical data he collected while at sea. In 1686, Halley published an untitled world map in the *Philosophical Transactions* that employed a series of arrows traversing the oceans to depict the directions of the trade winds, one of the earliest published meteorological maps (see fig. 776). Recognizing the value of communicating scientific observations by visual means, Halley noted that his ideas on the trade winds were "better expressed in the Mapp hereto annexed, than it can well be in words" (Halley 1686, 155).

Halley followed this with another pioneering map theme relating to maritime navigation, geomagnetism. Included in an edition of Mount and Page's *The English Pilot, the Fourth Book* (1701), Halley's *A New and Correct Chart Shewing the Variations of the Compass in the Western & Southern Oceans* depicted magnetic declination throughout the Atlantic Ocean (see figs. 348 and 442). As the first printed map to employ isolines, it is credited with popularizing their use (Robinson 1982, 49).

Halley also produced *A New and Correct Chart of the Channel between England & France* (1701), which carefully quantified the tides at various locations throughout the coasts of the English Channel. He used arrows to depict the direction of movement and roman numerals to mark the times of high water. An accompanying statistical table related to the position of the moon allowed one to calculate the movement of the tides.

Another theme in maritime mapping was oceanic hydrology. For Great Britain, an island nation in the North Atlantic, the Gulf Stream, sweeping from Florida to Europe, offered an important focus. Benjamin Franklin, once a British postal official, noticed that mail packets that sailed with the current traversed the ocean much more expeditiously than otherwise. Using information from Nantucket whaling captain Timothy Folger, he had the current drawn and printed a limited number of copies (ca. early 1769), which essentially grafted the assumed route of the Gulf Stream onto an old Mount and Page sea chart. Though it initially attracted little notice, Franklin's chart was the first to map the Gulf Stream (see fig. 346). The Gulf Stream was subsequently mapped by William Gerard De Brahm, with the *Hydrographical Map of the Atlantic Ocean* in *The Atlantic Pilot* (1772). De Brahm based his map of the current on firsthand observations carried out while sailing from South Carolina to England. James Rennell, already well known for his mapping of India, devised his *Chart . . . Exhibited with a Design to Prove the Existence of a Current, between Ushant and Ireland* (1793). Published in the *Philosophical Transactions,* it mapped the currents that flow about the western entrance of the English Channel.

In some instances, thematic maps concerned the act of mapmaking itself. John Cowley's "A Display of the Coasting Lines of Six Several Maps of North Britain" (1734) depicted the outline of Scotland's coasts as they were then thought to be shaped and overlay the outlines


FIG. 793. MAP OF SOLAR ECLIPSE. Edmond Halley, *A Description of the Passage of the Shadow of the Moon over England.* Printed in London by John Senex and William Taylor, 1715. Copper-engraved map. The first map printed in Great Britain to depict the path of a solar eclipse.
Size of the original: 45.5 × 28.5 cm. © The British Library Board, London (Cartographic Items Maps *23[2]).

of the coasts as they appeared on six important historical maps, thus highlighting the discrepancies between these maps (see fig. 11).

Thematic mapping also embraced astronomical phenomena. Halley produced a broadside, *A Description of the Passage of the Shadow of the Moon over England* (1715), the earliest such British map (fig. 793). On a base map of England and Wales, Halley charted the predicted course of the full solar eclipse of 1715 as its shadow moved diagonally across the country. Capitalizing on public fascination, commercial publishers followed with maps such as John Senex's *The Transit of the Total Shadow of the Moon* (1724). Eventually, Robert Sayer published a multiyear retrospective of eclipses: *A Map Exhibiting the Dark Shadow of the Moon over England and Other Parts of Europe, In the Five Great Solar Eclipses, of the Years 1715, 1724, 1737, 1748, and 1764* (1787) (Armitage 1997).

The eighteenth century saw a gradual increase in the appreciation of geology. Economic growth and industrialization made the discovery and management of mineral resources increasingly imperative. However, reliance on more sophisticated data meant that geological mapping developed only toward the end of the eighteenth century. Collecting data was labor intensive and required considerable scientific expertise, and drafting the maps necessitated the use of accurate base maps, which were often not available.

The concept of a "soil or mineral map" was proposed by Martin Lister of the Royal Society in 1683 (published 1684), although no map resulted (Robinson 1982, 52). Christopher Packe's *A New Philosophico-Chorographical Chart of East-Kent* (1743) was an innovative British contribution (see fig. 622). Packe, a physician, drew the river systems and drainage patterns of the regions almost in the manner of a physiological circulatory system, and he distinguished areas between four geologically based regions, although these distinctions were not nearly as refined as the bands of soil zones depicted on modern geological maps (Campbell 1949).

The first map to make clear distinctions between different soil and mineral zones was developed in France in 1746 by Philippe Buache for Jean-Étienne Guettard. It was another half-century before a geological map was published in Britain: William George Maton's *Mineralogical Map, of the Western Counties of England* (1797), which detailed ten different strata of the West Country (see fig. 778). By this time, William Smith had commenced his work leading to *A Delineation of the Strata of England and Wales with Part of Scotland*, celebrated as the first large-scale, detailed scientific geological map of any country, though it was not published until 1815. Louis Albert Necker created a geological map of Scotland in 1808 by demarcating strata on a relatively accurate printed map.

John Gibson's *Plan of the Collieries on the Rivers Tyne and Wear also Blyth, Bedlington and Hartley with the Country 11 Miles round Newcastle* (1788) might be considered a proto-thematic map (fig. 794). Although it appears to be an uncomplicated topographical map, its purpose is found in its detail, which shows the locations of the region's various coal deposits along with the means by which the coal was to be transported to market.

British thematic mapping also sought to classify and quantify various aspects of human endeavors, including


FIG. 794. DETAIL FROM JOHN GIBSON, *PLAN OF THE COLLIERIES ON THE RIVERS TYNE AND WEAR ALSO BLYTH, BEDLINGTON AND HARTLEY*, 1788. This map of collieries shows their depth in fathoms and the wagon ways (in red) by which the coal was moved to the River Tyne to be shipped to London. Copper-engraved map with hand color.
Size of the entire original: 64 × 99 cm; size of detail: ca. 28.5 × 37.5 cm. Image courtesy of Special Collections, Palace Green Library, Durham University (Rm5/PFC/22/5).

transportation, military science, special-purpose land use, and the mapping of archaeological sites. The mapping of transportation routes, particularly the mapping of roads, led to the development of some of the earliest thematic maps in Britain. John Ogilby's *Britannia* (1675) (see fig. 866) contained strip maps of various itineraries along the main roads of England and Wales and inspired a wave of commercially driven road mapping in Britain. While most road maps from this period were essentially multipurpose geographical maps featuring roads, some maps were designed exclusively as aids for planning transport. John Adams's *Angliæ totius tabula* (1677) detailed the linear distances between key points across the country. John Seller's *A New Mapp of the Roads of England* (ca. 1690) depicted the main roads, names of places along the route, and the distances between those points. Like a twentieth-century underground railway map, the routes were stylistically drawn for clarity not planimetric accuracy, and the map was intentionally bereft of details that did not strictly inform its specific purpose.

While most topographical maps could be used for military purposes, maps specifically designed to depict information critical to martial control of a region or country developed during the eighteenth century. A proto-thematic work, Clement Lempriere's manuscript "A Description of the Highlands of Scotland" (1731) was primarily intended to quantify the potential military capabilities of the Highland clans in the wake of the Jacobite Rebellion of 1715 (fig. 795). To that end, the map labels the territories of each of the clans, along with the number of men of fighting strength, as well as forts and certain roads that could function as key military corridors.

John Knox's *A Commercial Map of Scotland* (1782) presaged later thematic maps that sought to express quantitative economic data or patterns within geographic space. While proto-thematic, it was specifically intended to provide a merchant with vital information for running a business or conducting trade in Scotland. It shows all major roads with distances between points and provides detailed notes on the products and economic attributes of each region, shipping routes, information on customs duties, and notes discussing potential future infrastructure.

Rapid economic growth and urban development demanded increasingly critical regulation of land use. Britain's earliest special-purpose land use map of a large area was Thomas Milne's plan of London and Westminster (1800), which employed color coding for land use (fig. 796). Milne, an estate surveyor and county mapmaker, employed an accurate topographical base map on which he depicted various types of agricultural, industrial, and residential land use over an area of 673 square kilometers around London.

The Enlightenment desire to record and analyze historical events gave rise to the study of archaeology. In this context, the antiquary William Stukeley produced *In gratiam itinerantium curiosorum, Antonini Aug. itinerarium per Britanniam* (1724), which depicted the towns and road system of Roman Britain projected onto a modern map of England and Wales. William Roy's *Mappa Britanniæ septentrionalis faciei Romanæ* (1793) showed the main towns, roads, and constructions in southern Scotland as they would have appeared during Roman times, all grafted onto Roy's own first military survey of the region. By 1800, the precedents for many distinct forms of thematic mapping had been established, laying the basis for the proliferation, diversification, and refinement of thematic cartography in nineteenth-century Britain.

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SEE ALSO: Antiquarianism and Cartography; Eclipse Map, Solar; Great Britain; Gulf Stream; Halley, Edmond; Packe, Christopher

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FIG. 795. THE DISTRIBUTION OF HIGHLAND WARRIORS. In his manuscript map "A Description of the Highlands of Scotland" (1731), Clement Lempriere located and displayed the number of fighting men commanded by each of the Highland lairds. This detail shows the area south of Fort William, originally erected after Oliver Cromwell's invasion of Scotland in the mid-seventeenth century.
Size of the entire original: 130.0 × 93.2 cm; size of detail: ca. 8.5 × 20.0 cm. Image courtesy of the National Library of Scotland, Edinburgh (Acc. 11104 [Map.Rol.a.42]).


FIG. 796. LAND USE MAP. Detail across sheets 3 and 6 of Thomas Milne, *Milne's Plan of the Cities of London and Westminster, Circumjacent Towns and Parishes &c.* (1800). Copper-engraved map. The first special-purpose land use map of a large area produced in Britain, this map employed four colors and letter codes to delineate and portray arable fields, market gardens, hop grounds, orchards, meadows, and woods. Size of north/south sheets: 53.1 × 104.3/53.8 × 103.7 cm; size of detail: ca. 21.5 × 36.5 cm. © The British Library Board, London (Cartographic Items Maps K.Top.6.95).

Halley, Edmond. 1686. "An Historical Account of the Trade Winds, and Monsoons, Observable in the Seas between and near the Tropicks, with an Attempt to Assign the Phisical Cause of the Said Winds." *Philosophical Transactions* 16:153–68.

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***Thematic Mapping in the Italian States.*** As in France, England, and Germany, thematic maps in Italy began to develop during the long period of the Enlightenment. In general, they appeared as geographical or topographical maps to which specific marks, such as letters or numbers, were added, with an explanatory key in an inset or within the cartouche. This style of depiction followed the trend typical of sixteenth- and seventeenth-century mapmaking but also saw the development of morphological details, such as lava flows, as well as the tentative use of colors to show thematic subjects.

All these early attempts may be associated with the initiatives of individual scientists who wished to illustrate expressly the results of their research. Such initiatives are exemplified by the *Mundus subterraneus* (1665 and 1678; see fig. 782) of Athanasius Kircher, SJ, who taught at a Jesuit college in Rome; his book includes maps of oceanic currents and a planisphere showing the ocean depths related to major volcanic activity. The works of Luigi Ferdinando Marsigli also demonstrate a scientist's need to use maps to illustrate his research. His interest in a variety of themes led him to prepare maps showing a wide range of subjects: commerce, postal services, mines, antiquities, magnetic declination, disease, and even the distribution of mushrooms. Marsigli's great atlas *Danubius Pannonico-Mysicus* (1726) contains an interesting mineralogical map of the Danube basin (see fig. 777); his *Histoire physique de la mer* (1725) is illustrated by the detailed *Carte du Golfe de Lion*, which uses isobaths to represent depth (Sartori 2003) (see fig. 361).

While the geopolitical subdivisions of Italian territory (lasting well into the nineteenth century) did not encourage peninsula-wide efforts for geodetic and topographical surveying, nevertheless, widespread interest in natural history and mathematical cosmography encouraged some use of thematic signs in maps during this period. Early manifestations may be found in the cartographic representations of regions with impressive natural features, such as the volcanic area of Phlegraean Fields and the volcanos of Vesuvius and Etna. These regions attracted both maps and perspective views, especially after the violent volcanic eruption of Monte Nuovo near Pozzuoli in 1538 and of Vesuvius in 1631, which caused serious damage to coastal villages. Maps and views of Etna were equally numerous, such as Giuseppe Recupero's *Carta oryctografica di Mongibello* (drawn shortly before his death in 1778 and included in the posthumous work *Storia naturale e generale dell'Etna,* dated 1815), which detailed the lava flows. Immediately after the disastrous Calabria earthquake of 1783, Eliseo della Concezione and other technicians conducted a series of on-site inspections and produced a large atlas with sixty-eight engravings as part of the *Istoria de' fenomeni del tremoto avvenuto nelle Calabrie, e nel Valdemone nell'anno 1783* (1784). A map accompanying the atlas, *Carta corografica della Calabria Ulteriore*, used asterisks to show the magnitude of the destruction of individual villages (fig. 797).

Other topics for thematic mapping included environmental problems, such as the reclamation of the Pontine Marshes south of Rome, whose configuration was detailed on the maps of Giovanni Antonio Magini (*Campagna di Roma olim Latium*, 1604–20) and Kircher (*Latium: Id est, nova & parallela Latii tum veteris tum novi descriptio*, 1671). Similarly, the network of tributaries to the lagoon of Venice interested Cristoforo Sabbadino, whose manuscript topographic maps in the Museo Correr, Venice, use color to express features of hydrography and vegetation, anticipating the suggestive and exact representations of Baron Anton von Zach in his "Topographisch-geometrische Kriegskarte von dem Herzogthum Venedig" (1798–1805).

Another rich subject of thematic maps concerned the numerous historic sites and archaeological remains with which Italy is replete. Plans and maps enclosed in the guidebooks for *forestieri e viaggiatori* (foreigners and travelers), printed in many editions from the sixteenth century in Naples, Venice, and Rome, illustrate texts describing the ancient heritage of these cities and their environs. But significant references to the morphology and volcanism of regions may be found in the maps included in the guidebooks for Naples and Campania, such as those of Paolo Antonio Paoli (*Avanzi delle antichità esistenti a Pozzuoli, Cuma e Baja*, 1768, in-folio, with more than sixty engraved plates), Pompeo Sarnelli (*Gvida de' forestieri, curiosi di vedere, e considerare le cose notabili di Pozzoli, Baja, Miseno, Cuma, ed altri luoghi convicini*, 1685 and continuous editions to the end of the eighteenth century), and Domenico Romanelli (*Viaggio a Pompei a Pesto e di ritorno ad Ercolano ed a Pozzuoli*, 1811 and 1818, first and second editions, with many maps and plans).


FIG. 797. DETAIL FROM THE *CARTA COROGRAFICA DELLA CALABRIA ULTERIORE* (NAPOLI: STAMPERIA REALE, 1784). A seismic map showing the destruction caused by the Calabrian earthquake in February 1783 in which the magnitude of destruction is differentiated with asterisks, from one to three. The map was drawn by Francesco Progenie and engraved by Aniello Cataneo, based on surveys of the Palermo physicist and astronomer Eliseo della Concezione. Engraved in nine sheets, scale ca. 1:142,000; detail here is from sheet 4. Size of the entire sheet: 79 × 53 cm; size of detail: ca. 29.0 × 17.5 cm. By permission of Pusey Map Library, Harvard University, Cambridge (MAP-LC G6713.C3 1784 .E5).

Before the Enlightenment, the topics mentioned above (environment, volcanoes, archaeology) generated a mass


FIG. 798. *TOPOGRAPHIA AGROIATRICA MEDIOLAN. O DESCRIZIONE DELLE CONDOTTE MEDICHE NELLA CAMPAGNA MILANESE,* 1782. Hand-colored engraving, scale of 20 Milanese miles.

Size of the original: 38.5 × 49.5 cm. Image courtesy of the Archivio di Stato, Milan (Atti di governo, Sanità parte antica, cartella 243, MMD 14D).

of documents, both cartographic and iconographic, and were included not only in numerous printed works but also in manuscripts and as single broadsheets, now preserved in the archives and libraries of most Italian towns. An idea of the range of these collections may be gleaned from the bibliographic works on the Phlegraean Fields and Vesuvius by R. T. Günther (1908) and Federigo Furchheim (1879, 1897).

In addition to themes of natural features and historic or archaeological sites, some maps exhibited civic or social interests. For example, the hand-drawn "Lo stato di Milano e i svoi confini" (1721) by Bernardo Maria Robecco outlines the political-administrative units within a single state and the extension of its frontiers by showing a four-mile strip of land contiguous to the borderline. The distribution of public health resources is the focus of the "Topographia agroiatrica mediolan[ensi]" (1782), a very detailed map made by the physician Giuseppe Cicognini, director of the faculty of medicine at Pavia University, which uses color and asterisks to show the distribution of the districts served by a municipal doctor (*condotte mediche*) (fig. 798). The "Carta postale delle province di Lombardia" (1820) by G. B. Ceppi displays the network of mail communications. All three maps are conserved at the Archivio di Stato in Milan.

Other subjects for thematic maps emerged as military and hydrographic cartography rapidly improved with the development of geodetic and topographical surveys. As a result, morphological and bathymetric themes attracted the attention of cartographers, as seen in the work of Giovanni Antonio Rizzi Zannoni, who supervised the delicate and precise engraving of Giuseppe Guerra for the twenty-three charts of the *Atlante marittimo delle Due Sicilie* (1785–92), which show morphological and bathymetric features of the southern Italian coasts. The *Carte générale du théâtre de la guerre en Italie et dans les Alpes* (1802), prepared by the French engineer Louis Albert Guislain Bacler d'Albe for the second Napoleonic campaign in Italy, was engraved by the brothers Benedetto and Gaudenzio Bordiga in thirty sheets. The map covers central and northern Italy and nearly all the Alps; with specific symbols it shows the positions of the opposing armed forces, the sites of battles, trenches, and the more static situation of forts, roads, mines, mineral springs, marshes, and woods. Its scale, about 1:250,000, allows it to be considered a topographic map, but the wide variety of symbols employed adds a layer of thematic and strategic information, vital for carrying on the war.

Among the maps attempting to reveal distribution of natural resources were so-called mineralogical maps. They were generally created by adding the sites of mines to topographical or geographical base maps, using letters or symbols representing the chemical elements (e.g., copper, silver, lead) found in particular mines. The maps by the Piedmontese engineer Spirito Benedetto Nicolis di Robilant exemplify this type; *Carte topographique-mineralogique des etats du roi en terre ferme* was included in his work on mining in the Kingdom of Sardinia (Robilant 1786, pl. VI). The manuscript map by the Milan naturalist Ermenegildo Pini, "Carta mineralogica della Valsassina e della Valcavargna" (1779, Milan, Archivio di Stato), depicted a valley near Lake Como with color coding to identify different categories of minerals. Pini had been commissioned by the authorities to investigate the extent of mineral resources and the damage caused by mining to woodlands and forests. Similar to these is the *Carta mineralogica dell'isola di Sicilia* (1810), by Francesco Ferrara, professor at Catania University. The splendidly colored *Carta fisica del suolo di Roma* (1820) with its display of many different lithological formations (fig. 799), based on the surveys of the mining engineer Giovanni Battista Brocchi, contrasts sharply with these. Although it appeared late in the Enlightenment, the work of Brocchi followed the systematic geognostic research carried out earlier in the Papal States: Kircher's maps included in his abovementioned account of Latium (1671); the maps of the Papal States containing information about mines and mineral springs by Giacomo Filippo Ameti (*Il Lazio con le sue piu cospicue strade, antiche e moderne* [1693]; *Patrimonio di S. Pietro, olim Tuscia suburbicaria* [1696]); those of Pier Maria Cermelli (in his *Carte corografiche, e memorie riguardanti le pietre, le miniere e i fossili* [1782]); and the map of different ores by Giuseppe Morozzo della Rocca, which is included in a work about the Papal States (*Analisi della carta corografica del patrimonio di S. Pietro* [1791]). The famous geologist Scipion Breislak prepared the *Plan physique de la ville de Rome* for his *Voyages physiques et lythologiques dans la Campanie* (1801) and drew other maps of the volcanic areas of Campania (the Phlegraean Fields and Vesuvius) using simple geological colors, but without reference to other European developments in color selections to distinguish rock types. Only at the end of the first quarter of the nineteenth century did the botanist Michele Tenore prepare a true geologically colored map of the region in which each color was assigned to a specific lithological formation, included in his *Cenno sulla geografia fisica e botanica del Regno di Napoli* (1827). At the midpoint of the eighteenth century, a deep interest in mines and geology permeated the incomplete work of the Florentine Giovanni Targioni Tozzetti, who proposed a survey for a "Carta Oreografica" that would be drawn along the main tectonic lines, and for a "Carta Icnografica" that would show the various lithological formations differentiated by a specific color (Targioni Tozzetti 1754, 19, 22). Unfortunately, technical and other obstacles prevented their completion.

The current state of research allows only a synthetic overview of thematic cartography in the Italian region during the Enlightenment. Other subjects, such as population distribution or agricultural land use, would require extended research in numerous libraries and state and notarial archives in order to create a more nuanced and complete picture.

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SEE ALSO: Italian States

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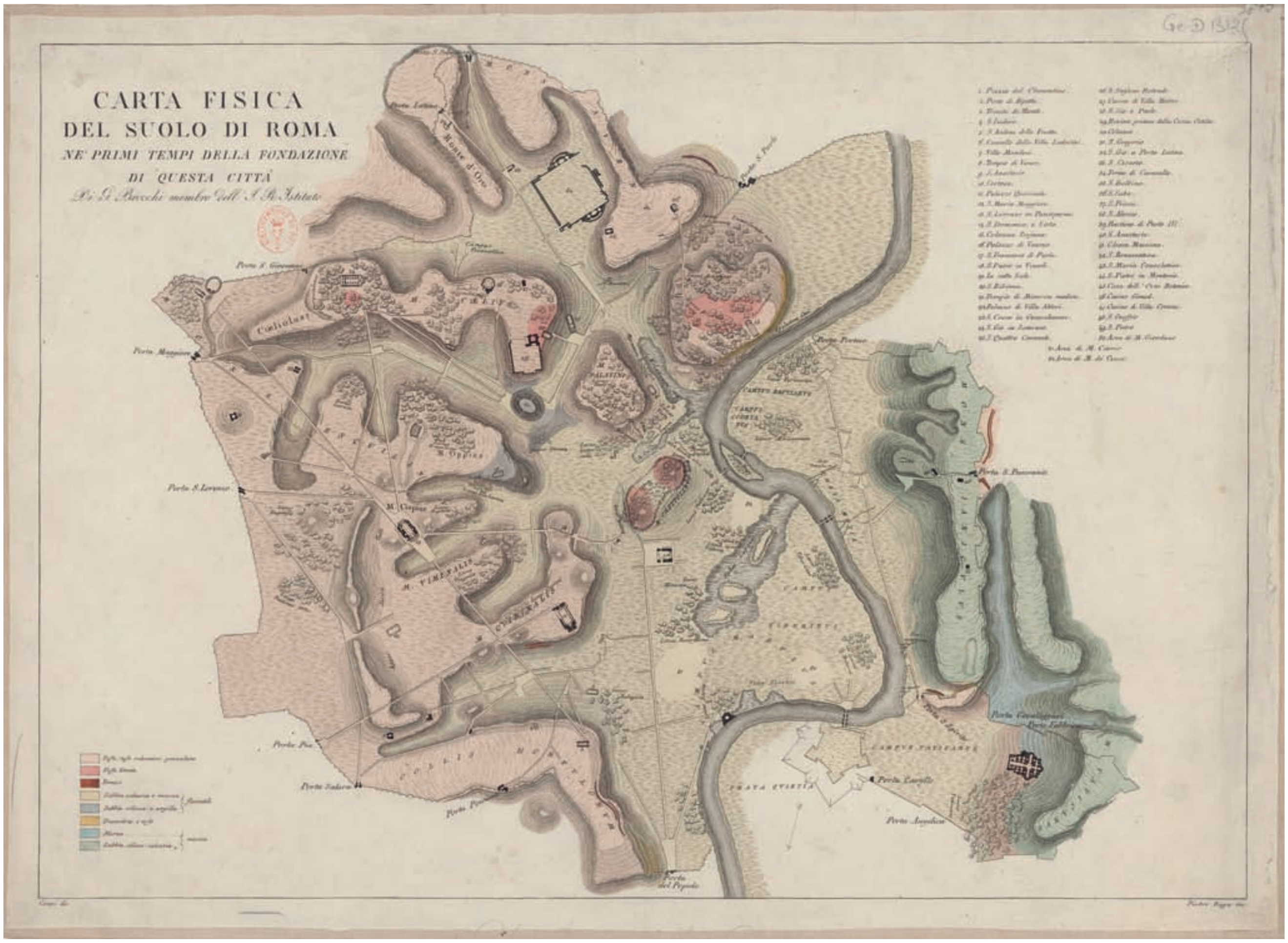


FIG. 799. *CARTA FISICA DEL SUOLO DI ROMA*, 1820. Hand-colored engraving inserted in the work of Giovanni Battista Brocchi, *Dello stato fisico del suolo di Roma, memoria per servire d'illustrazione alla carta geognostica di questa città* (Rome: Stamperia de Romanis, 1820), this map was drawn by Campi and engraved by Pietro Ruga. It uses eight colors to express different lithological formations; it accompanied two sheets of geological sections using sixteen lithological colors. Scale, ca. 1:10,000.
Size of the original: 43 × 60 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge D 13125).

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***Thematic Mapping in the Netherlands.*** During the Enlightenment, thematic mapping in the Netherlands was only incidental. Apart from the instances cited below, thematic maps were produced ad hoc, using existing topographic or geographic maps as base maps, rather than being produced in series on customized base maps as would be the case in centrally governed European states after 1800. Two principal trends carried over from pre-1650 thematic mapping: river and drainage mapping and land use mapping. New fields of application were celestial maps and the use of maps for urban planning, similar to the maps drawn for lake drainage in the previous period.

From 1650 to 1800, no extension of the techniques used for thematic graphic representation took place, with the exception of drainage cartography, whose maps were combined with cross-sections and longitudinal sections for analytical purposes. The distribution of area-covering phenomena was rendered either by a repetition of point symbols, as seen in the map *Designatio orbis christiani* in the *Atlas minor* by Jodocus Hondius (1607) with crosses, crescents, and spears denoting Christians, Muslims, and Pagans, or by colors. The 1596 soil map of the Zijpe polder area in northern North Holland produced by Gerrit Dirksz. Langedijk is an example of the use of color to represent area-covering phenomena (fig. 800); one finds this technique on printed maps infrequently as it was impossible to apply homogeneous tints to maps before the advent of lithographic printing.

On many printed maps hand-applied colored borders indicate the extent of area-covering phenomena, as was also customary for showing the boundaries on administrative maps. For continuous phenomena there was also the use of isolines, first applied in 1584 by Pieter Bruinsz., on his map of the River Spaarne in Haarlem. This technique was reinvented a century later in the mapping of the Nieuwe Maas River near Rotterdam by Pierre Ancelin, later by Nicolaas Samuelsz. Cruquius on his map of the Merwede (1729–30) (see fig. 33), and was used on the river maps necessary to keep the slowly subsiding delta navigable. There were also the dotted lines that indicated distances, first used by Erhard Etzlaub on his route map, *Das ist der Rom Weg* (1500), and also applied by Jacob van Deventer in his series of urban maps of the Netherlands (surveyed 1555–75). To represent objects that would be regarded as points on small-scale maps, point symbols were deployed; a good example is the use of Dutch flags to indicate Dutch

FIG. 800. LEGEND OF THE MANUSCRIPT SOIL MAP OF THE ZIJPE POLDER AREA BY GERRIT DIRKSZ. LANGEDIJK, 1596. The legend describes the meaning of each color: bottle green for clay; sea green for clay covered with one foot of sand; beige for clay newly covered with over two feet of sand; rose beige for three feet of sand on top of the clay; and olive green for clay improved by silt.

Size of the entire original: 19.3 × 30.1 cm; size of detail: ca. 6.5 × 12.0 cm. © Archives nationales (France) (CP/N/III/Pays-Bas/17).

fortifications on the map of Ceylon in Isaac de Graaf's "Atlas Amsterdam" (ca. 1700). Distinctly colored toponymy was another option. In the overview maps in De Graaf's atlas, names of areas or cities with which the Verenigde Oost-Indische Companie (VOC) was trading would be colored black while all other names would be rendered in red.

By 1650 drainage maps (*waterschap* maps, produced to help maintain the *waterschappen* [water management boards]) were a well-established map type. They showed the explicit delineation of polder areas (each with its own statutory ground water level) with all the construction works to either keep the water from coming in or to mill it out and the infrastructure of canals, locks, and mills. These maps helped plan small, specific technical works or large projects such as the drainage of lakes or sea inlets and their allotment. Marc Hameleers (1991) distinguished drainage maps for administrative and judicial purposes, to illustrate requests and permits, as well as large-scale working drawings. A planning map would, for example, show the location of proposed dikes and windmills that would be needed to drain the lake. If drainage efforts were not realized, storms could cause lakes to expand and grow ever more threatening, and these were mapped in a way now called dynamic mapping.

For inland trade, the Rivers Rhine, Meuse (Maas), and Scheldt played an essential role, and in the eighteenth century their changing depths became a major concern, especially in the many channels through their common delta. In order to keep their depths up to standard, river flow redistribution works were envisaged, and for planning purposes the drainage expert Cruquius designed river maps—the first to contain printed isobaths (without fixed intervals)—for the Merwede River, a branch of the lower Meuse. Apart from detailed isobathic representation, Cruquius also pioneered the use of longitudinal sections and cross-sections and combined them with his maps in order to provide a better three-dimensional image (see fig. 190). Cruquius's colleague Melchior Bolstra, in his map of the Meuse River (1739), used fixed and systematic intervals for his isobaths, an improvement over Cruquius. He also added tidal diagrams (see fig. 34). As the scale of human intervention increased, new analytical techniques were needed (fig. 801).

From 1640 onward, an extensive network of ship canals was built in the northern and western provinces to accommodate towboats. For maintenance purposes, maps of the various routes were produced showing the halting places. Towboat operations for passengers and minor freight generally were financial successes, perhaps another reason for mapping them. One example is the map of the towboat route from Meerkerk to Gorinchem in southeastern Holland (1777) (The Hague, Nationaal Archief, Collectie Ersting, 4.ZHPB4, inventory nr 178).

Most manuscript precadastral maps produced in this period show a subdivision of land use into pasture, arable land, orchards, and some specific crops like madder, tobacco, or hemp. The colors usually imitate nature with greens for pastures and yellows for arable land. A manuscript map by Langedijk for the Staten van Holland shows the extent of the arable land in Schellinkhout, a municipality close to Enkhuizen on the coast of the former Zuiderzee, and was produced to reevaluate the tax assessment based on the arable acreage ("Kaart van de zaadlanden gelegen in den ban van Schellinkhout," dated 4 December 1603, The Hague, Nationaal Archief, ARA Hingman no 2500). Another example is the manuscript map of the Gooi area depicting heathland, pastures, bogs, and forests ("Kaart van Gooiland met de heiden, weiden, uitgegraven veenen, bosschen, etc.") produced by Justus van Broeckhuysen in 1709 (ARA Hingman no 2592).

Some influential examples of celestial mapping were produced in this period. The first to put the various star constellations in relation to each other on maps of the total sky was Johannes Bayer, who published his *Uranometria* in 1603 based on observations by Tycho Brahe. A major Dutch-German contribution was the *Harmonia macrocosmica* by Andreas Cellarius, published by Johannes Janssonius in 1660 in Amsterdam. Cellarius's engravings of the various constellations and cosmographic views were renowned. His map of the southern celestial hemisphere contained the names given to constellations by the early Dutch explorers, such as Cornelis de Houtman, when they sailed south of the equator.

More in line with the general trends of contemporary thematic cartography is Cruquius's visualization of his computations about the visibility of the 3 May 1715 eclipse, where lines indicate the magnitude of the eclipse (fig. 802). It is drawn on a map by Guillaume Delisle that was published by Petrus I Schenk.

Finally, during this period ecclesiastical maps, language maps, and urban planning maps were produced. An ecclesiastical map by reverend Willem Albert Bachiene, published in his four-volume reference work *Kerkelyke geographie der Vereenigde Nederlanden* (1768–73), shows the administrative subdivisions of the Dutch Reformed Church. The towns and cities where synodical meetings were held are indicated with special symbols.

Language maps that showed the actual distribution of spoken languages had been produced since the sixteenth century. The *Kaart van oud Europa, tot verstand van het XXI.ste boek van den geest der wetten*, drawn by Johann Christoff de Roeder in 1786, inspired by the work of renowned linguist Lambert ten Kate, was the first socially oriented thematic map in the Netherlands, dividing languages into Slavonic, Cimbric, Teutonic, and Gallic by means of colored borders.

The many extensions of Dutch towns and cities in the seventeenth century, such as the one planned for Am-

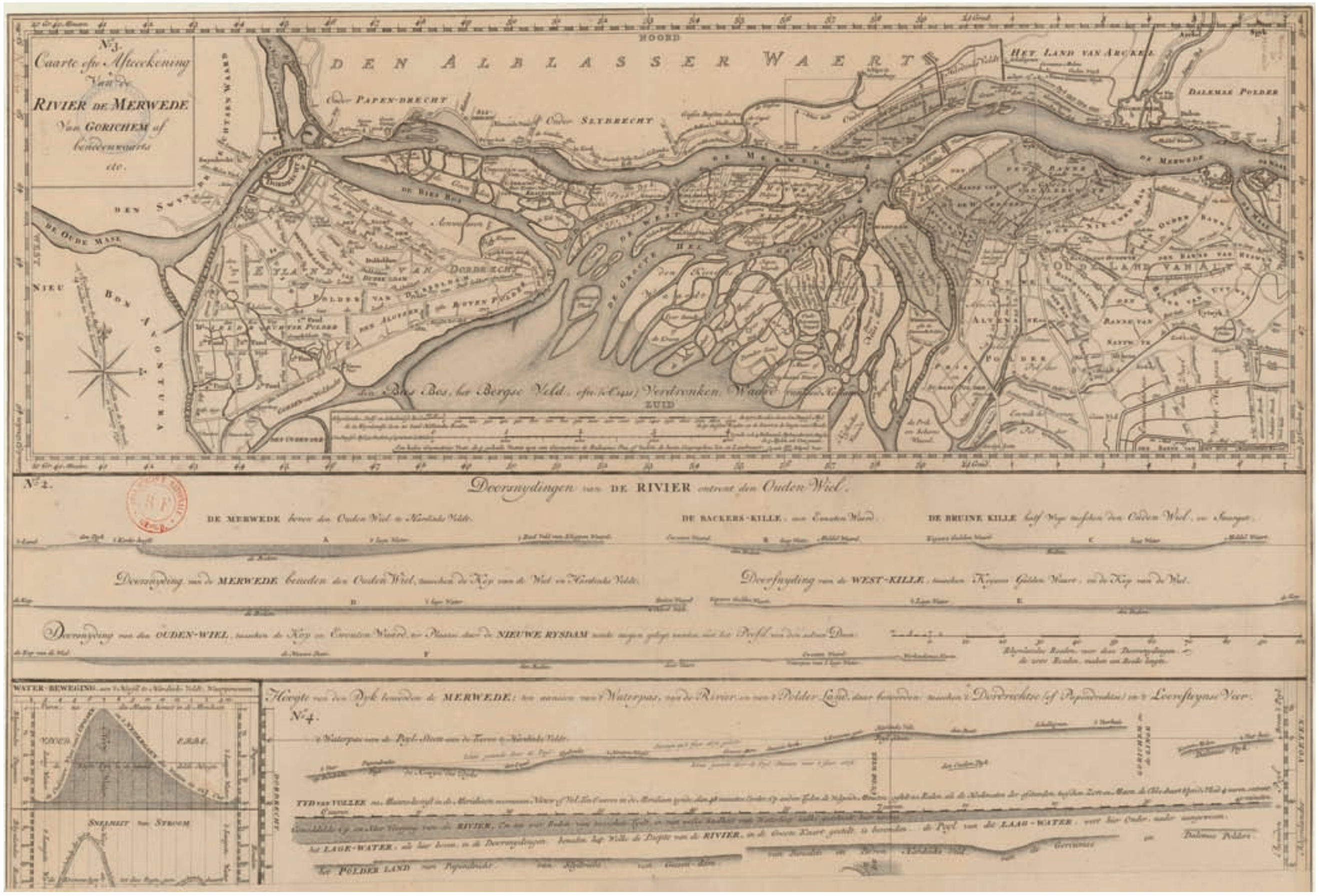


FIG. 801. NICOLAAS SAMUELSZ. CRUQUIUS, OVERVIEW MAP OF THE MERWEDE RIVER. The complex assemblage of data needed to manage water in the Netherlands is displayed. This map was published in conjunction with Cruquius's large 1729–30 detailed map of the river (see fig. 33); the extent of the two sheets of that map are outlined on this map. The several elements of the work include the map itself (*N°-3. Caarte ofte afteeckening van de rivier de Merwede van Gorichem af benedenwaarts, etc.*, at ca. 1:50,000), a series of cross-sections (*N°-2*), graphs of the ebb, flow, and speed of the tide, profiles of the river and polders (*N°-4*), and a temporal plot of high and low water levels recorded from June 1729 through March 1730.
Size of the original: 53 × 64 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge DD 2987 [4650]).

sterdam in 1658, called for maps that would help in laying out the canals, building up the areas in between, and ramming in piles to prepare the marshy area for construction sites. As a large capital outlay was needed to develop the building lots, the sales had to be planned in advance, and to this end maps were produced as well. Overview maps such as the one by city architect Daniel Stalpaert for Amsterdam and printed by Nicolaas II Visscher in 1662 (*Amstelodami veteris et novissimæ vrbis accvratissima delineatio*) put the many new urban lots available in perspective. In the same vein, fortresses were designed. In 1598 the Frisian academy at Franeker started a program for engineers, and in 1600, the University of Leiden did likewise. At Leiden the program, developed by Simon Stevin, consisted of courses in mathematics, applied geometry, fortification, hydrologic engineering, and surveying. Hydrological engineering enabled the engineers to devise inundations and thus deny invaders access to the rich Dutch cities in the western part of the country. Maps were drawn to show the areas to be inundated, presupposing leveling activities. Similar to the drainage mapping activities in this period, the basis also was laid for the systematic surveying and thematic map production after 1800.

FERJAN ORMELING

SEE ALSO: Administrative Cartography: Netherlands; Netherlands, Republic of the United

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FIG. 802. SOLAR ECLIPSE MAP DRAWN BY NICOLAAS SAMUELSZ. CRUQUIUS. Manuscript additions, "Meetkūnstige-Vertooning van de grootheijt, de tijdt van 't midden begin en eynde der zon-eclips vanden derden meij 1715," to a printed map of Europe by Guillaume Delisle published by Petrus I Schenk in 1708 in Amsterdam. The additions predicted the 1715 eclipse. The degree of coverage is indicated by inches in the margin, twelve inches denoting total coverage. Size of the original: 45 × 57 cm. Image courtesy of the Universiteitsbibliotheek Amsterdam (Bijzondere Collecties, OTM: HB-KZL 102.07.11).

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***Thematic Mapping in Poland.*** The generally high mortality rate of Polish maps in the period between 1650 and 1800 affected some thematic maps, such as the still-unlocated *Hydrographia Sarmatica* from the early eighteenth century, a work analogous to Philipp Heinrich Zollmann's *Hydrographia Germaniæ*, published by Johann Baptist Homann before 1712 (see fig. 296) (Piasecka 1970, 98). More generally, Poland's repeated wars and unsettled political conditions were unfavorable for the kinds of systematic investigation that might have led to the construction of thematic maps. The few such maps that were made were all undertaken by foreigners; their common hallmark was the frequent misspelling of Polish toponyms.

Thus, the French polymath Jean-Étienne Guettard took advantage of his residence in Poland as physician to the French ambassador (1760–62) to investigate the natural history of the region; in addition to taking meteorological observations, he examined mines and collected mineralogical information (Tarkowski 2004; Wójcik 1992). On his return to Paris, Guettard published a series of memoirs on his researches, including a two-part essay on Poland's mineralogy, complete with a monochrome map in the second part (Guettard 1764). For his *Carte minéralogique de la Pologne*, Guettard took a standard small-scale geographical map of Poland at about 1:4,400,000—showing rivers, the administrative boundaries of the voivodeships (palatinate), and localities, together with the Carpathian Mountains in relief—and added a combination of shading and letters to show several geological bands and mineralogical deposits of economic interest, which included the sand zone, marked by stippling, and the saline (salt) zone, marked by vertical hatching. In the essay he also distinguished and characterized the zones of marlstone, slate, and metallic ore-bearing shale, but he did not show the limits of the marl and shale zones on the map.

The first hydrographic map of Poland was made in 1785 by Charles (Herman Karol) de Perthées, a French colonel and the court geographer of King Stanisław August Poniatowski. The original manuscript is lost, as is a copy of this map made in the same year by Grzegorz Czapski at a scale of approximately 1:1,600,000 and titled "Hydrografia generalna Królestwa Polskiego" (Piasecka 1970, 108). A further manuscript does, how-


FIG. 803. MANUSCRIPT HYDROGRAPHIC MAP OF THE KINDOM OF POLAND, "MARA HYDROGRAFICZNA KROLESTWA POLSKIEGO," 1785. Size of the original: 63.5 × 79.0 cm. Image courtesy of Archiwum Główne Akt Dawnych Collection, Warsaw (AGAD sygn. 96.1).

ever, survive—"Mara [*sic*] hydrograficzna Krolestwa Polskiego"—which was probably copied by a foreigner given the spelling mistakes in the map title and toponyms. The drainage basins are shown in separate colors (fig. 803). The map's rich hydrographic content corresponds to the number of details typically shown on modern maps at 1:500,000. This map was later printed in 1809 by Jan Konarzewski in Paris, as *Carte hydrographique de Pologne*. Also in 1785, Perthées set an inset of a smaller and adequately simplified version of his hydrographic map in the margin of a detailed map of two canals in Polesie (*Carte servante a montrer la destination de deux canaux enterpris en Lithuanie*). The canals had recently been opened to navigation. The majority of detailed maps of rivers and canals in the years 1764 to 1795 were made as ordered by the committee of the Crown treasury, Komisja Skarbowa Koronna. The activity of the committee was directed at, among other things, adapting the largest number of rivers for navigation (rafting and transportation of commodities) and building canals (Piasecka 1970).

PAWEŁ KOWALSKI

SEE ALSO: Poland

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***Thematic Mapping in Russia.*** Maps and plans in eighteenth-century Russia contained a variety of geographic, military, industrial, and demographic information. The three most important subjects for thematic mapping were waterways, mining, and forests.

One of the chief interests of Russian emperors in the first half of the eighteenth century was the creation of river transport systems to link the empire's two largest cities, Moscow and St. Petersburg. After the capital moved to St. Petersburg in 1712, Peter I and his successors sought to connect markets on the Baltic Sea with those on the Caspian and the Black Seas and into the interior to the mineral-rich lands of Siberia, the Urals, and Altai. To create navigable waterways, the river systems of Vyshniy Volochek, Tikhvin, and Mariinsk were studied, charted, and reconstructed.

Peter I entrusted exploration of waterways in northwest Russia to the English hydraulic engineer John Perry, who later explained that his commission was to explore three routes from Lake Ladoga to the Volga. He was to "trace the several Rivers, as they fall into each other, to the Places where, at the Heads or first Springs from whence they take their Rise, they come nearest, and are most commodious for a Communication to be made" (Perry 1716, 41). Although Perry's sketches do not survive, a draft plan listed in Peter's map collection, titled "A Drawing of Many Rivers and Lakes Showing Which Flowed into Which" (*Istoricheskiy Ocherk* 1961) is very likely Perry's work on this topic.

A large number of period charts describe the water system of Vyshniy Volochek, whose main hydraulic technical installations (the Tver' Canal and locks near the Tsna River) were built between 1703 and 1708. In the second half of the eighteenth century, hydraulic engineering began on the Tikhvin water system, which included the Rivers Syas, Tikhvinka, Volchina, Bystraya Sosna, Somina, Lit', Kolp, and Chagodoshcha. During the same period, charts and plans of the Mariinsky Canal, the precursor to today's Volga-Baltic Canal, helped complete the network by the early 1800s. Labor on these water systems was greatly assisted by earlier prospecting work that had revealed a considerable section of northwest Russia, including the Rivers Sheksna, Kovzha, Vytegra, Svir', and their tributaries.

Naturally, the largest waterways generated the most attention. The Dnieper, the Volga, and the Don were among the earliest rivers charted. The "Atlas reki Volgi ot sela Kimry" (St. Petersburg, Rukopisnyy otdel Biblioteki Rossiyskoy Akademii Nauk, Kartograficheskoye Sobraniye, no. 692), compiled from surveys carried out by Pëtr Pronchishchev and Pëtr Avraamovich Chaplin in 1735–36, was highly accurate for its time and circulated for at least thirty years. The surveys were performed under Admiralteystv kollegiya supervision using standard (for the time) naval hydrographic techniques. These entailed fixing the latitude and longitude of key points along the river, latitude by observations of the sun's altitude at noon and longitude by dead reckoning, and locating topographical details by intersecting sight lines from those key points (Postnikov 2001, 34).

Large-scale general Russian cartographic projects were typically organized in a highly centralized fashion. But waterway charting operated on a different principle. There was no national administration, and no generally agreed upon method was employed. Virtually all the surveys and reconstruction of waterways in European Russia were ordered by the governors of those *guberniyas* where water transport played an important economic role. Not until the 1790s did centralization begin. The department of water transportation, Departament vodnykh kommunikatsiy, founded in 1798 on par with the other senate departments, set up a drawing office and a Depo kart for all hydraulic charts of the empire. One of the department's early publications, *Gidrograficheskaya karta chasti Rossiyskoy imperii* (1801), 1:4,200,000 on five sheets, reveals the achievements of Russian hydraulic engineers in improving the water transport network over the course of the eighteenth century.

The main objective in the state-sponsored study of rivers in European Russia was to link the economies of widely separated regions (mainly north and south), for which hydraulic engineers eventually carved new pathways. In Siberia, however, the main objective was to explore major rivers, which were still the only routes leading into remote taiga regions. In its reconnaissance and exploratory work, the Akademiya nauk prepared many descriptions and surveys, some of which proved especially useful on the Second Kamchatka Expedition (1732–42). This and subsequent expeditions in the 1760s and '70s, involving scholars across disciplines, procured not only cartographic and geographic knowledge, but geological and mineralogical as well.

Russia's vast mineral wealth was an important object of exploration and development. Maps of the mineral resources in the Urals multiplied from the 1720s on and helped to launch Russian mining industries. Early organizers like Vasiliy Nikitich Tatishchev and Georg Wilhelm de Gennin established a pattern for maps and plans with mining-related themes: land plots allotted for mine works, mine operations and shaft cross-sections, mining factories (some went bankrupt or burned down), prospecting, and mining districts and towns. After 1750, government authorities viewed such cartographic material as essential to mining administration, as shown by the "Zavodskoy atlas" (1777–78), which contains nineteen maps of state factories and one general map (fig. 804). Each factory, with the exception of those at Nerchinsk and Olonets, had its own map.

Occasionally, private industry sponsored its own survey work. The Nerchinsk Expedition of 1797–1800, for example, was organized by the Kolyvano-Voskresenskiy mining factories in Altai to survey extensive territories around Lake Baikal and river basins that included the Selenga, Angara, and the Upper Tunguska. Altai geologist Pëtr Koz'mich Frolov and geologist-cartographer N. E. Karelin led the expedition. Frolov's detailed instructions were remarkable for their time (Postnikov 1989, 186–87). These instructions included detailed recommendations on surveys of rivers' courses, depth measurements, and descriptions of coasts and mineral deposits that could be found along them. All of the surveyors had been ordered to pay special attention to forests on the banks as very important natural resources for the development of the mining industry. A hydrographic atlas of the expedition survives in the Gosudarstvennyy arkhiv sotsial'no-pravovoy dokumentatsii Respubliki Altay, Gorno-Altaysk. Titled "Karta chasti ozera Baykala" (1797–1800), the atlas contains fifty-six sheets of large-scale charts, as well as a comprehensive chart of part of Lake Baikal (1799), which identifies, at a scale of 10 versts to the inch (1:420,000), the routes taken and the location of minerals—granite, sandstone, and lime—discovered in outcrops along the river banks. Copies of the Lake Baikal chart from the Nerchinsk expedition are located in the Rossiyskaya gosudarstvennaya biblioteka, Moscow. The copies record the depth of Lake Baikal at between 1,100 and 1,234 meters, according to measurements taken by expedition members S. Smetanin and Ye. Kopylov in 1797 by means of sounding using a weighted line (Postnikov 2001, 34). The present-day estimate of 1,742 meters makes it the deepest lake in the world.

In addition to waterways and mining, forests provided the third important theme for mapping in eighteenth-century Russia, reflecting the crucial role of timber in the construction of the Russian fleet (of increased importance beginning with Peter I) as well as the ever-present need for fuel. In 1703, Peter I ordered a survey of all riverside woodlands. Empress Anna Ivanovna went further, calling for all regions with usable ship timber to be surveyed and mapped with notations indicating the location of timber, how far it stood from rivers, and whether it could be transported to and floated down them. The result of government decrees for the surveying and mapping of woodland was the "General'noy atlas sochinyonnoy iz imeyushchikhsya pri Admiralteyskoy chertyozhnoy raznykh godov opisey vsyakogo roda Iesam 1782 goda," a manuscript atlas with fifty-two maps, the earliest titled "Karta Kazanskoy gubernii" (1733) of Kazan *guberniya* from a survey by Vasiliy Shishkov and Ivan Shishkov (fig. 805), and a later one of Kazan that shows specific tree species.

Much of the surveying work in forests was undertaken by the Admiralteystv, which stood to benefit significantly from the results. The methods used in surveying forests differed little from those used in the land and river mapping done at the time. In 1798, all woodlands outside landowner estates were officially transferred to the Admiralteystv, which managed the work under the newly founded forestry department, Lesnoy departament.

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SEE ALSO: Russia

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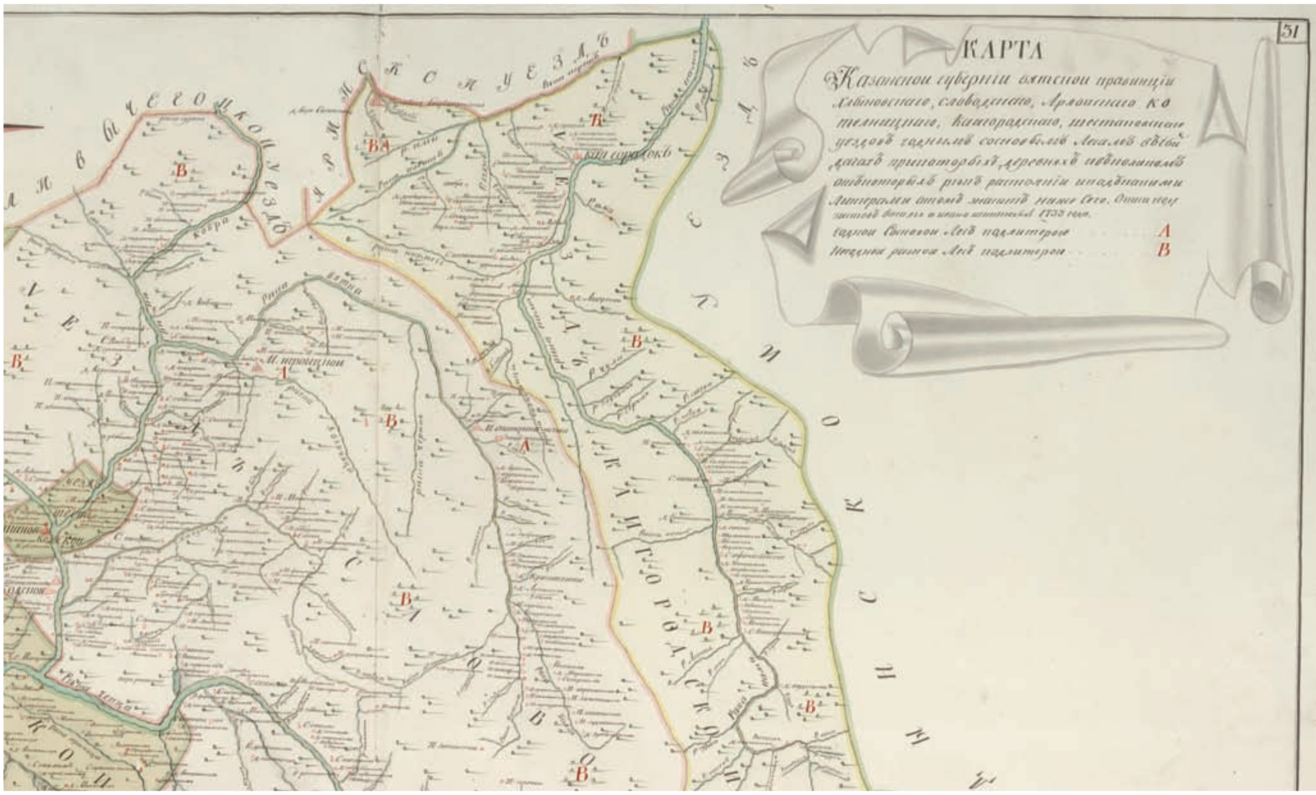


FIG. 805. DETAIL FROM MANUSCRIPT MAP OF FORESTS AND WOODLANDS. From "Karta Kazanskoy gubernii . . . opisi geodezistov Vasiliya i Ivana Shishkovykh" (1733), in the "General'nyy atlas sochinyonnoy iz imeyushchikhsya pri Admiralteyskoy chertezhnoy raznykh godov opisey vsyakogo roda Iesam 1782 goda." This map of the Kazan *guberniya* from a survey by Vasiliy Mikhailovich Shishkov and Ivan Shishkov distinguishes two areas: a good pine forest designated by the letter A and a worthless mixed forest designated by the letter B.
Image courtesy of the Rossiyskaya natsional'naya biblioteka, St. Petersburg (Manuscript Department, Hermitage Collection, f. 885, d. 610, map 31).

niya malykh rek evropeyskoy territorii rossii." *Voprosy Geografii* 118:55–77.

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***Thematic Mapping in Spain.*** Thematic maps were rare in Spanish cartography prior to the nineteenth century. Their appearance is linked to the new technical and

(*facing page*)
FIG. 804. MANUSCRIPT MAP OF THE EKATERINBURG STATE PLANT IN THE SIBERIAN PROVINCES, LOCATING INDIVIDUAL MINES. Map number 2 from the "Zavodskoy atlas ili mesto polozheniya vsem kazennym i partikulyarnym zavodam Rossiyskoy imperii" (1777–78), which depicted the location of all state and private factories in the Russian Empire.
Image courtesy of Rossiyskaya natsional'naya biblioteka, St. Petersburg (Manuscript Department, no. 110).

economic conditions under which the Industrial Revolution developed. This event encouraged the deeper knowledge of territory and its resources, which led to the appearance of geological, agronomical/agricultural, forestry, hydrological, and demographic/population maps. Nonetheless, some advances in thematic cartography did develop during the eighteenth century. In order for this to happen, some preconceived notions about the value of maps had to be surmounted. Kings, princes, and others in power believed that maps containing thematic details of their territories would reveal the weaknesses or poverty of their country, or, if the country was rich, such maps might attract the attention of their competitors. The absence of thematic cartography during this period was also due to the desire to hide certain privileges pertaining to the ownership of land and, more generally, of its primary resources. This view was corroborated in Spain when Zenón de Somodevilla y Bengoechea, marqués de la Ensenada, planned for the creation of a cadastre, which presupposed the meticulous measurement of the territory and an inventory of the land and its resources. The resulting data would have provided a foundation for the development of thematic mapping in Spain. However, very powerful sectors within Spanish society were opposed to the cadastre, including the Catholic Church, which feared that its immense properties would be represented and exposed. The enlightened friar, Martín Sarmiento, advisor to noteworthy officials of the Spanish administration, wrote a proposal for a *descripción geográfica de España*, opposing the inquiries of the cadastre and supporting a superficial and synthetic cartography (Reguera Rodríguez 2006, 342–58). Such was the official cartography produced by Tomás López during the second half of the eighteenth century.

Ensenada fostered other reforms while he was head of government between 1743 and 1754. In 1748 a forest law was passed, "Ordenanza para la conservacion y aumento de los montes de Marina en las provincias y distritos," covering peninsular Spanish territory (*Novísima recopilación* 1805, L. VII, T. XXIV, Ley XXII [3:532–43]). The procurement of timber for the navy forced the state to control forests, giving precise instructions to the chiefs of the maritime departments to inventory the timber-worthy trees of their provinces. These inventories were to include the extent of the forests, the species, the age of trees (young, mature, and old), and the locations of new plots of land that could be replanted. In each province, the engineer in charge of the study produced a geographical map of towns and forests and their main wood lots and extensions (fig. 806). Those for the maritime Andalusian provinces, produced between 1748 and 1765, were published in the *Atlas histórico-forestal de Andalucía, siglo XVIII* (Gómez Cruz 1991). Centered on each sheet was a map showing the topography of each province and emphasizing the presence of vegetation; in the margins of each sheet was information on the type of trees included—the principal species being poplar (*Populus*), pine (*Pinus*), two types of oak (*Quercus*), ash (*Fraxinus*), and chestnut (*Castanea*)—and their developmental stages—young, mature, and old. Statistical information contained on the map included a summary caption of forests of the province and a summary of the socioeconomic interest regarding seafaring workers and the number of commercial and fishing vessels. In only one instance, that of the province of Ayamonte, forestry statistics include "plantings ordered"—that is, the reforestation. This was the most contentious aspect of the study and of the application of the law, since the replanting in which the royal navy was interested removed pastureland and cropland from livestock raisers and farmers in local towns and villages.

A number of maps containing specific information on forests—and whether their timber was to supply artillery or blacksmith factories—were produced for other regions of Spanish territory. However, none of them was similar to the maps of the southern provinces, whose drier Mediterranean climate meant greater difficulties in forest development.

By the mid-eighteenth century, Spanish officials began to regard mineralogy as a more serious and systematic body of knowledge. The Irish naturalist William Bowles was hired to direct the Gabinete de Historia Natural and the Laboratorio de Química de Madrid. Bowles traveled throughout the entire Iberian Peninsula to discover and inventory its mineral wealth. Among his noteworthy works, which pioneered the study and cartography of Spanish geology, are "Memorie sur la Mine d'Almaden" (1755, manuscript), "Some Observations on the Country and Mines of Spain and Germany" (*Philosophical Transactions*, 1766), and his primary contribution, *Introducción a la historia natural, y la geografía física de España* (1775) (Ribera i Faig 1988, 52–55). These studies foretold the importance that inventories and cartographies of mineral resources would have at the onset of the nineteenth century.

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FIG. 806. MANUSCRIPT MAP OF THE PROVINCIA DE MARINA DE SEVILLA, 1754. "Carta geographica, o Mapa gerl, de los pueblos, montes, y svs principal[s] arbole[as], y extencion[s], justicias, gvardas" by José Espelius, Ingeniero Extraordinario de Su Majestad, ca. 1:125,700. Size of the original: 111 × 122 cm. Image courtesy of the Biblioteca Nacional, Madrid (MR/42/367).

***Thematic Mapping in Sweden-Finland.*** Thematic mapping in Sweden-Finland reflected the economic concerns of a very militaristic state. Mining and metallurgy assumed an exaggerated importance in mid-seventeenth-century Sweden because they were so essential to supplying weapons and equipment. The natural resources of copper and iron predominated, while the silver output was modest. The four-hundred-year-old Stora Kopparberg (Great Copper Mountain) in Falun remained the most impressive symbol of the Scandinavian mineralogical scene. It dominated the Bergslagen region in central Sweden with the Sala silver mine in the same district. The many place-names with the suffixes *-hyttan* (furnace site) and *-fors* (a waterfall site with a forge) indicate the presence of iron mines. During the eighteenth century, iron mining became the main industry in Sweden with an outlier in southwest Finland and, later, in Lapland. This entry focuses on the processes of mapping mines as a highly specialized example of thematic mapping.

During the sixteenth century, the mines were the responsibility of the Crown lands judiciary board, Kammarkollegium. But in 1630, a new government authority was established, which after 1649 was called Bergskollegium (board of mines). It was stated in 1736 that it had "all the mines in the realm, with their appurtenances, under its control and charge" (quoted in Lindqvist 1984, 96).

Mine surveyors originally surveyed mine sites at ground level, naturally using the same instruments as field surveyors. In 1594, Sweden acquired its first qualified mine surveyor from Germany to deal with construction and water problems besetting the Sala silver mine and later the Stora Kopparberg mine. His title was *markscheider* (still used in the twenty-first century), borrowed from the German *Mark* (border, boundary line), *scheiden* (divide).

Subordinate to the executive board of the Bergskollegium (consisting of a president [after 1713], two *bergsråd* [mine counselors] and five assessors) was the central administration in Stockholm, consisting of nine sections, with about twenty officials. Four of these sections were technical: the Proberkammaren (chamber of assaying); two Laboratorii, *chemicum* and *mechanicum*; and the Ingeniörsstaten (engineer corps), consisting of the *markscheider,* his assistant, and *lantmätare* (land surveyors).

The local administration consisted of nine to (after 1715) eleven mining districts, each headed by a *bergmästare* or mine inspector. The influence of German practice is reflected in the titles of other officials in addition to *markscheider*: *bergshauptman* (a mine inspector; from *Haupt* [head]) and *geschworner* (second in command and responsible for making sure rules were followed; from *schwören* [to swear]). The largest numbers of officials were in mining districts 1 and 2, in Falun and Sala, and the smallest in districts 10 and 11, Lapland and Finland. In 1751, another post, *övermasmästare*, was created for production control. Its first holder was the iron chemist Sven Rinman. This office was discontinued in Finland in 1809 and in Sweden in 1856.

From the chemical laboratory flowed reports on new discoveries, which were promptly published in the *Kongliga Svenska Vetenskaps Academiens Handlingar*, founded in 1739. Thus international scientists were made aware of developments in Swedish mineralogy. In 1788–89, Rinman published his *Bergwerks Lexicon*, which became a standard work on the mining industry.

Since the Middle Ages more or less the same method of surveying (first described in chapter 5 of Agricola's *De re metallica,* 1556) had been employed in German and Swedish mines. It suited the shallow and narrow galleries that were common in the Erzgebirge and Harz regions of Germany and was even easier to use in Swedish mines, where assiduous fire-setting (splitting the rock by lighting wood fires against it) had created wide galleries.

In the German method, the *markscheider* took plumb lines down the shaft, together with his "compass"—not the magnetic kind, which could be disturbed by the proximity of iron ore, but a square or round piece of wood that had concentric grooves filled with differently colored wax. Measurement started from two fixed points and the "compass" was placed on a stand at the apex of the angle to be measured. As the lines were pulled from the fixed points, grooves and angles were scribed into the wax. When a series of triangles had been measured, the *markscheider* collected the lines, climbed out of the mine, and then replicated his findings in a cleared area on the surface (called the surveyor's field), using the marks on the "compass" to set out the angles and posts to represent the corners. This life-size "map" was then drawn on paper and marked with the degrees noted down in an anglebook. The measurement chits were then gathered into an amalgamation sheet from which a draft version was produced. The final map was drawn from this, generally on a scale of 1:500. Through continuous improvements by the *markscheider*, the maps became technically more useful. A grid of 10 × 10 fathoms was introduced, the altitude to the roof was entered, the scale became 1:800, and fixed points were established in the mine and inserted on the maps. In an instruction from 1671, it was stipulated that the *markscheider* should each year map all changes in the mine and draw a completely new map every third or fourth year. Most mine maps remained in manuscript.

The Bergskollegium maintained an apprenticeship system for young men wishing to gain experience in the mining industry. On average, three or four apprentices (*ausculators*) were admitted each year. After 1635, when gunpowder came into use as a substitute for fire-setting with timber, fortification officers with military experience of sapping and mining began to be admitted to the Ingeniörsstaten.

In 1629, Olof Hansson Swart (ennobled Örnehufvud) produced a map of the Stora Kopparberg mine (Mead 2007, 1797–98 [fig. 60.15]) that was to set the pattern of Swedish mining cartography. He had been confronted by a large open pit and, deeper down in the mine, by wide galleries. Basically he mapped in the German way, but at suitable levels in the mine he aggregated his readings to form five separate sheets representing five levels of the mine. The shafts connecting the levels were marked by holes cut into the parchment or paper. In this way, starting with the ground-level sheet, one could leaf one's way downward to gain an illusion of the increasing depth. No elevation figures were given, but it is clear from the first "daylight" sheet that one of the horse-driven winches formed a fixed point on the surface. This horizontal mode of cartography became a distinct feature of the Swedish method (fig. 807).

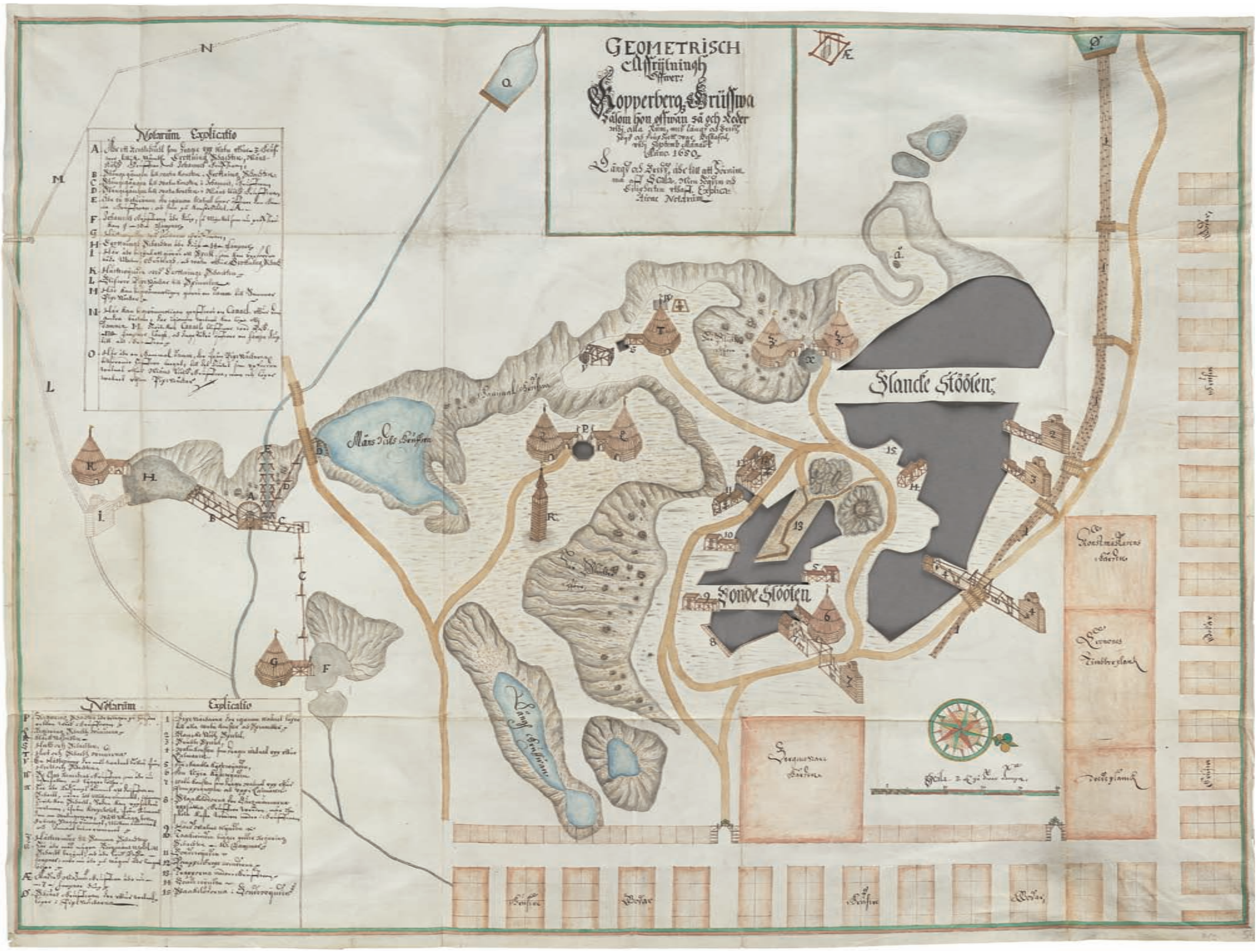


FIG. 807. THOMAS CHRISTIERSSON HEDRAEUS, "GEOMETRISCH AFFRIJTNINGH ÖFFWER KOPPERBERGS GRÜFFWA," 1650. Hedraeus was a *markscheider,* and this is the upper (ground-level) sheet of his map of the Stora Kopparberg mine with holes for the shafts. Seven other sheets show the underground levels of the mine. Manuscript map on parchment; ca. 1:520.

Size of the original: 66.5 × 89.5 cm. Image courtesy of Kungliga biblioteket, Stockholm (KoB 54 nr 478).

With the German method, all the galleries and workings in the mine were plotted on one and the same sheet, regardless of their level. These ground plans showed the boundaries of the mining area and all the tunnels and galleries, but unlike the Swedish method with a different map for every horizon or level, they relied on different colors and shadings to indicate depths—darker if tunnels and galleries were higher, paler if they were lower. A separate profile drawing showed the depths and angles of the shafts.

The ground surface, however, was realistically depicted in an oblique perspective, with landscape, buildings, and people working. Down in the mine, galleries were also shown as views, so that fire-setting or devices for raising ore to the surface and for removing water, for example, were visible. Artistic mapmakers often used these perspective views as an opportunity for decoration.

Swedish *markscheiders* who went abroad in the seventeenth and eighteenth centuries often commented on how confined the mine workings were there. In the account of his travels in 1691, Hans Ranie described a worker clad only in headgear and leggings, crawling along a gallery with a little cart lashed to one foot. They also found that mine maps abroad lacked the extremely true-to-life quality that characterized their own work. Ranie's works (in the archives of Sala and Falun mines and in Riksarkivet, Stockholm) are full of dramatic descriptions of life in the mines.

The most prominent *markscheider* in artistic terms was Johan Tobias Geisler, who wrote the first Swedish handbook on mine mapping (Kungliga biblioteket, Stockholm, MS X 280). In the first Swedish handbook of mine mapping to be printed, that of Leonhard Horneman (1802), Geisler was frequently cited, even if many of his methods were by then deemed obsolete. Nevertheless, Horneman still recommended the old tradition of cutting holes into the level sheets to signify vertical shafts. This practice was discontinued later in the nineteenth century. In 1718, Geisler drew a beautiful mineral map of Stora Kopparberg as a gift for the future King Fredrik I (now in the Astronomisch-physikalische Kabinett, Kassel, Germany). On the level sheets in this volume, Geisler combined the German and Swedish methods of mapping.

The first systematic geological investigations in mines were carried out in the 1730s. The *auscultator* (later *bergsråd*) Daniel Tilas proposed in 1738 that a geological key map of Sweden together with special and detail maps should be drawn up. His intention was to publish a history of the mineralogy of the Swedish realm. In 1746, Tilas recommended that, in addition to surveying the mine and its veins of ore, the *markscheider* should also indicate minerals by means of coloring. Tilas suggested using crimson to indicate gold, azure blue for silver and lead, Spanish green for copper, and dark blue for iron. In this way, a mine map would be given geological content. In the main, Tilas's ideas were accepted and eventually, as the knowledge of rocks increased, coloring of mineralogical maps to show geological details became common. The first official mineral maps of this type were hand colored, but in 1836 they were published as chromolithographs. Tilas's work ended when his private papers were destroyed by a fire in 1751, but it was later taken up by Samuel Gustaf Hermelin and other colleagues in the Bergskollegium.

Hermelin had qualified in mining and was appointed *bergmästare* in 1770. Between 1782 and 1784, he journeyed through Germany, the Netherlands, and France to North America to study mining science and commerce. Back home, he devised plans to draw up a geographical description with maps of the country. He had financial interests in the iron industry, particularly in the Lapland ore-fields, and decided to intensify the mapping work there. He found assistants among the *bergmästare*, *markscheiders,* and *lantmätare* at the Bergskollegium. Between 1795 and 1797, he published four engraved county maps of northern Sweden and part of Finland. Although they showed mining districts, they were in fact topographical maps.

In November 1796, Hermelin took on as an assistant the Finn Carl Petter Hällström and made sure that Hällström became a teacher at the Bergskollegium. Hällström did not draw any mineral maps, but instead became the main contributor to the so-called Hermelin atlas, *Geographiska kartor öfver Sverige*, published in 1818 with thirty-three engraved topographical maps.

In the 1730s, the Swedish export of iron amounted to 75 percent of the total export value of the country. But then a fall in prices and exhaustion of old ore reserves and of charcoal supplies forced ironmasters to seek additional means of support. In 1747, Jern-Kontoret (literally, The Iron Office, and in operation in the twenty-first century as the Swedish Steel Producers' Association) was founded as a trade association. It also promoted study tours to foreign mining industries. Since 1817 *Jernkontorets Annaler* has been the main Swedish journal for the science of mining—including mine surveying and mapping.

ULLA EHRENSVÄRD

SEE ALSO: Sweden-Finland

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***Thematic Mapping in Switzerland.*** The first thematic maps of Switzerland were historical maps, first made in the sixteenth century. In the seventeenth century archaeological maps and in the eighteenth century maps with scientific content, especially mineralogical maps, were created as well.

The map *Nova Rhætiæ atq[ue] totivs Helvetiæ descriptio* by Aegidius Tschudi (1560), which is identical to one from 1538 that no longer exists, already constituted a partially historical map, as the borders of ancient peoples are depicted and Latin geographic names dating from antiquity and the Middle Ages are supplied in addition to the contemporary names and borders. *Die vierdt Landtafel haltet inn die alt Helvetiam Julij Cesaris* in Johannes Stumpf's Swiss chronicle (1548) also provided geographic names from antiquity. The map largely follows Tschudi, but depicts less content. Based on the 1585 map *Helvetia* by Gerardus Mercator, Philipp Clüver published the first purely historical map of Switzerland, *Helvetiæ conterminarumque terrarum antiqua descriptio*, which depicts ancient features without supplying modern place-names. It was first published in his *Germania antiqua* (1616) and until 1729 was reprinted time and again in partially modified form, especially in many editions of his *Introductio in universam geographiam* (Van der Heijden 2002). The remaining eighteenth-century domestic and foreign maps of Roman Helvetia only contain marginal modifications when compared with Clüver's map. Only the *Carte pour l'histoire ancienne de l'Helvétie* (1749), published in *Mémoires critiques, pour servir d'éclaircissemens sur divers points de l'histoire ancienne de la Suisse* by Charles Guillaume Loys de Bochat, distinguishes itself by virtue of originality. He sketched Roman streets onto an otherwise completely modern map.

The first archeological map of Switzerland is the plan *Geneve ancienne* in the *Histoire de la ville et de l'estat de Genève* by Jacob Spon, which appeared in 1680 (Santschi 1998). In 1731, Johann Adam Riediger drew a manuscript plan of ancient Avenches, of which only copies have been preserved (Leu 2004). The first printed plan of the Roman antiquities of Avenches, *Plan de la ville d'Avenghe en Suisse et de l'ençeinte d'Aventicvm Helvetorvm,* dated 1786, stems from Erasmus Ritter and can be found in Ritter's *Mémoire abrégé et recueil de quelques antiquités de la Suisse,* 1788 (Herzig 2003).

The coloration of some eighteenth-century Swiss maps does not distinguish political divisions, as is customary, but rather the distribution of denominations, separated into Protestant, Catholic, and denominationally mixed areas. In a few instances, this coloration is explicitly referred to in the legends such as those on *Nova totius Helvetiæ tabula* by Benedikt Roth (1730) and Johann Baptist Homann's *Potentissimæ Helvetiorum reipublicæ cantones tredecim* (1732). Some maps by Gabriel Walser in Homann's *Atlas novus Reipublicae Helveticae* (1769) depict the religious affiliation of a locality in denominationally mixed cantons through the use of disparately designed church spires.

The oldest mineralogical map of Switzerland is the *Carte minéralogique de la Suisse* (1752) by Philippe Buache, published in an article by Jean-Étienne Guettard in the *Mémoires de l'Académie Royale des Sciences* in 1756. In addition to point-by-point information, it also features a shaded region labeled *bande marneuse* (marl). Gottlieb Sigmund Gruner published the first map showing places of discovery of minerals in Switzerland, *Die Eisgebyrge des Schweizerlandes: Mit allen dabey vorkommenden Mineralien*, attached to his three-volume *Die Eisgebirge des Schweizerlandes* (1760) (Heitzmann 2008).

The eighteenth century also saw publication of the first regional mineralogical maps. In the *Carte du gouvernement d'Aigle . . . avec des explications petrographiques* by Isaac Gamaliel de Rovéréa, published in *Essai sur la montagne salifère du gouvernement d'Aigle* by Franz-Samuel Wild (1788), Rovéréa added petrography, including surface colors for the various formations of rock. In 1791, Charles-François Exchaquet, Henri Struve, and Jacob Pierre van Berchem drew the *Carte petrographique du St. Gothard* for the Gotthard area, which was published in 1795 in *Itinéraire du St. Gothard* by Christian von Mechel.

Grigoriy Razumovskiy published a paleo-geographical map, the *Carte de l'ancien bassin formé par la réunion des grands lacs de la Suisse et des petits lacs intermediaires,* in *Histoire et Mémoires de la Société des Sciences Physiques de Lausanne* (1790). It shows the circumference of the fresh water lake he assumed had covered the Swiss Plateau. Hans Conrad Escher von der


FIG. 808. HANS CONRAD ESCHER VON DER LINTH, FIRST GEOLOGICAL PROFILE OF THE SWISS ALPS. From Escher von der Linth, "Geognostische Nachrichten über die Alpen, in Briefen aus Helvetien: Erster Brief (Profilreise von Zürich bis an den Gothard)," *Neues Bergmännisches Journal* 1 (1795): 116–60, pl. II (after 192).
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Linth was first to sketch a geological profile traversing the Swiss Alps from Zurich to the Gotthard on the basis of his own view, which was printed in 1795 (fig. 808).

HANS-PETER HÖHENER

SEE ALSO: Switzerland

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***Theodolite.*** See Instruments for Angle Measuring: (1) Theodolite, Graphomètre, and Similar Instruments, (2) Great Theodolite

***Tofiño de San Miguel y Vandewalle, Vicente.*** Vicente Tofiño de San Miguel was a sailor, chartmaker, and astronomer. Born in Cádiz in 1732, he entered the army (Ejército) in 1747. In 1755 he was appointed instructor of mathematics at Academia de Guardiamarinas de Cádiz, and two years later he transferred into the navy (Armada). From 1768, he served as director of the Academia, and from 1776 also directed the academies at El Ferrol and Cartagena. In 1783, he designed the curriculum and a program for astronomic observations for the officers of the Real Observatorio de Cádiz. His activities in observational astronomy were acknowledged internationally by astronomers and scientists such as Joseph-Jérôme Lefrançais de Lalande and Jean-René-Antoine de Verdun de la Crenne. But it was the surveys of the coasts of Spain and the *Atlas marítimo de España* that gave him international renown for introducing astronomical and geodetic methods to Spanish nautical cartography. Tofiño de San Miguel died at age sixty-two on 15 January 1795 in San Fernando (Cádiz), as a brigadier in the Armada.

During the hydrographic campaigns from the summer of 1783 until the summer of 1788, Tofiño was accompanied by student-officers of the Academia de Guardiamarinas, such as José Espinosa y Tello, Dionisio Alcalá-Galiano, José María de Lanz, Felipe Bauzá, and Alejandro Malaspina. Their scientific method followed the model of James Cook, who in 1763 had combined terrestrial triangulations with hydrographical surveys. Tofiño's reasoning for this was: "The best method to secure success was to combine land operations with those on sea and surveying our shores with a series of continuous triangles, from the initial one whose base was measured with accuracy, and from which others would be obtained. This is the same method that the celebrated Picard and La Hire followed in their map of France: and all possible points should be established at the observatory" (Tofiño de San Miguel 1787, XLvii).

The survey of the Mediterranean coasts of Spain occupied Tofiño and his assistants during the summers of

1783, 1784, and 1785. After they surveyed the coasts of Portugal and Galicia in the summer of 1786, they continued with the Cantabrian coast and the Azore islands in the summers of 1787 and 1788.

The best engravers of the period engraved the charts of the *Atlas marítimo de España,* and it enjoyed immediate success throughout Europe (see fig. 499). In 1787 the *Derrotero de las costas de España en el Mediterraneo* was edited and published with an atlas containing fifteen charts of the Mediterranean. In 1789 a second volume, *Derrotero de las costas de España en el Océano Atlántico,* appeared with an atlas of thirty charts and an allegorical title page by Rafael Mengs (see fig. 593). Also in 1789, a second edition combined the two volumes under the title *Atlas marítimo de España* with two new charts (fig. 809).

From the efforts to create the coastal charts, it was possible to determine an exact measure of Spanish ter-


FIG. 809. DETAIL FROM VICENTE TOFIÑO DE SAN MIGUEL, *PLANO DE LA CIUDAD, PUERTO, Y ARSENAL DE CARTAGENA,* [MADRID], 1788. From the *Atlas marítimo de España,* 1789; scale, ca. 1:14,152, scale bar of 1,000 varas castellanas. Cartagena, a maritime department of the Armada en el Mediterráneo and the site of an important observatory, received a scientific hydrographic survey only in the late eighteenth century. The chart offers both details of the plan of Cartagena as well as soundings, marks for the sea bottom, and sailing directions for the shoals in the inset.

Size of the entire original: 62 × 96 cm; size of detail: 62 × 69 cm. Image courtesy of the Museo Naval de Madrid (MN A-10055, map. 35).

ritory. The result was 10,891 square leagues of 8,000 varas each, a figure anticipating by nearly half a century the geographical map of the territory.

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SEE ALSO: Atlas: Marine Atlas; Marine Charting: Spain

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***Topographical Mapping and the State.*** Between 1650 and 1800, state topographical mapping changed from being a series of sometimes inspired but often discontinuous projects to part of the apparatus of state. As maps secured the approval of governors and consequently became more abundant and reliable, scholars have in the past found them less interesting. More recent research, however, increasingly looks beyond the technical construction, artistic quality, and geographical content of state topographical maps to consider the institutional, political, and economic circumstances in which they were produced and used to explain why mapping became progressively institutionalized. State topographical surveys are analyzed as tools of statecraft (e.g., Akerman 1998), the military revolution (e.g., Buisseret 2003, esp. 113–51), imperialism (e.g., Edney 1997; Zandvliet 1998), and as consumer goods and part of the book trade (e.g., Pedley 2005).

"State" here includes quasi-state bodies such as the English East India Company (EIC) and the Dutch Verenigde Oost-Indische Compagnie (VOC) and West-Indische Compagnie (WIC). Metropolitan authorities granted these companies monopolistic quasi-state powers over the areas under their control, as well as over trade; they were the instruments through which intra-European state rivalries were played out in colonized areas, and eventually the state took over their functions. Their quasi-state activities sometimes included cartography; for example, the VOC was granted a privilege in 1619 by the States General to organize and control mapping and charting of areas of interest (Zandvliet 1998, 94–95). State topographical mapping also includes mapping of princes' personal lands. Princely mapping projects, like princely revenues and responsibilities, were poorly differentiated from those of the states. The survey of Norwegian forests (1737–46) (fig. 810) and that of French royal forests begun in 1661 by Jean-Baptiste Colbert are just two examples of projects whose maps had national strategic and defense uses quite different from nonroyal estate maps (Kain and Baigent 1992; Barber 1997, 106; Baigent 2005b).


FIG. 810. DETAIL FROM FRANZ PHILIP VON LANGEN'S MAP OF THE FOREST AREA AROUND KONGSBERG, 1746. This manuscript map, 1:34,000, is the best known of the important series made by the German von Langen brothers for Christian VI to improve forest management.

Size of the entire original: 71 × 95 cm; size of detail: ca. 15.5 × 16.0 cm. Image courtesy of Norsk Bergverksmuseum, Kongsberg (KS II A VIII 28).

Topographical mapping was an important part of the emergent apparatus of the state (Akerman 1998), but for much of this period mapping projects depended very largely on the tenacity and vision of individuals. Monarchs and ministers continued to exert a decisive influence on mapping projects after 1650, as in previous centuries; they were joined as apologists for and as driving forces behind state mapping projects by both scientists, individually and jointly in their new academies, and military men. Reforming monarchs with visions that encompassed or depended on surveys included Emperor Joseph II (r. 1765–90), who saw to completion the Josephinische Landesaufnahme, the first survey of most of the hereditary lands of the Austrian Habsburgs, which produced nearly 3,600 maps at a scale of 1:28,800 between 1763 and 1787 (Nischer-Falkenhof 1937; Fasching and Wawrik 1989, 118). Peter I (r. 1682–1725) was the driving force behind reforms, such as the creation of the all-Russian market, which depended on state mapping (Goldenberg and Postnikov 1985, 63). The determination of Elector Maximilian III Joseph (r. 1745–77) to push through reform led to the mapping of much of Bavaria (1752–1800, at scales of ca. 1:30,000). Although the maps were intended as the basis for improvement of the road network, with their representation of prominent landmarks and hachures to show relief, they were also the first step toward a new general topographical map of Bavaria. The elector's reforming zeal also lay behind Bavarian customs maps (1764–69), which, as official carriers of legally binding information, were important instruments in reform (Schlögl 1997, 122–25). The continuing importance of ministerial enthusiasm for maps is epitomized by Colbert in France, one of whose first actions in 1663 was to demand maps of all parts of France as a basis for reforms aimed at restoring French glory (Konvitz 1987, 1–2).

The new importance of scientists in driving through map projects is exemplified by César-François Cassini (III) de Thury and his son Jean-Dominique Cassini (IV). Cassini III designed and directed the project, persisting after Louis XV, who had commissioned the map in 1747, ended financial support in 1756; thereafter Cassini relied on support from a society of individuals many of whom shared an interest in science. The Cassinis produced 175 maps between 1749 and 1790 in a project that stressed national unity under royal sovereignty and whose quasi-state nature was emphasized in 1793 when the Republican government appropriated its plates and printed sheets. But its success rested on the tenacity of individual scientists. An appreciation of the benefits of science also inspired military men to effect and promote substantial topographical mapping projects: William Roy undertook the military survey of Scotland 1747–55 that prefigured wider mapping of the state by the Board of Ordnance, which he had long championed.

The cumulative success of these mapping projects made Enlightenment princes, and latterly republican governments, realize the value of maps in state administration, but not until the end of the period did individual mapping projects driven by individuals, albeit with official backing, commonly become embedded in dedicated cartographic institutions that outlived individual projects and people. The Great Trigonometrical Survey of India and Ordnance Survey, for example, began just at the end of the period, and the great state surveys inspired by Napoleonic reforms flourished at the same time. The steady successes of Lantmäteriet in Sweden proved the benefits of institutionalizing mapping, although institutionalization could detrimentally distance map production from map use. Draftsmen in the Board of Ordnance Drawing Room sometimes produced maps that promised them professional advancement, rather than maps that best provided topographical intelligence, while the army increasingly relied on men not trained in the Drawing Room for maps (Marshall 1980, esp. 33–34).

Changes in the art of war brought increasing cartoliteracy (Harley 1978, 1). Rulers and strategists needed maps to plan campaigns, take stock after wars, and ward off invasions. The Josephinische Landesaufnahme was undertaken for purely military reasons after the defeats of the Seven Years' War (1756–63), and the resulting maps were a closely guarded secret (Nischer-Falkenhof 1937; Fasching and Wawrik 1989, 118). Generals in the field needed maps to build fortifications, site artillery, and plan tactics, especially as warfare became larger in scale and armies more mobile. Friedrich II (r. 1740–86) had a traveling Plankammer (map office) and insisted his generals pay attention to detailed maps (Buisseret 2003, 118). The result was an explosion of map production and use affecting all kinds of maps, including topographical maps made by army or ordnance staffs. In the North American wars, for example, British engineers, American geographers, and French *ingénieurs géographes* made topographical maps for their respective armies (Harley 1978, 3).

David Buisseret (2003, 150) argues that the effect of the military revolution "is most obvious in the case of large-scale topographical mapping, which in many countries was first undertaken for military purposes, but then became an indispensable tool for a great variety of civilian activities, from town-planning to the reconstruction of ancient landscapes." The names of state survey bodies (Britain's Ordnance Survey, France's Carte de l'État Major, Germany's Generalstabskarte) attest to this. In Sweden, Buisseret's trajectory was reversed. There, the Fortifikationskår (founded 1635) undertook military topographical mapping, and the state hydrographic office triangulated and mapped the whole coastline of Sweden by 1786, but their maps remained secret. It was the topographical (*geografiska*) and cadastral (*geometriska*) maps of actual and potential Swedish lands by the world's first national institution for land survey (Lantmäteriet, founded 1628) that served as the basis for the 1688 map of Sweden (fig. 811) by the office's head, Carl Gripenhielm, and later informed wider public purposes. For example, Lantmäteriet's national and provincial topographical maps were published after 1735 to support industrialization. Only in the nineteenth century were military topographical maps produced by the Generalstaben (general staff) used for wider purposes. Although Lantmäteriet is best understood as part of Gustavus Adolphus's military state, its early establishment as a civil mapping body reduced the wider importance of military mapping in Sweden (Baigent 2005a; Runnberg and Carlsson 1986).

In the eighteenth century, European trading companies became less clearly concerned with trade (for which charts were vital) and more involved in administering


Nor. Siön.
Norrige
Lappmark
Ume Lappmark
Öster
Mare album.
Norre Bottn
Finske Bottn
Ryssland
Öster Siön

large areas and taxing their populations (for which maps, including topographical maps, were vital). Kees Zandvliet (1998) argues that the employment by the VOC and WIC of land surveyors, military engineers, and other mapmakers was seen as essential for the development of an efficient infrastructure. Similarly, the British set great store on mapping their overseas territories, exemplified by James Murray's survey of Quebec (1760–62) and Samuel Holland's survey of eastern North America (1764–1775) (Barber 1997, 91). Under James Rennell, surveyor general of Bengal from 1767, EIC territories were surveyed and accurately mapped for the first time. His map *Hindoostan* (1782) was the most detailed map of India yet produced in Europe (Edney 1997, 9–14). The French and Spanish also produced notable topographical maps of their empires in the new world (Buisseret 1991; Reinhartz 1998). Some of the lands in which Western powers established outposts had been mapped within their indigenous cartographic tradition, for example by Inuit, other Native American, or Mughal Indian mapmakers, with varying effects on Western European mapping and administrative understanding (Mapp 2011, 194–232).

Imperial mapping was not confined to maritime empires: continental imperial powers used maps to control outlying parts of their empires. Empress Marie Theresa (r. 1740–65) ordered and Emperor Joseph II continued the survey of the Austrian Netherlands by Joseph Jean François de Ferraris. Its 275 manuscript maps at a scale of 1:11,520, produced between 1770 and 1778, gave a detailed picture of this restive and vulnerable territory that was far from the seat of power. Russian state surveying after 1737 paid particular attention to remoter provinces such as Siberia, Kazan, and Irkutsk (Goldenberg and Postnikov 1985, 68).

Topographical maps were increasingly used to fix state boundary lines, such as those agreed in 1760 between France and Savoy (Pelletier 1998, 47) or in 1783 between British North America and the fledgling United States (Buisseret 2003, 181), and to control border areas that were mapped early and often compared with heartlands, because of their strategic importance and vulnerability and because trading companies needed reliable maps of coasts and port hinterlands in metropole and colony. Unruly Scotland was the first region of Britain to be mapped by the Board of Ordnance, with Roy's survey, followed by England's southern counties, vulnerable to French attack (O'Donoghue 1977). Swedish military surveys focused on the easternmost areas (Ingria, Karelia, and Lake Lagoda) at the end of the seventeenth century and through the Great Northern War (1700–1721), until advancing Russians drove the surveyors out (Kokkonen 1998, 60). The detailed mapping by *ingénieurs géographes* of French border regions in the second half of the eighteenth century is "among the greatest achievements of French cartography" (Konvitz 1987, 39). Inspectors compiled maps of the northern reaches of New Spain in the eighteenth century (Reinhartz 1998), and the WIC and VOC produced cartographically crude but strategically valuable maps of border areas vulnerable to attack by natives or, more often, rival European powers in the seventeenth and eighteenth centuries (Zandvliet 1998).

Most state topographical maps remained in manuscript. Some were kept secret for defense reasons, but Zandvliet (1998, 31) joins historians of the book in arguing that manuscripts circulated more effectively than was previously thought. The move to a print culture and rising bourgeois incomes undoubtedly brought wider circulation of maps, and the way in which engraving and book trades were organized in any area affected maps' availability and use (Pedley 2005). The sale of maps printed from copperplates (organized in house or contracted out) underpinned some state mapping, notably that in France (Konvitz 1987, 24–25). The French example and that of the Ferraris map of the Austrian Netherlands, which was engraved and published in 1777–78 in twenty-five sheets at a scale of 1:86,400, were exceptional among eighteenth-century state topographical mapping projects in being published in their entirety. There was also ad hoc publication of topographic maps, such as the engraving (by independent craftsmen) and sale of some VOC and WIC maps (Zandvliet 1998), which exemplifies the intersection of commerce, consumption, and strategic topographic mapping.

The period saw a quest for standardization of symbols, colors, and techniques to show land use, drainage, and relief. Standardization affected maps of all kinds, though it was arguably of particular value in topographical maps used by the military, who needed to be able rapidly and reliably to interpret maps in a wide variety of situations (fig. 812). Standardization was promoted by the establishment of schools with professional standards, the publication of surveying manuals and treatises, the exercise of control by surveying authorities, and the exchange of personnel among armies. The draftsmen of the Board of Ordnance had to implement the fixed repertoire of symbols (Marshall 1980, 33–34). Ivan Kirilovich Kirilov's instructions for geodesists

(*facing page*)
FIG. 811. CARL GRIPENHIELM, MAP OF SUECIAE AND GOTHIA, 1688. This manuscript map (ca. 1:3,000,000), compiled by the head of Lantmäteriet from larger-scale topographical maps of the country, was a significant milestone in the cartographic representation of Scandinavia. Size of the original: 74 × 51 cm. Image courtesy of Kungliga biblioteket, Stockholm (KoB 50a Nr 2).

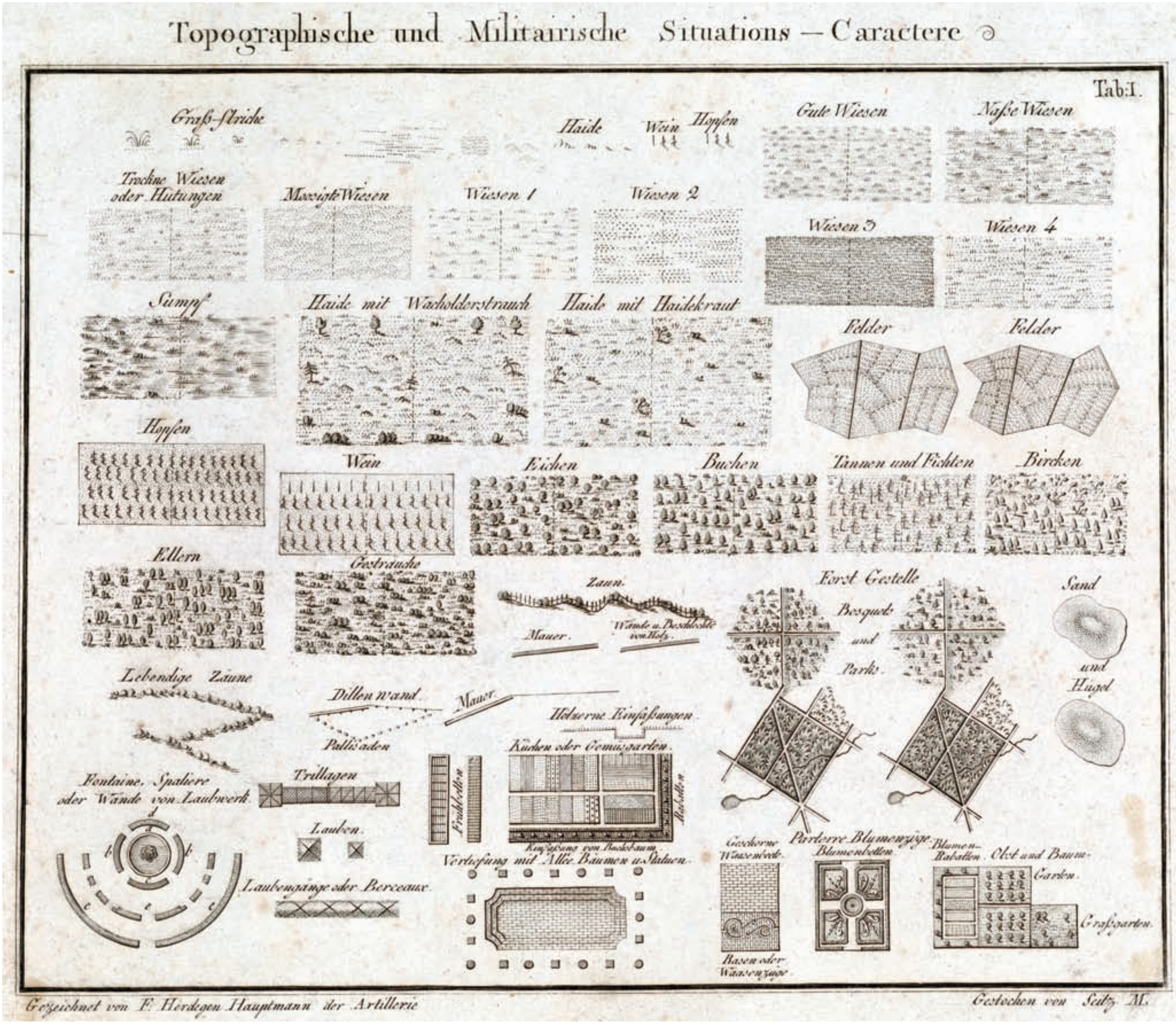


FIG. 812. A TYPICAL STANDARDIZED REPERTOIRE OF SYMBOLS FOR TOPOGRAPHIC MAPS. Advocates argued that the use of such symbols would make military maps clearer, more uniform, and easier to interpret, but ensuring standard usage was problematic. One of twenty-six sheets of signs published by the Bavarian geographical engineer Friedrich (J. C. F.) Herdegen in a portfolio, *Topographische und Militairische Situations—Caractere*, from Herdegen's *Caractere zu Militairisch-Topographischen Situations, u. Chorographischen, Geographischen, Hydrographischen und Petrographischen Karten* (Munich, 1809), pl. 1.
Size of the original: 20.0 × 23.5 cm. Image courtesy of the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland (OS-1809-2).

(1732) prescribed the symbols to be used by Russian state surveyors (Goldenberg and Postnikov 1985, 65–66). Efforts at standardization were never completely successful and some individuality remained.

Despite aspiration to (or at least aping of) scientific standards in mapping, pictorial representation survived. Some symbols, such as trees to represent forests, were evocative and pragmatic, and symbols in general could be readily controlled by the issuing body because they were embedded in the engraving process and not dependent on subsequent coloring. Hachures were used to represent terrain until well into the nineteenth century, despite theoretical knowledge of contouring. Hachuring gave a general idea of the lie of the land, which could be very useful in mountainous areas, but it was only impressionistic, and this made it difficult to site artillery accurately (Buisseret 2003, 118).

By 1650 scale mapping (the drawing of maps to a precise mathematical scale) was fully established, having been widely introduced in the sixteenth century to meet the demands for accuracy in distance and angle in the new arts of war. Important technical advances of the period were the standardization of linear measures and the development of triangulation. Geodetic triangulation had been invented before 1650 but became widespread only later because of previous limitations of instrumentation and mathematical calculation, in particular the calculation of longitude and the measurement of the figure of the earth (Konvitz 1987, 2–5). The creation of large geodetic surveys based on triangulation with accurate measurement of a baseline and use of astronomical observations and advanced instruments, such as elaborate theodolites, were largely confined to surveys by astronomers and military officers. Such high standards were not universal: the Josephinische Landesaufnahme was not based on a triangulated framework because of shortage of time and personnel (Fasching and Wawrik 1989, 118–19), and in Russia the greater use of plane tables in the eighteenth century was a technical advance in some military topographical surveys (Goldenberg and Postnikov 1985, 75).

Behind much topographical mapping of the Enlightenment lay "patriotic science" (Widmalm 1990, 35–54, 402)—that is, apparently disinterested attempts to test scientific theories through observation, sometimes in concert with other countries, underlying which were nationalistic attempts to increase prestige. The surveying and mapping of France by the Cassini family in concert with the Académie royale des sciences (Konvitz 1987, 1–31), the Greenwich-Paris triangulation to measure precisely the longitudinal separation of London and Paris (1784–87) (O'Donoghue 1977, 52), and William Lambton's 1799 proposal for what would become the Great Trigonometrical Survey of India (Edney 1997, 293–318) were instances of patriotic science.

States were at once cavalier with and covetous of topographical maps. On the one hand, some state institutions regularly destroyed maps they considered superseded or lost them in poorly maintained archives. The VOC and WIC collections, for example, suffered from the destruction of a huge number of maps from administrative neglect as well as to climate and pests (Zandvliet 1998, 263, 269). On the other hand, states coveted maps of areas newly under their control. When Sweden lost its Baltic lands, many of its Baltic maps were handed over to the new authorities, though it contrived to retain some (Ehrensvärd 1990, 116). Poland lost the results of one of its earliest state surveys (1796) to occupying Russian forces almost immediately after completion (Barber 1997, 94). As a consequence of invasion, war, and unrest, many state topographic maps are either missing or not in the archives of the state that commissioned them. Conversely, state map collections may hold maps of areas outside the state: military topographical mapping often encompassed theaters of war that respected few state boundaries. William Roy saw service in Germany in the Seven Years' War and drew fine topographical maps there. Buisseret (2003, 139) makes the point that the German authorities had far fewer good maps of their territories in the eighteenth century than did the French army. Maps made for established institutions often survived better than those made for others, but this survival may be misleading. The survival of elegant maps tells us that men had time to draw such maps, for example, during long traditional sieges, but reveals little about their use (Marshall 1980, 33). Sketch maps drawn in haste by officers on battlefields may have been simultaneously the most useful and the least likely to survive.

Constraints of cost, time, personnel, and instrumentation hampered and in some cases prevented state topographical mapping. Constraints were more acute than in, for example, estate mapping, because technical demands were higher and the areas covered were more extensive. Shortage of trained men was met in this period less by importing skilled labor, as had been done earlier, and more by setting up state training schools: Louis XV set up the École des Ponts et Chaussées in 1747 and the École du Génie de Mézières in 1748 to provide personnel for civilian and military mapmaking (Pelletier 1998). The Moskovskaya matematiko-navigatskaya shkola, established in 1701, trained naval officers and land surveyors in surveying techniques (Kokkonen 1998, 62). In England, cadets learned surveying and mapping in the Drawing Room (established 1717) of the Board of Ordnance and the Royal Military Academy, Woolwich (established 1741) (Marshall 1980). Such training was arguably no substitute for training on the job, and many schools incorporated field training, sometimes producing pioneering maps in the process: maps made by English cadets in the last quarter of the eighteenth century of eastern England, the Channel Islands, and the south of England prefigure Ordnance Survey maps.

Lack of adequate instruments was a less tractable problem. London was the European center for scientific instrumentmakers in the eighteenth century, and instruments such as Jesse Ramsden's theodolite set new standards of accuracy in Ordnance Survey work (McConnell 2007) (see fig. 410). Some state surveys bought critical instruments in London, sent men to train with London instrumentmakers, or brought London makers to their countries to train local men. More ambitiously, Cassini IV tried to set up a rival center, establishing a foundry at the Paris Observatory where instruments could be made and craftsmen trained to meet French needs (Godlewska 1998). But as with the surveys generally, the provision of instruments would not be institutionally regularized until the early 1800s.

Impediments to substantial state topographical mapping projects were overcome in the period 1650 to 1800 where strategic need was great, as in the Ferraris and Roy maps, or where zeal was unextinguishable, as in the Cassini maps. These examples, together with the increasing general acceptance of maps by the literate public and state institutions at all levels and the embedding of surveying skills in state institutions of various kinds, laid the foundations for the rapid expansion of state topographic mapping in the nineteenth century.

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SEE ALSO: Administrative Cartography; Commission topographique of 1802; Engineers and Topographical Surveys; Indigenous Peoples and European Cartography; Military and Topographical Surveys; Signs, Cartographic; Topographical Surveying

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***Topographical Survey Map.*** The primary feature distinguishing topographic maps from other maps is scale: their scale is large enough to synthesize all the natural and manmade features of a locale without requiring the user to be on site. The map must meet the needs of the user and depict at the appropriate scale all necessary details of the landscape. Features and landscape details must be immediately identifiable without keys or other explanatory devices. Like a painted portrait, representations on a topographic map try to *imitate* the objects of the natural landscape (Bousquet-Bressolier 1995).The topographic map may therefore be conceived as a message elaborated by a "designer" (*concepteur*) who surveys and draws up the map, for a "recipient," an institution or a person. Without having to travel, the recipient of the topographic map has in hand a *substitute* for the reality of the terrain. In its final form, each topographic map follows its own course in how it is used, a path that may lead away from its initial destination toward other users. Many texts from the period call for compiling all the existing plans and previous documents before beginning a new project. To understand fully a topographic map is to understand the interaction of scale, principles of imitation, and the map as an object produced by a designer for a recipient.

Evolution of a Concept In 1802 the French Commission topographique fixed the standard scales that would distinguish topographic maps from their geographic and chorographic counterparts. It defined the conventional symbols to be used for representing terrain, opted to represent relief with hachure lines with spacing proportional to slope, and established a hierarchy of scripts. In fact, the Commission's work codified in terms of standard scales the practices of most European countries and gave them a universal expression—the numerical ratio or representative fraction—that the Napoleonic conquest of Europe would subsequently confirm.

Yet this standardization resulted from a long evolution begun in the sixteenth century. At that time, it was typical to follow Claudius Ptolemy in distinguishing between geography and chorography or topography, the two latter terms then being synonymous. Antoine Du Pinet explained in 1564 "that one could take for geography that which represents a body in general and for chorography [i.e., topography] that which dissects all the parts of the body down to the smallest hair of a beard," by representing "particular locales in their natural state, without dealing with measurements, proportions, longitudes, latitudes, or other cosmographic distances: being content to display to the eye, as naturally as possible, the form, the setting, and the dependencies of the locale that it depicts" (1564, xiiii). Du Pinet's definition did not require measurement: the map should resemble a vivid picture of the landscape *d'après nature* (according to nature).

To do this, the scale had to be large enough for the user to discern all the map's details. At topographic scales (greater than 1:100,000) the map became first and foremost a painting and, like a painting, subject to the rules of the art of natural imitation. However, contrary to Du Pinet's statement, the veracity of representation did depend on precise measurements. The debate over representation in the seventeenth century rested on developments during the Scientific Revolution concerning perspective and the mathematization of space.

Thus, in the middle of the seventeenth century, at the beginning of the Enlightenment, pictorial representation, like topographic representation, was attracted by two ostensibly opposite poles: imitation/resemblance on the one hand and precise measurement on the other. During the 1650s, Europe's academies of fine arts theorized about the principle of the imitation of nature, while their academies of sciences dealt with precision of measurement.

During the eighteenth century, the need for precise measurement became increasingly clear. The principle of imitating nature to represent objects became standardized in signs that gradually became symbolic. However, it was only at the end of the period that the problem of cartographic generalization (the adaptation of signs and renderings on a map to its scale) came to be treated in an objective and standardized fashion.

By 1802, pushed by the Commission topographique, which was composed principally of military men, topographic cartography was becoming a wholly normative science (employing a geodetic framework with sea level as the reference point for measuring altitude). But the question of what geographic projection would be used was not discussed. Standards of scale were synthesized in a table that compared former scales to metric scales for all types of cartographic documents (fig. 813). Thus, the term *topographie de détail* was reserved for city plans (as detailed as ca. 1:500) and for plans of fortified places (ca. 1:2,000) or their reductions (1:5,000). *Topographie générale* encompassed topographical maps of a particular area or military encampment or itinerary (ca. 1:10,000), the products of military reconnaissance (ca. 1:20,000), and engraved, reduced maps of topography (from ca. 1:50,000 to ca. 1:100,000). At the end of the eighteenth century, any map drawn at a scale between 1:2,000 and about 1:100,000 (slightly smaller than the Cassini *Carte de France* scale of 1:86,400) was thus considered a topographic plan (see also Dainville 1964, 54).

The use of the term "topography," which appeared at the beginning of the fifteenth century, reflected this evolution and was apparent in the definitions of the term given by dictionaries of the principal European languages. For example, in French, topography was "the description of a particular place" (*Dictionnaire* 1694, 2:572) and an "exact and detailed description of a place, of a particular canton" (*Dictionnaire* 1762, 2:847). In German, it was "the description of a place and at times whole areas and regions, with the places therein, named according to their location, according to their district and jurisdiction, [. . . and] which show clearly the borders with all the villages belonging thereto and other relevant parts of the place" (Zedler 1732–50, 44:1278). The term was contrasted with "geography." Until the nineteenth century, the semantic frontier between chorography and topography remained imprecise: topography described "particular" places, while chorography described "countries." By the eighteenth century, the term "chorography" was seldom used, occurring merely as a reference to an earlier nomenclature.

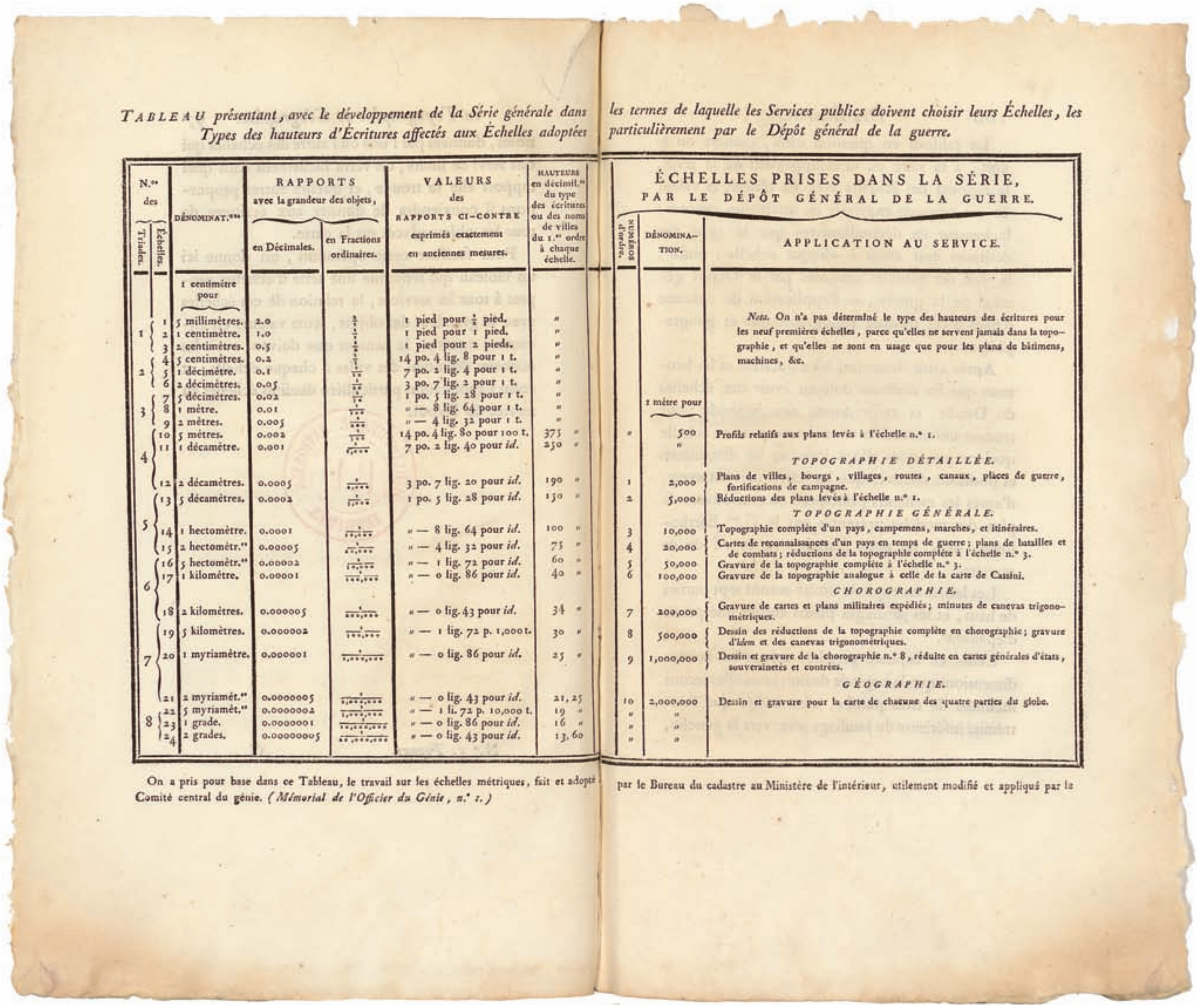

*TABLEAU présentant, avec le développement de la Série générale dans les termes de laquelle les Services publics doivent choisir leurs Échelles, les Types des hauteurs d'Écritures affectés aux Échelles adoptées particulièrement par le Dépôt général de la guerre.*

| N.os des Triades. | N.os des Échelles. | DÉNOMINAT.ons (1 centimètre pour) | RAPPORTS avec la grandeur des objets, en Décimales. | RAPPORTS en Fractions ordinaires. | VALEURS des RAPPORTS CI-CONTRE exprimés exactement en anciennes mesures. | HAUTEURS en décimil.es du type des écritures ou des noms de villes du 1.er ordre à chaque échelle. |
|---|---|---|---|---|---|---|
| 1 | 1 | 5 millimètres. | 2.0 | 2/1 | 1 pied pour ½ pied. | ″ |
| | 2 | 1 centimètre. | 1.0 | 1/1 | 1 pied pour 1 pied. | ″ |
| | 3 | 2 centimètres. | 0.5 | 1/2 | 1 pied pour 2 pieds. | ″ |
| 2 | 4 | 5 centimètres. | 0.2 | 1/5 | 14 po. 4 lig. 8 pour 1 t. | ″ |
| | 5 | 1 décimètre. | 0.1 | 1/10 | 7 po. 2 lig. 4 pour 1 t. | ″ |
| | 6 | 2 décimètres. | 0.05 | 1/20 | 3 po. 7 lig. 2 pour 1 t. | ″ |
| 3 | 7 | 5 décimètres. | 0.02 | 1/50 | 1 po. 5 lig. 28 pour 1 t. | ″ |
| | 8 | 1 mètre. | 0.01 | 1/100 | ″ — 8 lig. 64 pour 1 t. | ″ |
| | 9 | 2 mètres. | 0.005 | 1/200 | ″ — 4 lig. 32 pour 1 t. | ″ |
| 4 | 10 | 5 mètres. | 0.002 | 1/500 | 14 po. 4 lig. 80 pour 100 t. | 375 ″ |
| | 11 | 1 décamètre. | 0.001 | 1/1,000 | 7 po. 2 lig. 40 pour *id.* | 250 ″ |
| | 12 | 2 décamètres. | 0.0005 | 1/2,000 | 3 po. 7 lig. 20 pour *id.* | 190 ″ |
| 5 | 13 | 5 décamètres. | 0.0002 | 1/5,000 | 1 po. 5 lig. 28 pour *id.* | 150 ″ |
| | 14 | 1 hectomètre. | 0.0001 | 1/10,000 | ″ — 8 lig. 64 pour *id.* | 100 ″ |
| | 15 | 2 hectomètr.es | 0.00005 | 1/20,000 | ″ — 4 lig. 32 pour *id.* | 75 ″ |
| 6 | 16 | 5 hectomètr.es | 0.00002 | 1/50,000 | ″ — 1 lig. 72 pour *id.* | 60 ″ |
| | 17 | 1 kilomètre. | 0.00001 | 1/100,000 | ″ — 0 lig. 86 pour *id.* | 40 ″ |
| | 18 | 2 kilomètres. | 0.000005 | 1/200,000 | ″ — 0 lig. 43 pour *id.* | 34 ″ |
| 7 | 19 | 5 kilomètres. | 0.000002 | 1/500,000 | ″ — 1 lig. 72 p. 1,000 t. | 30 ″ |
| | 20 | 1 myriamètre. | 0.000001 | 1/1,000,000 | ″ — 0 lig. 86 pour *id.* | 25 ″ |
| | 21 | 2 myriamèt.es | 0.0000005 | 1/2,000,000 | ″ — 0 lig. 43 pour *id.* | 21, 25 |
| 8 | 22 | 5 myriamèt.es | 0.0000002 | 1/5,000,000 | ″ — 1 li. 72 p. 10,000 t. | 19 ″ |
| | 23 | 1 grade. | 0.0000001 | 1/10,000,000 | ″ — 0 lig. 86 pour *id.* | 16 ″ |
| | 24 | 2 grades. | 0.00000005 | 1/20,000,000 | ″ — 0 lig. 43 pour *id.* | 13, 60 |

ÉCHELLES PRISES DANS LA SÉRIE, PAR LE DÉPÔT GÉNÉRAL DE LA GUERRE.

*Nota.* On n'a pas déterminé le type des hauteurs des écritures pour les neuf premières échelles, parce qu'elles ne servent jamais dans la topographie, et qu'elles ne sont en usage que pour les plans de bâtimens, machines, &c.

| NUMÉROS d'ordre. | DÉNOMINATION. (1 mètre pour) | APPLICATION AU SERVICE. |
|---|---|---|
| ″ | 500 | Profils relatifs aux plans levés à l'échelle n.° 1. |
| | ″ | |
| | | *TOPOGRAPHIE DÉTAILLÉE.* |
| 1 | 2,000 | Plans de villes, bourgs, villages, routes, canaux, places de guerre, fortifications de campagne. |
| 2 | 5,000 | Réductions des plans levés à l'échelle n.° 1. |
| | | *TOPOGRAPHIE GÉNÉRALE.* |
| 3 | 10,000 | Topographie complète d'un pays, campemens, marches, et itinéraires. |
| 4 | 20,000 | Cartes de reconnaissances d'un pays en temps de guerre; plans de batailles et de combats; réductions de la topographie complète à l'échelle n.° 3. |
| 5 | 50,000 | Gravure de la topographie complète à l'échelle n.° 3. |
| 6 | 100,000 | Gravure de la topographie analogue à celle de la carte de Cassini. |
| | | *CHOROGRAPHIE.* |
| 7 | 200,000 | Gravure de cartes et plans militaires expédiés; minutes de canevas trigonométriques. |
| 8 | 500,000 | Dessin des réductions de la topographie complète en chorographie; gravure d'*idem* et des canevas trigonométriques. |
| 9 | 1,000,000 | Dessin et gravure de la chorographie n.° 8, réduite en cartes générales d'états, souverainetés et contrées. |
| | | *GÉOGRAPHIE.* |
| 10 | 2,000,000 | Dessin et gravure pour la carte de chacune des quatre parties du globe. |
| ″ | ″ | |
| ″ | ″ | |
| ″ | ″ | |

On a pris pour base dans ce Tableau, le travail sur les échelles métriques, fait et adopté par le Bureau du cadastre au Ministère de l'intérieur, utilement modifié et appliqué par le Comité central du génie. (*Mémorial de l'Officier du Génie, n.° 1.*)

FIG. 813. TABLE OF SCALES USED FOR THE GENERAL SERIES OF MAPS PRODUCED BY THE DÉPÔT GÉNÉRAL DE LA GUERRE, 1803. The table also provides recommendations for the height of lettering on maps at different scales. From "Des caractères et des hauteurs des écritures pour les plans et cartes topographiques et géographiques," *Mémorial Topographique et Militaire, rédigé au Dépôt Général de la Guerre* (1803), no. 5:92–125, table on 98–99.
Image courtesy of the Bibliothèque nationale de France, Paris.

USES OF THE TOPOGRAPHIC MAP Whether produced by an artist-painter who learned the laws of perspective and geometric projection with ruler and compass or by an engineer who surveyed the map with measuring instruments, each topographic map was designed for a specific use that affected the nature of the data it contained. Each map allowed its users to mentally place the information they needed within the real space that the map transcribed. For example, a soldier might require the plan of a fortification or a map of a theater of military operations; a local magistrate, a map of a city and its surroundings; a sailor, a plan of a port and adjacent land; and an administrator, a map of roads, paths, and forests to be improved. As an object, each topographic map was conceived with a specific goal in mind (such as the depiction of roads or fortifications, orders of battle, patterns of landholding, and improvements of ports or cities), but the same map might have multiple subsequent uses beyond that initial objective.

In spite of their diverse uses, all topographic maps shared the characteristic of being prepared at a scale sufficiently large to represent the details of the terrain.


FIG. 814. DETAIL FROM "CARTE DU 11E QUARRÉ DE LA GÉNÉRALE DES CÔTE DE BAS POITOU, PAYS D'AUNIS," BY CLAUDE MASSE. Large-scale manuscript map of the southwest coast of France, 1:28,800.
Size of the entire original: 70.5 × 69.5 cm; size of detail: 9 × 9 cm. © Service historique de la Défense, Vincennes (Vincennes, 11e carré Aunis J 10 C 1293 28).


FIG. 815. DETAIL FROM "CARTE DE PARTIE DE BAS POITOU, D'AUNIS & SAINTONGE AVEC LES ISLES ADJACENTES REPRÉSENTÉES D'HAUTE MER" [1715], BY CLAUDE MASSE. A smaller-scale manuscript map of the area around the southwest coast of France, 1:97,800, which is the reduction of fig. 814.
Size of the entire original: 90 × 67 cm; size of detail: 7 × 7 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge SH 18E pf 53 pièce 21).

As noted above, the nomenclature adopted at the end of the Enlightenment by the Commission topographique suggested that the levels of precision required by the surveys varied according to the category of scale. Similarly, for the objects represented, the reduction of scale required that symbols be adapted and appropriately reduced in order to maintain a good visual relationship between the size of the objects represented and the scale of the map. For the user to have the illusion of terrain, the designer had recourse to cartographic generalization. The smaller-scale general maps of Claude Masse, which were the reductions of his large-scale particular maps (1:28,800), are good examples of this (figs. 814 and 815) (Bousquet-Bressolier 2008).

The symbols were also subject to cartographic generalization, changing proportionally as the scale of the representation decreased. However, it was rare for designers to be aware of this problem. To distinguish among objects in the terrain, they would draw small, repeating symbols on the surface: small poles for vineyards, foliage of treetops for forests, furrows for land under cultivation, clumps of reeds amid marks signifying marshes—giving to each feature the quality of symbolic convention. While these conventions may have accorded well with the reality of the terrain for maps at a scale larger than 1:28,800, they became disproportionate at smaller scales. Designers sometimes used a system of colors, shades of gray, or repeated signs. While certain administrative units (e.g., the Ponts et Chaussées and specialized engineering and military schools of the eighteenth century) were able to emphasize the importance of having an appropriate relation between symbols and scale (visual coherence), this constraint was not truly discussed prior to the Commission topographique of 1802.

Nevertheless, theoreticians, such as the English mathematician and surveyor William Leybourn, the German mathematician and architect Johann Friedrich Penther, and the French military engineer-geographer Louis Charles Dupain de Montesson, had long been conscious of the need to standardize modes of representation in topographic maps. Nonetheless, their primary preoccupation concerned the process of applying mathematical knowledge to the surveying of maps, maintaining, in effect, that the protocol affected the precision of the surveys (Leybourn 1657; Penther 1732; Dupain de Montesson 1763, 1775).

PRODUCTION OF TOPOGRAPHIC MAPS Topographical surveying was closely linked to the learning of mathematics. The usual procedures rested on understanding the properties of triangles and basic trigonometry that allowed measuring linear distances as well as differences in altitude. These procedures were described in specialized works that circulated increasingly during the Enlightenment (Jordan 2003). These works clearly described the process of representing terrain on a map at a given scale; their illustrations emphasized that the map was a reduction of the terrain. Some of these manuals also included conventions for representation. Yet most maps at a topographic scale continued to express relief in a general way, by shading or hachures, but rarely specifying altitude. Most of the time the indications of altitude took the form of transections related to a local base that were drawn separately or on a reserved part of the map, as they appeared in some works of civil engineering. For example, they are found on certain road maps such as the Trudaine atlases and their derivatives (Blond 2008).

Geodetic maps based on astronomically determined locations (ca. 1:10,000) and geometrically measured maps at a topographic scale (ca. 1:50,000–1:100,000) constituted a separate type. They positioned certain locations in relation to each other with precise measurements. While some locations were only determined astronomically, a secondary network of measurements was obtained by geometric trangulation. Such maps should not be considered topographic maps in the strictest sense, though they included numerous topographic features (forests, roads, rivers, habitats). They contained very precise data for the point locations of the first-order triangles, but their precision varied for locations in between the primary points. These maps often relied on earlier maps to fill in missing information, rather than on direct geometric measurements, as was case with the geodetic and geometric *Carte de France*. It was also necessary to account for the distortion produced by the projection used at these scales. Furthermore, every country employed its own reference meridian and its own system of projection. Distortions created by the projection used were generally greater at the borders of countries because the parallel and meridian of origin were generally in the middle of the country; distortions increased away from the center, which made joining maps between countries difficult. At scales larger than 1:30,000, the system of projection was not so great a source of error.

The systematic cartographic coverage of a country at a topographic scale demanded a large number of technicians, which was both costly and difficult. In 1707, the French geographer François Chevalier presented to the Académie des sciences the ingenious *châssis* method he had perfected to reduce the costs of time and manpower. Jean-Baptiste Bourguignon d'Anville used this method to some advantage to prepare several diocesan maps, beginning with Blois in 1732 (ca. 1:86,400). The method also served the *Carte de France* and its derivatives. The originality of Chevalier's method consisted of the production of a continuous network of measurement by unskilled observers. It relied on the observation of specific points and objects from a high point (such as a bell tower) located in the center of a given delimitated area: the point of sunrise or sunset on the horizon and the estimation of the distances of objects on the terrain from the observation point. These observations were transcribed directly onto a sheet of paper, the *châssis,* fixed on a board held perfectly horizontal, and previously prepared with (1) the cardinal directions, (2) concentric circles at half-league intervals from the center (the observation point), and (3) directions of the rising and setting of the sun during the longest and shortest days of the year indicated with dotted lines (fig. 816). Between these last two axes, a graduated scale with marks for every five days allowed the observer to locate the sunrise point in the east and the sunset point in the west for each month of the year. He fixed a pin perpendicular to the center in order to sight precisely the point of the horizon where the sun rose or set on the day chosen for observation, which was then marked by another pin. He used a wooden ruler to draw the "alignments" on the paper, i.e., the direction of the points sighted in the field and plotted on the *châssis*. All the completed *châssis* were collected (joined together) by the geographer, who deduced from tables the geographic coordinates of each observation point and placed the relative position of the objects observed on the map.

D'Anville was inspired to ask parish curates to make these observations from their local church towers. He distributed a printed *châssis,* which included a legend of symbols and an accompanying *Mémoire instructif*. The curates filled out the *châssis* along with *mémoires* prepared according to the template provided by the *Mémoire instructif*. D'Anville could then assemble, cross-check, and correct the data gathered parish by parish. Subsequent topographical survey operations made use of this economical and effective approach (Dainville 1956, 62–70).

The *châssis* method was, however, reserved for general topographic maps (ca. 1:100,000), for it was too imprecise to rival those surveys using a plane table or graphomètre, the most frequently used instruments for maps at topographic scales, or the theodolite, as recommended by John Hammond (1725, 1765). Surveying methods were based on the properties of similar triangles and trigonometry, like that of Gemma Frisius (1544), and books on applied geometry always

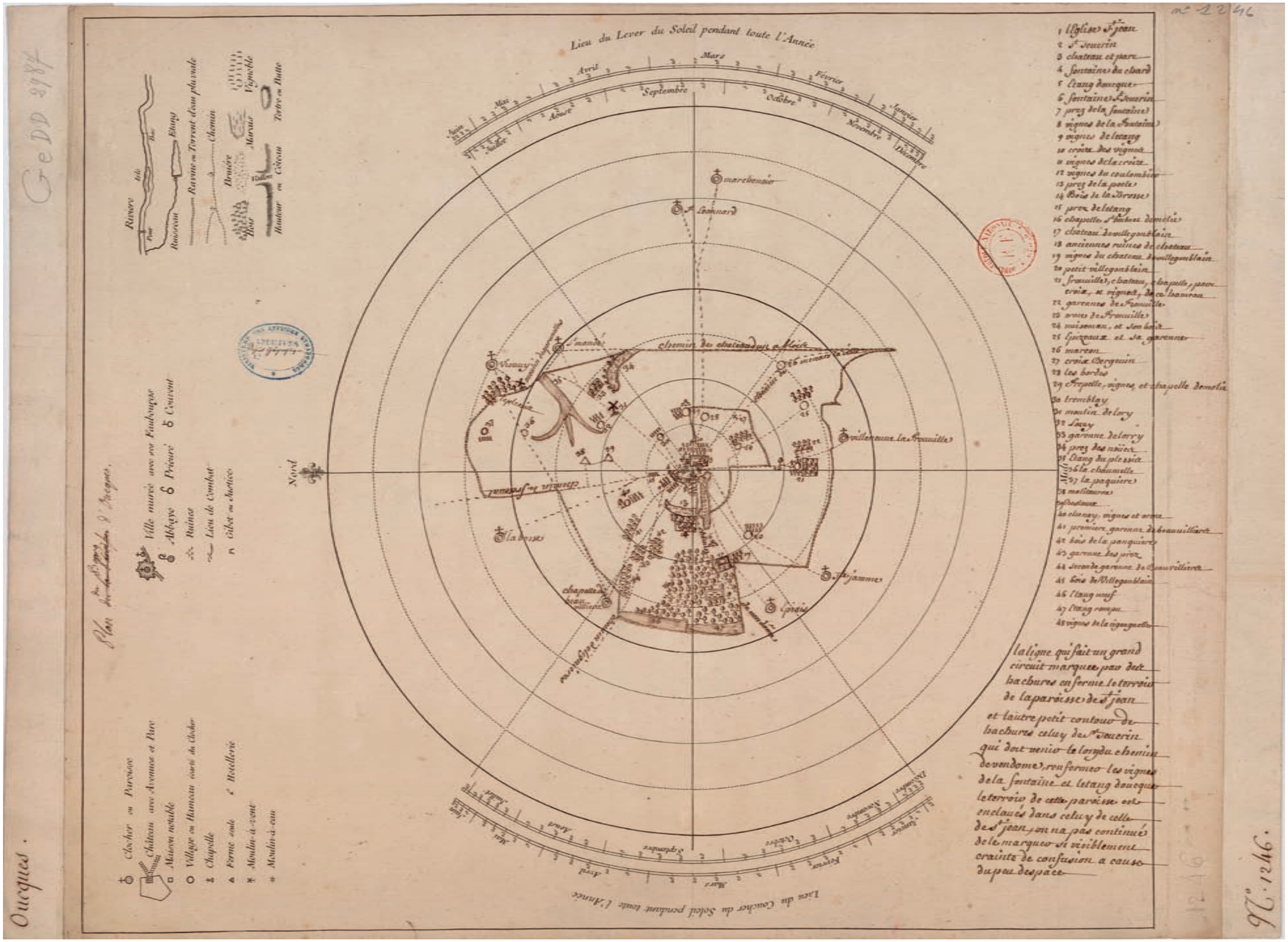


FIG. 816. "PLAN DU BOURG D'OUCQUES" [LOIR ET CHER, FRANCE]. The printed *châssis* following the Chevalier method used for the manuscript map of the town of Oucque in the diocèse of Blois by d'Anville (1732).

Size of the original: 46 × 53 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge DD 2987 [1246]).

described trigonometric principles. Surveys by military engineers, geometers, and civil engineers in France and the new surveys of counties in England were always conducted by triangulation (Bousquet-Bressolier and Pelletier 1998, 72–85; Harley 1965). The precise measurement of a baseline in the field determined the accuracy of both geometric and geodetic triangulation. Errors increased with the steepness of the slopes because of inaccurate measurements of altitude. French surveying techniques played a prominent role in European cartography—as attested by the number of French engineers surveying abroad (Lemoine-Isabeau 1984, 213–18)—but the best instruments for measuring were British, and British makers of scientific instruments were in many ways responsible for a renewal of topographical surveying in the English counties (Harley 1965).

In the course of the eighteenth century, topographic mapmaking in manuscript evolved and broadened in application. Alongside thematic maps produced by the military (including those of army marches, plans of camps, fortified places, and battles), purely topographic maps described terrain in minute detail, sometimes in order to showcase projects and improvements (such as roads and canals, land reclamation, mining ventures, gardens). Some projects were linear and described all the objects along a band of terrain, producing maps that seemed to give material form to man-made lines that were subject to change, such as transportation networks (road maps) or administrative borders (limits) or diplomatic boundaries (frontiers). The systematic coverage of entire states by printed maps at topographic scale was decided at the highest level, along with the creation of state map archives, designed to conserve existing maps (mostly printed and produced abroad) with their related documents. These efforts reflected the new status accorded topographic maps by those in power. The methodical coverage of entire countries at topographic scales gave authorities a synthetic and continuous vision of their territories and promoted a new way of thinking about space reorganized visually around new interests (roads, coasts, mountains, and frontiers), bearing witness to an open exchange of ideas and a desire for rationalization and administrative organization.

CATHERINE BOUSQUET-BRESSOLIER

SEE ALSO: *Carte de France*; Commission topographique of 1802; Heights and Depths, Mapping of: Relief Depiction; Masse Family; Military Map; Projections: Topographical Survey Plans; Signs, Cartographic; Topographical Surveying; Urban Map

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## *Topographical Surveying.*



***Topographical Surveying in the Enlightenment.*** "Topography (*Land surveying*): a description or plan of any specific site or small area of terrain, such as a city, a town, an estate, a farm, a field, a garden, a castle, a country house, etc. These are the plans drawn up by land surveyors. . . . *Topography* differs from chorography just as the less extensive differs from the more extensive; chorography being the description of a county, a diocese, a province or some other considerable extent of terrain" (Anonymous 1765). This definition, which opens the entry in Denis Diderot and Jean Le Rond d'Alembert's *Encyclopédie*, reflects how notions regarding the construction of geographical knowledge had developed in Europe since the Renaissance rediscovery of the work of Claudius Ptolemy. The starting point for such a development had been Ptolemy's own distinction between geography, which uses mathematical concepts to describe the earth as a whole (that is, not as the object of direct experience), and chorography, which describes individual regions of the earth on the basis of direct observation, producing realistic representations thereof in a language akin to the language of picture making. For Ptolemy, "topography" had no clear and independent connection with these two contrasting terms; indeed, it appeared to be indistinguishable from the latter. This state of affairs continued into the sixteenth and even the seventeenth century (Nuti 1995), even if geographical writings and dictionaries produced in the latter century did show increasing refinement and precision in their definition of the various categories used by Ptolemy (Dainville 1964, 3). Gradually, chorography and topography were distinguished on the basis of the size of the spaces they covered and thus the degree of detail in the representations they offered (a distinction that can be seen in examples cited in the eighteenth-century *Encyclopédie*).

It was, however, only toward the end of the period under discussion—when the introduction of the metric system can be said to have provided a context of uniformity—that the rather vague and ambiguous reference to "small spaces" as the characteristic object of topography gave way to a more precise quantitative definition in terms of scale. Set up in 1802 with the express purpose of simplifying and standardizing the language of topographical cartography, the Commission topographique—part of the Dépôt de la Guerre—defined the relevant terms by reference to a precise threshold of scale: maps at a scale larger than ca. 1:100,000 were "topographical," while those of smaller scale were either chorographical or (if still smaller in scale) geographical ("Topographie" 1803) (see fig. 813).

In the period of transition from the Renaissance to the Enlightenment, topography would undergo more than a gradual refinement of its theoretical definition. There was, at the same time, also a decisive change at the practical level, with huge growth in the production of such works and a vast increase in the areas they depicted (within both Europe and its colonial possessions). The proliferation of topographical surveys—and of the cartographical, pictorial, and textual descriptions they generated—is one of the distinctive features of this period. However, a precise quantification of this increase poses a number of problems that do not arise with regard to geographical or chorographical studies, most of which generated printed and published works. Topographical surveying, by contrast, was expressed in forms now difficult to trace and quantify because they were either heterogeneous and composite (ranging from planimetric renditions to sketches, views, and written memoirs) or produced solely in manuscript (which limited their circulation and scattered extant documents in archives of various types).

The increase in topographical surveying began at the end of the seventeenth century and accelerated throughout the eighteenth. It appears primarily to have been due to the growing military and administrative needs of modern states. Topographical surveys were no longer the occasional studies of circumscribed areas that they had been during the Renaissance; instead, they became the systematic and coordinated study of ever larger regions, ultimately covering the entire territory of the state. Although this was a common trend throughout Europe, the precise timetable of this expansion varied according to the specific political, military, and institutional development of the individual state. Nonetheless, one can still identify three specific factors that played key roles.

FACTORS ENCOURAGING TOPOGRAPHICAL SURVEYING

The first factor was the changing nature of warfare. Although siege warfare remained central to military thinking throughout the seventeenth century, there was a gradual shift away from strategies based on maintaining position to those predicated on movement and maneuver. The first signs of this change may be seen in the wars in the Netherlands and in the Thirty Years' War (1618–48) (De Vries 1994, 35–42). They became more clear-cut as a result of the various European wars of succession and the Seven Years' War (1756–63) (Bousquet-Bressolier 1999, 81–82; De Vries 1994, 41). The Napoleonic Wars ultimately established movement and maneuver as standard military tactics (Widmalm 1990, 200–206). Such a change in military praxis meant that if military strategists planned rapid troop movements and wished to organize a coordinated defense of their frontiers, they needed specific territorial knowledge that went well beyond the sites of individual fortresses. Detailed information regarding the lie of the land and routes of communication, obstacles or protective features, and precise details regarding the distribution of settlements and of the other resources that could provide shelter and supplies for troops could not be acquired from either medium-scale chorographical maps or from large-scale surveys of individual locations. Previously, military engineers had mainly been required to apply their expertise to ballistics and the design and building of fortresses. Now they were expected to develop their knowledge of topographical surveying in order to provide information regarding ever larger areas of terrain—for example, the entire theater of a war or the land and coastal borders where a state was most vulnerable to attack.

The second factor was the gradual rationalization of the borders between European states. From the end of the seventeenth to the beginning of the eighteenth century, the concept of a "natural frontier" became a guiding principle in the negotiated resolution of conflicts (for example, the Treaty of Nijmegen [1678], the Treaty of Ryswick [1697], and especially the Treaty of Utrecht [1713]). The idea of a natural frontier meant great importance was attached to precise topographical surveys of areas where sovereign states came into contact. Detailed knowledge of such border areas was essential not only in preparing treaties (enabling negotiators to obtain the most advantageous territorial concessions) but also in the diplomatic definition of precise borders and in their demarcation on the ground. An increasingly systematic use of topographical engineers to survey border areas inevitably generated its own specific genre of cartography. Although some antecedents existed for these maps in the seventeenth century (Buisseret 1984), the production of such works developed most fully in the eighteenth century, when the boundaries between European states were redrawn after the various wars of succession (Konvitz 1987, 32–41). With regard to the carving up of colonial territories, the role of cartography was sometimes less clear-cut than that of other sources of information (Pedley 1998). Nevertheless, topographical surveys were a fundamental instrument for the expansion and definition of European dominions (Abeydeera 1993, 104).

After military and diplomatic requirements, the third factor that stimulated an increase in topographical surveying was the enlightened reform of civil government enacted by many European sovereigns during the course of the eighteenth century. The implementation of large public works schemes, the supervision and exploitation of environmental resources, the enactment of agricultural improvements, and the introduction of fiscal and administrative reform all turned the topographical survey into an essential political tool that provided practical knowledge that could then be applied in both the management and transformation of territory.

Alongside such sources of information as large-scale administrative surveys and the reports drawn up by scientists and travelers, topographical surveys contributed significantly to the compilation of an exhaustive inventory of the natural and social world and of domestic and colonial resources. In this way, they played a key role in an endeavor that was not only characteristic of the encyclopedic spirit that inspired the Enlightenment but also proved indispensable to the projects whereby nascent modern states consolidated their power. At the same time, the rigorously geometrical grid that provided the structure for topographical cartography would prove to be the instrument that embodied, and imposed, a modern conception of territory and its organization. The rational and standardized image offered by a topographical map not only brought into focus the spatial aspects of certain problems, as for example, those relating to the structure of transport networks or to the jumble of different jurisdictions that was so characteristic of the Ancien Régime states; it also suggested that the solution to such difficulties might lie in a transformation, a rationalization, of space itself. This was the case in the Grand Duchy of Tuscany in the second half of the eighteenth century or in Republican France toward the end of that century; in both cases, topographical surveying and cartography were used to reform the mesh of administrative districts.

Inspired by specific economic or administrative purposes, the resultant topographical surveys produced maps and documents that were almost thematic in content; they focused on the control and administration of specific territorial features or problems. The numerous hydrographical maps produced in the Netherlands, the cartography relating to land reclamation in Tuscany, and the early topographical surveys of the English fens (the last actually the fruit of private initiative) were, for instance, all produced in relation to projects concerning the control of water resources. Another example of such "thematic" topographical surveys was the mapping of royal woodlands and hunting preserves produced in various European states. Similar thematic selectivity in the depiction of territory can be seen in the surveys and topographical maps produced for the planning and implementation of road-building schemes, as for example, the famous plans prepared by the students of the École des Ponts et Chaussées in France (Konvitz 1987, 111–23; Picon 1995).

Such topographical initiatives were developed in specific and contingent contexts and often responded to pressing military requirements. Nevertheless, as a whole they promoted the idea within the minds of sovereigns and bureaucrats that topographical surveys and the production of large-scale maps might become "a routine public activity" at the service of the state (Konvitz 1987, 22). This possibility became a concrete reality in the second half of the eighteenth century, when, at the end of the Seven Years' War (1763), many European states began to organize systematic topographical surveys as part of their peacetime activities. As such operations became firmly established, they tended toward the exhaustive and standardized coverage of the entire territory of the state. The systematic official topographical cartography of the nineteenth century, the general map of the state, developed in effect from an eighteenth-century innovation. Its aim was to create an overall image that would provide much more detailed and precise information than did existing maps, which were compiled primarily from works of chorographical (i.e., geographical) cartography by *géographes de cabinet*. These compilations were proving increasingly inadequate to the needs of territorial government and management.

The work that best embodies the goals behind such a project is the *Carte de France* produced by the Cassini family (Pelletier 2013). Combining the practical requirements of the absolutist state with the intellectual concerns of the Académie des sciences, this enterprise applied astronomical and geodetic methods for the measurement of an arc of the terrestrial meridian to the task of producing triangulation grids of varying extents, which were then used as a framework for detailed topographical surveys, although detailed landscape features were not emphasized. César-François Cassini (III) de Thury himself worked to extend this survey to other European states, contacting various sovereigns to this end, while Jean-Dominique Cassini (IV) proposed the repetition of the project (at both a topographical and geodetic level) for the territories of the Grand Duchy of Tuscany (Pelletier 2013, 112). Nevertheless, the French map remained the unequaled benchmark throughout most of the eighteenth century, and by the late eighteenth and early nineteenth centuries was widely imitated at an international level, as seen, for example, in the English Ordnance Survey (Delano-Smith and Kain 1999, 216–18; Widmalm 1990).

The scientific and organizational model adopted for the *Carte de France* placed greater focus on the creation of a geodetic framework than on procedures of detailed topographical surveying; in fact, the technical quality of the topographical process was open to some criticism (Pelletier 2013, 248–49). It is also significant that this model was not the only one adopted by other European states that tried during the course of the eighteenth century to construct general maps of their own territories. In some cases, the approach was predicated on large-scale topographical surveys of extensive areas (combined with the creation of the first modern cadastres). Carried out independently of a preliminary geodetic triangulation, these topographical surveys and cadastral maps were then assembled or reduced to form an overall picture. This was the solution adopted, for example, in the Duchy of Savoy, where the creation of cadastral maps was from the start explicitly intended to be a step toward the production of a general map of the state. Similarly in the Austrian monarchy, where the first official topographical survey, the Josephinische Landesaufnahme, created between 1763 and 1787 a large-scale map at ca. 1:28,000 but involved no first-order triangulation (Kretschmer 1997, 143); as outlined by Johann Jakob Marinoni, *Hofmathematiker* (court mathematician) to the imperial Austrian court, the procedure to be used in producing this general map of the state required only "the reduction [of large-scale maps] to a smaller size, leaving out superfluous information and carrying out only a few on-site observations and geographical operations" (Marinoni 1775, 108).

During the course of the eighteenth century, the huge increase in size of the territories to which topographical surveying was applied naturally created the need for substantial organization and coordination. In effect, the investment of financial, human, and technical resources was such that it could be borne only by states enjoying a sound economy and a powerful, centralized military-bureaucratic apparatus; even such states as these could not always support the costly endeavor. The demands were such that the Cassini operations in France, initially financed and overseen by the state, later (1756) had to resort to the support of private subscriptions due to a shortage of public funding; subsequently, the whole project was again nationalized by the Convention in 1793 (Pelletier 2013, 189–90). In federal entities like the Netherlands (De Vries 1994, 51) or the Swiss Confederation (Feldmann 1997, 203), the particularism of the local administrations and the financial weakness of their central institutions hindered the implementation of a French-style project for the mapping of the state for decades. Indeed, in such states as Spain, Portugal, Prussia, Russia, and England, topographical projects only got underway (and then with some difficulty) in the last decade of the eighteenth century or the early part of the nineteenth.

Throughout the eighteenth century, it was generally the central government or sovereign that commissioned such works, acting at times in collaboration with military authorities, as for example in Savoy and Portugal. However, these were not the only bodies that played a part in the growth of topographical surveying. Sometimes regional and city administrations supplemented or even assumed altogether the role of promoter: modern topographical maps of provinces, counties, and dioceses served as important instruments of government and as status symbols. Local governments also played their part in France; the Cassini map drew not only on private subscriptions but also on the involvement of various *états* and *généralités* (Pelletier 2013, 174–77), which at times promoted further topographical surveys in parallel with those being carried out for the national map (Pelletier 2013, 205–36).

Finally, topographical surveys of medium-sized areas also resulted from private initiative, carried out by mapmakers of varying social and professional standing (civil or military technicians or local amateurs). They enjoyed the protection and financial support of a wide network of aristocratic patronage and local administrative backing and often worked in connection with commercial publishing interests. Yet while private support for topographical surveys was to be found alongside the state-sponsored schemes in various parts of Europe, it was hardly ever predominant. Among the rare exceptions are the private surveys for the county maps in England (and parts of Ireland), beginning around 1700 and continuing to the middle of the nineteenth century, by which time it ran parallel to the development of the official project of the Ordnance Survey (Delano-Smith and Kain 1999, 81–88; Harley 1965). However, the predominance of private commercial interests in the British Isles may be explained partly by the social and economic power of the local gentry, whose subscriptions supported such schemes, and partly by the existence of a flourishing market for maps that "had few if any parallels elsewhere in the world" (Delano-Smith and Kain 1999, 101). One should also note that in areas of strategic importance, these private commercial initiatives were flanked by military interests—as with William Roy's military survey of Scotland, carried out in the years 1747–55 after the Jacobite Rebellion (Anderson 2009).

TRAINING OF SURVEYORS Whether for military purposes, for use in civilian government and the control of growing colonial dominions, or for mapping of the state as a whole, the development of topographical surveying rapidly increased demand for skilled technical personnel, providing increasingly permanent employment for surveyors. These needs were sometimes met by looking abroad. The internationalization of recruitment existed not only at the higher level of scientists enjoying royal patronage (for example, Jean-Dominique Cassini [I]) but also at the less exalted levels of technicians with middling-rank qualifications. Many of the foreign military engineers at work in the Kingdom of Portugal or the multinational background of the numerous land surveyors employed in drawing up the cadastral maps of Savoy from 1728 to 1731, or the engineers in the British Army's 60th Regiment of foot (the "Royal Americans") provide examples of the porous boundaries of this workforce (Campbell 2010; Blond, Hilaire-Pérez, and Virol 2017).

However, the extensive topographical surveying carried out in the first half of the eighteenth century was made possible primarily by on-site training of unspecialized personnel of varying initial skills and abilities. In many European states, the type of training surveyors had received up to this period had been largely based on practical know-how, involving such informal channels of education as the handing down of skills from father to son or from master to apprentice. This practical, hands-on form of training would, for example, continue for some time to come in the colonies, where technical schools for surveyors made their appearance much later than in Europe (Abeydeera 1993, 103; Edney 1997, 128–32).

Together with the predominance of family links and patronage in the acquisition of professional qualifications, these various and unequal levels of expertise posed numerous problems, especially when such skills were under the rigid control of corporative-type associations. To resolve these difficulties, many European states set about institutionalizing courses of training and standardizing access to the technical professions (such as engineering and architecture) that supplied surveyors. This was particularly the case for the military, with the numerous military schools and academies that appeared all over Europe dedicating ample time to the teaching of mathematics and its practical applications (including topographical surveying and drawing). The earliest such institutions were to be found in the Netherlands, where Prince Maurits van Nassau encouraged the establishment of a school of military engineering within the University of Leiden in 1600 (De Vries 1994, 36). Spain established its most important center as the Academia Real y Militar del Ejército de los Países Bajos (also known as the Academia Real y Militar de Bruselas), in the Spanish Netherlands, with Sebastián Fernandez de Medrano serving as its director from 1675 (Capel, Sánchez, and Moncada 1988, 14–18). However, most of the academies for the training of military engineers were set up in the early decades of the following century—for example, the Real Academia Militar de Matemáticas de Barcelona (1720) and the Académie militaire du Génie à Bruxelles (refounded in 1713 after the Southern Netherlands came under Austrian rule) and joined fifty years later by the Académie militaire de Malines, which played a crucial role in the topographical surveying of the Netherlands (Lemoine-Isabeau 1969, 74–83). These were followed by the Militär-Ingenieurakademie of Vienna in 1717, the Inzhinernaya shkola of Moscow in 1735, the Scuole teoriche e pratiche d'artiglieria in Turin in 1739, the École royale du Génie de Mézières in 1748–49, the Royal Military Academy in Woolwich in 1741, and the Prussian Königliche Ingenieurakademie in 1788 (Del Negro 1992). In England, the special school set up within the Tower of London Drawing Room in 1776 also focused particularly on mapmaking (Marshall 1980, 25).

Only in some cases—most notably that of the French *ingénieurs géographes* (Berthaut 1902; Pelletier 1995)—did this increasing institutionalization of training result in the recognition of military topographers as an exclusive professional category. More frequently, as in the Netherlands and the Austrian monarchy, no distinction was drawn between military topographers and military engineers and the same technicians worked at mapmaking, artillery, and fortifications.

One finds greater variety in training and professional definition for surveyors working outside the military. Nevertheless, there were attempts to regulate the professions of land surveying, architecture, and civil engineering with some structure given to the education provided by the universities. Furthermore, access to these institutions and to the military academies was increasingly subjected to meritocratic considerations that were beginning to function alongside the traditional criteria of social class and family connections (Picon 1995). Together with the usual practical apprenticeship in the field, there were courses in mathematics and technical drawing provided by institutions at various levels. The most elementary of such establishments were the practical training schools for land surveyors, particularly widespread in the colonies, for example, in North America (Bedini 1964, 6–8). The highest-level institutions were the religious colleges reserved to upper-grade technicians, where courses included applied mathematics (Capel, Sánchez, and Moncada 1988), and the universities, where future engineers could engage with the innovations in Enlightenment science (Van den Brink 2000). In some cases, civilian technicians working for the state received the same kind of specialized training as military engineers, supplied by specially instituted schools, such as the one established in France in 1747 for the engineers of the Corps des Ponts et Chaussées (Picon 1992, 1995) or the École d'hydraulique in the Austrian Netherlands, founded in 1773–74 (Lemoine-Isabeau 1969, 73–74).

However, the variety of institutional contexts in which surveyors had to work and the presence of private initiative alongside state patronage (in England, the former actually predominated over the latter) means that no linear trend toward standardized training and professional definition may be traced in Europe. Even in the most advanced European nations, such as France, technical know-how continued to be handed down from father to son through on-site experience. This remained the predominant form of training right up to the middle of the eighteenth century and even longer in the colonies. While there was an increasing tendency toward specialization, throughout the course of the eighteenth century professional divisions remained permeable. Military and civil surveying frequently overlapped or competed with each other, and within civil surveying itself. Similar competition sometimes existed between the neighboring disciplines of topography, land surveying, architecture, and painting. Furthermore, a number of surveys were carried out not by experienced professional cartographers but by self-taught amateur or "gentlemen" surveyors belonging to a wide range of social classes and professions: doctors, clergymen, teachers, merchants, soldiers, and even farmers (Harley 1965; Wallis 1978, 167–68).

The rapid increase in the need for technically qualified personnel naturally stimulated the production of a wide range of manuals dedicated to the subject of land surveying. Continuing and developing the practical geometries produced in the Renaissance, these books aimed to satisfy not only the growing pedagogical needs of military schools and academies but also the practical requirements of technical personnel who wanted to update their knowledge and skills.

Within military academies, manuscript treatises were widely used. Prepared specifically for the courses taught, these contained basic theoretical sections on geometry and trigonometry as well as practical information and instruction on the application and use of surveying instruments. Thanks to both espionage and the official channels of technical-scientific exchange, these works enjoyed a certain diffusion within Europe in spite of


FIG. 817. SURVEYORS IN ACTION. The frontispiece to this popular textbook shows surveyors with plane table, sketch pad, measuring rod, theodolite, and sighting target. From Louis Charles Dupain de Montesson, *L'art de lever les plans* (Paris: Jombert, 1763).
Size of the original: 17.3 × 11.5 cm. Image courtesy of the Special Collections Library, University of Michigan, Ann Arbor (GA236 D93).

their manuscript format. However, they could not compete with the medium of print, which was exploited skillfully by both writers and publishers to promote specialist publications for a growing market (Bousquet-Bressolier 1999, 85–86).

Within the various countries of Europe different traditions in the production of manuals responded to local needs. For example, in England about twenty or so texts were published to meet the specific requirements of land surveying, ranging from William Leybourn's 1650 *Pantometria, or, the Whole Art of Surveying of Land* to William Davis's 1798 *Complete Treatise on Land Surveying* (Richeson 1966, 114–18, 157). The most important texts remained in use for a long time (either in reprints or in new editions) and were even translated into other languages. Various treatises produced in France enjoyed international success during the course of the eighteenth century, not only as translations into English, Spanish, and German, but also as copies entering military libraries or owned by topographers throughout Europe (Capel, Sánchez, and Moncada 1988, 231–35; Sturani 2002, 111n9; Harley and Walters 1977, 18; Galland Seguela 2008, 314–23). The French works that enjoyed the greatest diffusion included both practical treatises on land surveying—for example, Jacques Ozanam's *Methode de lever les plans et les cartes de terre et de mer* (1693) and the various publications by the *ingénieur géographe* Louis Charles Dupain de Montesson such as *L'art de lever les plans* (1763) (fig. 817) and *La sience de l'arpenteur dans toute son étendue* (1766)—as well as texts dedicated to such specialist subjects as the construction of mathematical instruments, for instance Nicolas Bion's *Traité de la construction et des principaux usages des instrumens de mathematique* (1709), or the drawing and coloring of maps such as Henri Gautier's *L'art de laver* (1687) and Nicolas Buchotte's *Les regles du dessein, et du lavis* (1721).

Together with the documents produced at military academies, the works generated by official cartographical campaigns, the rare biographical accounts of the figures involved, and, of course, the extant instruments that have come down to us, these published texts inform us about the techniques of topographical surveying in use from the middle of the seventeenth to the end of the eighteenth century. Hence, they also make it possible to evaluate the impact that the spirit of the Enlightenment had on developments in this field of applied mathematics.

PRACTICE OF TOPOGRAPHICAL SURVEYING In effect, the variety of surveying instruments widely used in the middle of the seventeenth century was much more restricted than those described in the mathematical treatises of the previous century. Although during the sixteenth century and the first half of the seventeenth mathematicians had tried to devise various sophisticated and complex instruments, their efforts came up against the "implacable resistance of hard-headed surveyors," who wanted tools that met practical needs without putting excessive strain on their users' limited command of theory (Bennett 1987, 46). The compromise between these two approaches resulted in the development of a limited range of useful working instruments. From among all those that had been designed and created in the late sixteenth century, this small group would—

for the most part—remain in use up to the end of the eighteenth century (Bennett 1987, 50; Galland Seguela 2008, 313).

Foremost among them were the instruments for angular measurements that were derived from those used by astronomers and navigators. Made of metal (or more rarely wood), these had the shape of a full circle or the sector of a circle with a graduated edge and vanes (alidades) ending in pinnules (see fig. 405). Mounted on a rod or a tripod, the instrument was generally used in conjunction with a compass to make measurements in both the horizontal and vertical planes (depending on how it was set up). One such instrument was the surveyor's circle, derived from a prototype provided by the reverse side of an astrolabe and comprising a graduated circle with a moving alidade made up of two arms hinged to a central compass. Already described in sixteenth-century mathematical treatises, this surveyor's circle would be widely used in the following two centuries—both in England (where Leonard Digges coined its more common name "theodolite" in 1571) and in Europe, where there were such variants as Jan Jansz. Dou's "Holland circle" (with two pairs of fixed sights attached to a graduated circle and another pair of sights attached to a movable alidade) (see fig. 405). In France, however, surveyors preferred the graphomètre, an instrument that was designed by Philippe Danfrie at the end of the sixteenth century and would remain widespread throughout continental Europe up to the end of the eighteenth century (see fig. 407). Mounted on a tripod that could be adjusted to align it on different planes, this comprised a semicircle with a compass and two alidades (one fixed along the diametral line and the other rotating around the circle's center). There is also frequent reference to the use of surveying instruments, again derived from astronomy, in which the circular sector was smaller; in particular the quadrant comprised a graduated quarter circle equipped with fixed and moving alidades being mounted at its center of gravity (see fig. 265).

Much less common were the instruments that combined a number of graduated circles and sectors aligned on different planes, thus making it possible to measure vertical and horizontal angles at the same time (as does the modern altazimuth theodolite): their use at the time was generally limited to England (see figs. 409 and 410). First mention of these instruments comes in theoretical texts dating back to the Renaissance, but there are strong doubts as to whether they actually found practical application. In Digges's *A Geometrical Practise, Named Pantometria* (1571), such a piece is defined as a "Topographical Instrument," while Aaron Rathborne's *The Svrveyor in Foure Bookes* (1616) refers to it as a "theodolite," thus creating a certain ambiguity in English texts as to whether this latter term indicates the more complex instrument or the simpler surveyor's circle (Bennett 1987, 42–49; Richeson 1966, 104–13). Though there is rare evidence of its use as early as the end of the sixteenth century, the altazimuth theodolite would only very gradually establish itself as a practical instrument of topographical surveying; throughout the eighteenth century, it coexisted with the simple theodolite or circle.

The few other instruments of the seventeenth- and eighteenth-century land surveyor were designed to meet practical needs specific to this discipline rather than being derived from existing instruments used in astronomy. One example was the circumferentor, or surveying compass, which consisted of a compass with two sight vanes of fixed alignment (see fig. 400). This differed from the surveyor's circle in that angles were not indicated by an alidade moving along a graduated circumference but shown directly, as bearings, by the position of the magnetic needle of the compass with respect to the fixed axis of the sight vanes. Produced in both metal and wood, the circumferentor is known to have been used with particular frequency in England, and in Ireland and North America it was almost the only instrument surveyors used. This preference in the colonies is explained by the simplicity of the instrument's manufacture and by the fact that ease of use meant all necessary readings could be taken quickly. Furthermore, in North America there was the added consideration that "with the magnetic needle acting as a reference, the circumferentor was appropriate to surveying a new land, uncluttered by artificial landmarks [while in] Europe, the theodolite or plane table was suited to measuring or reproducing the angles already established on the landscape by fields, houses, churches, and so on" (Bennett 1987, 149).

Each of these instruments was used to measure the angles between the sight lines linking the suveyor to chosen observation points or between each sight line and magnetic north. Together with the linear distance between those observation points, the angular measurements enabled the surveyor to map out a scaled grid of regular geometrical figures on which he could plot the observed features of the terrain in relation to each other and to the points of the compass. From the Renaissance, treatises on topographical surveying had proposed the use of optical devices or graduated instruments to solve the simple problems of measuring distance or elevation; by applying Euclidean and Pythagorean theorems regarding triangles, the need for direct on-site measurements of distance was kept to a minimum. From the seventeenth century onward, trigonometrical calculus accompanied and gradually replaced these geometrical methods; the publication of technical manuals and tables facilitated this shift. For a long time, the spread of this theoretical innovation was hindered by the limited mathematical

FIG. 818. SURVEYOR USING A PLANE TABLE. Johann Jakob Marinoni's book explained the details of using his *tavoletta praetoriana,* or plane table, in the process of surveying. From Marinoni, *De re ichnographica* (Vienna: Kaliwoda, 1751), plate facing page 10.
Size of the original: 24.7 × 15.5 cm. Image courtesy of the Department of Special Collections, Memorial Library, University of Wisconsin–Madison.

knowledge of the surveyors themselves, but eventually this fundamental shift to applied trigonometry allowed one to determine all distances from a single measurement of distance by using repeated angular measurements: triangulation (Richeson 1966, 142–88).

Another important surveying instrument, the plane table, was based on entirely different principles (fig. 818; see also fig. 399). This instrument comprised a square (sometimes round) plane of wood mounted on a tripod and used as a drawing board onto which was fixed a sheet of paper (held in place either by pins or a frame). Fitted with pinnules at either end, the moving ruler that ran across this sheet was used to sight the various features of the landscape and then trace the sight lines onto the paper itself. Thus, the base map was drawn directly on site, without resort to calculation, greatly reducing the time necessary for surveying. Though widely criticized by mathematicians, the extreme simplicity of its structure and use made the plane table a great favorite from the beginning of the seventeenth century onward. With the one exception of Russia, where it was not introduced until the late eighteenth century (Goldenberg and Postnikov 1985, 75), it would, with only a few variations, be Europe's most commonly used surveying instrument.

Distances themselves were measured directly using poles and chains, or more rarely odometers (comprising a wheel of known circumference, whose rotations were counted as it was run across the ground) (see figs. 413 and 416). However, even in the eighteenth century, there is reference to distances being estimated on the basis of the number of paces or the travel time between points.

In work regarding roads and waterways and in the measurement of distances over uneven terrain, surveyors would also use levels of various kinds. From the second half of the seventeenth century, however, the age-old plumb line or water levels would be gradually replaced by spirit levels. As for altimetric measurements proper, these would become more frequent only in the eighteenth century, made either by means of a barometer or by using the instruments and geometric or trigonometric techniques employed in measuring distances (Broc 1991, 71–96). However, it was not until the last decades of the eighteenth century and the beginning of the nineteenth that altimetric surveys were systematic enough to permit topographical cartography to offer a geometrical (rather than purely conventional and pictorial) rendition of mountain areas (Dainville 1958).

Though there was no radical innovation in or addition to this group of instruments in the period from the middle of the seventeenth to the end of the eighteenth century, there were gradual improvements that by their increased precision in measuring angles and distances widened the gap between the best graduated instruments and such practical tools as the plane table. The first change came through advances in optical technology, which allowed surveying instruments to be fitted with telescopic sights equipped with lenses and pinpoints or cross hairs for exactly locating the center of the field of view (Daumas 1953, 71–74; Bennett 1987, 63–65). These innovations, initially made in the field of astronomy, were first applied to geodetic instruments in the work of Jean Picard during the 1660s, then extended to the instruments of topographical surveying during the course of the eighteenth century (as the old alidades with pinnules were gradually abandoned).

The second innovation occurred between 1720 and 1770, with the introduction of more advanced methods for the manual, then mechanical, division of the edges of graduated instruments. The techniques that made this enormous improvement in precision possible were developed by specialist craftsmen and workshops in collaboration with scientific academies on state commissions for equipment to be used in important geodetic and topographical campaigns. The more renowned centers of production were Paris (workshops of Pierre Lemaire, Claude Langlois, and Étienne Lenoir) and London (Jonathan Sisson, John Dollond, Edward Troughton, and Jesse Ramsden), where international supremacy in the manufacture of scientific instruments remained unchallenged during the course of the century (Daumas 1953; Bennett 1987; Richeson 1966).

The increase in precision also changed how these instruments were used, a decisive factor being the shift from the geometric surveying of limited sites to the topographical surveying of extensive areas of territory. When Jean-Baptiste Colbert and the Parisian Académie des sciences collected information in the 1660s regarding the methods employed in contemporary mapmaking (Pelletier 2013, 41–71), they discovered that many mid- to large-scale maps were still based on compilations of existing information or, at best, relied only in part on data generated by the use of instruments. The general practice was to use data gleaned from collating different documents and a few on-site measurements of angles and distances made using land surveying methods. Only rarely was the entire territory surveyed in a systematic manner.

The treatises of that time described three basic methods for combining on-site measurements and observations to form the basis of a map. The first of these might be described as a “radial” method. From a central and preferably elevated point, the topographer sighted the most prominent features of the territory to be mapped. Note was taken of the direction of the sight line, and then the distance between the landscape feature and the central point of observation was evaluated. Known to have been used in French mapmaking in the second half of the seventeenth century (Pelletier 2013, 116), this method had the serious drawback of requiring a number of direct measurements of distance; it was therefore unsuitable for large territories. The alternative was a resort to estimates, which necessarily reduced the precision of the final map. Because of these disadvantages, this method was only used for relatively circumscribed areas.

The second method was based on measuring traverses. Within an enclosed polygonal form (such as the banks of a lake or the boundaries of a wood) or along the length of an open form (such as a road or a river), the length of linear traversal segments was directly measured and the compass was used to determine their direction with respect to magnetic north. The combination of these traverses with the angles and distances relative to a few other features of the landscape enabled the topographer to reconstruct an image of the surveyed area. This method might be employed over extensive territory, but here too there were substantial margins of error due to difficulties in the precise on-site measurement of distances and to variations in the compass readings because of local factors. In spite of these drawbacks, the traverse technique seems to have been used widely up through the first half of the eighteenth century, not only in continental Europe (Pelletier 2013, 53; Goldenberg and Postnikov 1985) but also in England and Ireland (Delano-Smith and Kain 1999, 81). In colonial India, in fact, it was still being used in the nineteenth century (Edney 1997).

The third method was intersection, which is commonly known as triangulation. In the process of intersection, the surveyor established two viewing points, the distance between which was known and could be given to scale on the map. From each point, the surveyor sighted the prominent features of the landscape, measuring the angles formed by the sight lines with the line running between the two observation points. The angles might be determined graphically, using a plane table or by graduated circles and similar instruments. The position of each observed feature was determined by the intersection of the two sight lines. This technique substantially reduced the number of on-site measurements of distance: only the baseline between the two observation points was necessary. It was possible to determine the other points either by scale drawing or by the application of geometric or, later, trigonometric methods. The repetition of this procedure made it possible to create a geometric grid—a triangulation per se—that could be used to situate all landscape features with a degree of precision dependant on the quality of the baseline and angle measurements (fig. 819).

The theory of triangulation as a graphic-geometric method to be applied in topographical surveying had been outlined in the Renaissance. However, it would assume much greater scientific weight in the seventeenth century as increased interest in determining the shape and size of the earth stimulated reflection on geodetic procedures. Willebrord Snellius experimented with the method from 1615; however, it was primarily the fundamental geodetic work promoted by the Académie des sciences from 1668 onward that resulted in a more rigorous application of triangulation. Using high-precision instruments and applied trigonometry, triangulation was used to measure arcs of terrestrial meridians running between points whose positions were established via astronomical calculations. Supported and financed by monarchs, the geodetic campaigns carried out during

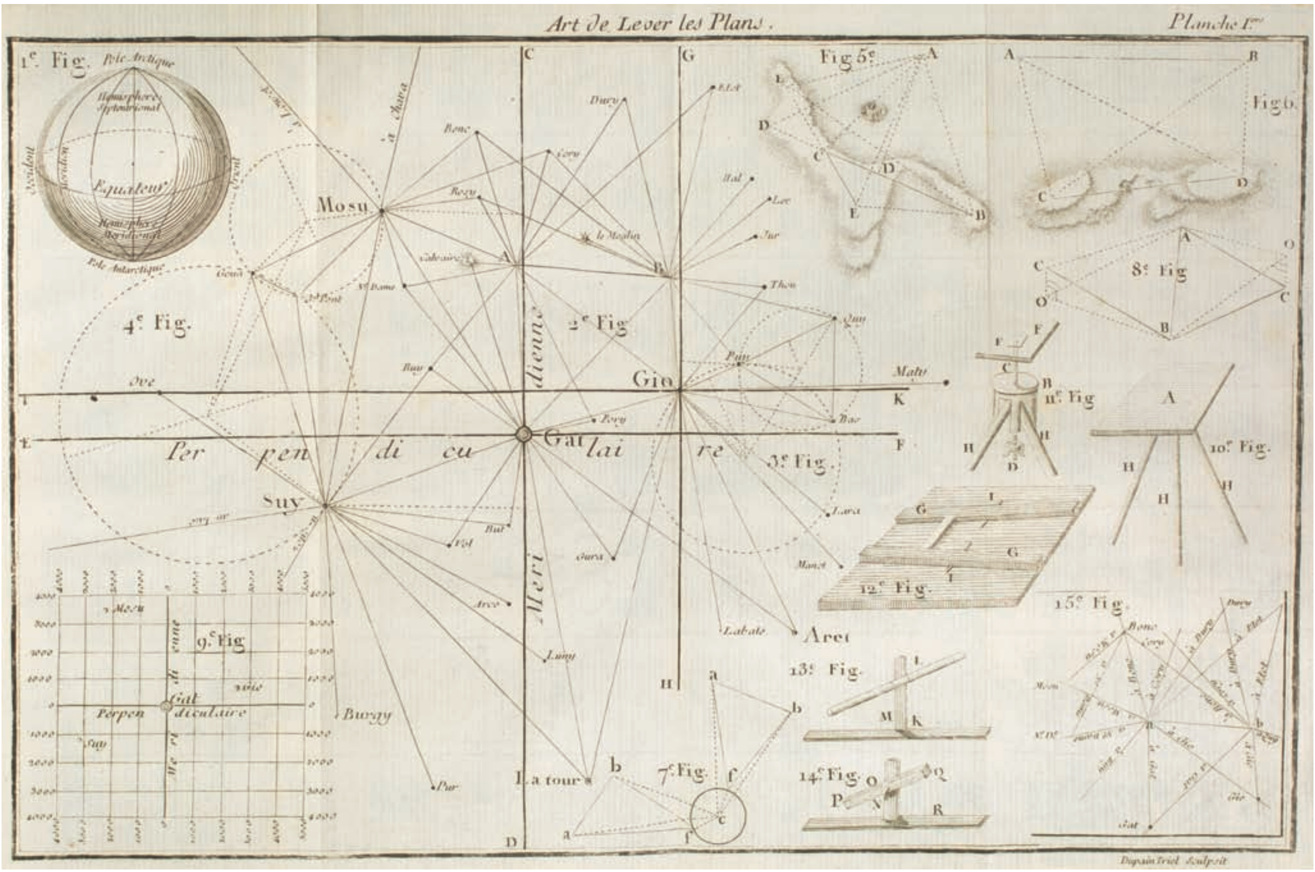


FIG. 819. INSTRUMENTS AND PROCEDURES USED IN SIMPLE INTERSECTION AND COMPLEX TRIANGULATION. From Louis Charles Dupain de Montesson, *L'art de lever les plans* (Paris: Jombert, 1763), pl. I. Size of the original: ca. 19.5 × 31.0 cm. Image courtesy of the Special Collections Library, University of Michigan, Ann Arbor (GA236 D93).

the seventeenth and eighteenth centuries involved the best astronomers of the day and relied on the most advanced instruments, designed and custom made by specialist craftsmen. The result was the development of networks of large triangles—known as first-order triangles in modern terminology—which could be used to establish the precise location of an increasing number of places within a geographical grid; these places could then be used as the precise fixed points for the development of second- or lesser-order triangulation. Thus, it was possible to make detailed, large-scale topographical surveys using a plane table or a compass and chain and then insert the results within a framework that had been established through the use of high-precision instruments and trigonometric calculations.

Trigonometric geodetic triangulation thus generated an extensive grid on national and even international scales that could then serve as the framework for ever smaller grids of triangles, ultimately making it possible to carry out large-scale topographical surveys of the landscape and its features. Linking together astronomical and terrestrial measurements, it functioned like a "geographical panopticon," providing a single schema that framed an increasing amount of information about the world. The accuracy of that schema was guaranteed by the precision instruments and mathematical rigor on which it was based (Edney 1997, 113).

In the late seventeenth and early eighteenth centuries, this combination of trigonometric triangulation and geodetic grids established itself as the most advanced model for topographical surveying. It was used not only in such large undertakings as the *Carte de France* but also, thanks to the influence exerted by new scientific institutions, in mapping commissioned by regional authorities or private individuals (Pelletier 2013, 41–71; Delano-Smith and Kain 1999, 81–84).

The French model appeared predominant for a variety of reasons: first, the growing number of academies generated an international scientific community; second, Napoleon's later dominion over the Continent resulted in the introduction of a uniform technical and cartographic culture throughout Europe. However, it would be incorrect to force the developments in the various areas of the Continent (and beyond) into a single uniform schema of progress. Similarly, it would be misleading to ignore the ample evidence that throughout the eighteenth century, each nation might simultaneously be home to different levels of technical and organizational competence with variations being explained by the individual reasons for a specific topographical survey and the conditions under which it was carried out.

High-precision instruments were costly, complex to use, and required specialized technical skill. Moreover, the organization of large-scale triangulation campaigns was very demanding. Hence, such triangulation was restricted to publicly commissioned topographical surveys of a certain level, which were in part inspired by the most advanced questions raised in contemporary scientific debate. However, there were cases, such as the Austrian monarchy in the second half of the eighteenth century, where topographical mapping developed without being integrally linked with the campaigns of geodetic measurement taking place elsewhere in the same period (Kretchmer 1997; Koeman 1978). There were even cases where the rhetoric of scientific precision merely covered up the technical or organizational shortcomings of the trigonometric surveying operations undertaken (Widmalm 1990; Edney 1997).

Furthermore, the very conditions in which surveyors, particularly military surveyors, had to work also played their part in the survival of outdated approaches. In war, measurements and field observations had to be taken quickly, perhaps even obtained through espionage within enemy territory, and such secretive work could hardly be inspired by the Enlightenment's overt scientific paradigm. Thus, at the height of the eighteenth century, one finds such operations resorting to out-of-date techniques and relying on rough estimates rather than instruments, on information gleaned from existing maps, and on the skillful use of local informers. As Ozanam commented: "Surveying in enemy country requires a man who is daring, resourceful, quick-witted and yet prudent enough to hide what he is about. Because, if he is discovered in possession of the instruments of his trade, circumstances might be such that he would run the risk (as Chevalier de Ville puts it) of lowering a perpendicular at the end of a line—that is, in less geometric language, of being hanged" (Ozanam 1750, 182–83).

MARIA LUISA STURANI

SEE ALSO: Administrative Cartography; Boundary Surveying; Engineers and Topographical Surveys; Garden Plan; Geodetic Surveying: Enlightenment; Heights and Depths, Mapping of; Heights and Distances, Geometric Determination of; Instruments for Angle Measuring; Instruments for Distance Measuring; Landscape, Maps, and Aesthetics; Measures, Linear; Military and Topographical Surveys; Military Cartography: (1) Enlightenment, (2) Austrian Monarchy, (3) Netherlands; Modes of Cartographic Practice; Signs, Cartographic; Topographical Mapping and the State; Topographical Survey Map; Traverse; Triangulation Surveying

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***Topographical Surveying in the Austrian Monarchy.*** See Military Cartography: Military Cartography and Topographical Surveying by the Austrian Monarchy

***Topographical Surveying in Denmark and Norway.*** See Geographical Mapping: Geographical Mapping and Topographical Surveying in Denmark and Norway

***Topographical Surveying in France.*** Father Augustin Lubin defined "topography" as a subset of "chorography," which is the description of a region, a realm, or a country. Both belong to the field of geography. Further refining his definition, Lubin discussed the methods of executing topographical drawings and distinguished two in particular: "by making a geometric plan of the location, with observation of all measures made to scale in toises; . . . by elevation or perspective view" (Lubin 1678, 6–8). The topographic map was thus like a "portrait" of the landscape, dependent upon the same laws as painting (proportions, geometry, perspective) and likewise subject to rules concerning the imitation of nature, which were codified at this time by the Académie royale des Beaux-Arts. Like painting, topographic representation was subject to pictorial aesthetics. Even as it appealed to the eyes, the topographic image had to be geometrically harmonious: the signs that differentiated objects in the landscape had to appear natural in keeping with the principle of imitation.

This assimilation of the "topographic" map into painting was not new. Following the Italian example, maps in the second half of the sixteenth century took the form of wall frescoes. Topographic maps of the first half of the seventeenth century often display a hesitation between pictorial representation and planimetric rigor. On the base map, the engineer or surveyor delineated a horizontal projection with the basic elements of watercourses, roads, natural habitat, and shoreline, but the relief and other objects of the terrain were shown in elevation or from a cavalier perspective.

Around 1650–60, a strict visual coherence was clearly sought after. This was no doubt a consequence of the Scientific Revolution, which for several decades had driven the debate regarding the mathematical expression of space. But the powerful Académie royale des Beaux Arts, which dogmatized the principle of the imitation of nature, also weighed in. Topographic maps were geometric, made "with the ruler and the compass" (from the text of Jacques Gomboust's map of Paris, 1652). Gomboust's map offered a good example: individual houses were no longer depicted, shading alone delimited blocks of houses. Only remarkable buildings were represented axonometrically (in false perspective), maintaining at scale the ground area of the buildings as well as their elevation. The eye of the viewer, elevated above the map landscape, considered features like a battle site, fortifications, or the objects composing the city or countryside as integrated into the planimetric projection of the topography. Thus, the topographic maps of the *commissaire général des fortifications,* Louis-Nicolas de Clerville, were abandoned as narrative and imprecise in favor of those of Sébastien Le Prestre, marquis de Vauban, and his engineers, among whom the most brilliant were Claude Masse and the Naudins. Large-scale mapping was generally carried out by surveying with a graphomètre, and most of the smallest details were recorded on the "minute" or draft. The signs employed imitated the shape of the objects represented. They tended to become generic symbols but their size remained proportional to the scale of the final map. The colors used replicated those of a painter in the countryside. The topographic map tried to emulate as nearly as possible the reality that it represented and, through its interplay of signs, created a synthetic and ideal image of the terrain (fig. 820).

To fit maps appropriately to nature required trained and competent personnel, versed in both mathematics and art. They were difficult to find; Vauban was the first to deplore the lack. At the beginning of the eighteenth century, France's social structure was rapidly changing. The transmission of public office as patrimonial property, a consequence of the growth of the venality of offices established by Henri IV (1604), and the spread of clientelism under powerful protectors sometimes led, beginning with the Regency (1715–23), to the acceptance as engineers of young men who were "not fit to serve" (Blanchard 1979, 177). Up until the middle of the eighteenth century, the *collèges* run by religious congregations (e.g., Jesuits, Oratorians, Doctrinarians) were able to teach the mathematical knowledge needed by future mapmakers, but few colleges offered a complete course including the three years of philosophy that included such mathematics, and only a few students benefited (Dainville 1978). On-site training remained the rule for topographical engineers. Aside from the regimental schools of artillery created in 1720, there was no specialized school before the late 1740s, with the creation of the École des Ponts et Chaussées (1747) and the École royale du Génie de Mézières (1748) (Serbos 1986; Hahn 1986). In addition to military literature, specialized books complemented training. Until the middle of the eighteenth century, these *géométries practiques* (practical geometries) competed with one another to inculcate the basic principles of geometry and to apply them to fortification and surveying. The book trade provided practical guides to architecture and drawing—giving symbols in current use, recipes for making colors, and methods of map design, e.g., Henri Gautier, *L'art de laver* (1687, 1708), and Nicolas Buchotte, *Les regles du dessein et du lavis* (1721, 1722, 1738, 1743) (see figs. 750 and 751). Most of these books were reprinted several times in the first half of the eighteenth century. The bookseller Charles-Antoine Jombert became the principal specialist publisher (Bousquet-Bressolier 1997).

Coincidental with the establishment of specialized schools, the Seven Years' War (1756–63) marked a significant change. The war's broad extent, in Europe and the overseas colonies, required individuals recruited from different backgrounds capable of preparing maps. Under the supervision of Jean-Baptiste Berthier, these *ingénieurs géographes* were trained to draw maps at the topographic scale: from 1:2,400 (fortification maps) to 1:86,400 (general maps) (Berthaut 1902, 1:27–62) (fig. 821). Those who had worked on the *Carte de France*, such as Claude Loupia de Fontenailles, became geodesists, while Louis Charles Dupain de Montesson, trained at the regimental school of La Fère, became a theoretician (Bousquet-Bressolier 1999, 85–92). His publications played an essential role in spreading the practice of terrain operations (including triangulation, transfer to paper, and production of a fair copy) and in codifying representation on topographic maps. Dupain de Montesson's *La science des ombres, par rapport au dessein* (1750) emphasized the importance of shading for representing objects in three dimensions and gave keys to representing different categories of features in the terrain, including gardens (see fig. 752). Translated into German beginning in 1759 and Portuguese in 1799, it would be reprinted in French in 1760, 1762, 1786, 1790, and 1792. His *L'art de lever les plans* (1763) was even more specialized, for it detailed all the operations of triangulation (along with logarithms) and their transfer onto paper (see fig. 819). It was reprinted in 1775, 1777, and 1792, and it was updated in 1804 by J. J. Verkaven, who issued a "second edition" under his name alone in 1811. It was also translated into German (1781). Dupain de Montesson's *La science de l'arpenteur dans toute son étendue* (1766), augmented in 1775 by *Le Spectacle de la campagne*, opened surveying operations to a large


FIG. 820. CLAUDE MASSE, "CARTE DU HUITIEME QUARRÉ DE LA GENERALLE DU MEDOC DU'NE PARTIE DE LA GUIENNE, ET DE LA SAINTONGE," 1709. This large-scale manuscript map (ca. 1:28,800) contains the part of Saintonge northeast of the Garonne, as well as parts of the course of this river toward its mouth and the coast from Royan to Mortagne and a small corner of Médoc. It represents the area at low spring tide, with the numbers showing the depth of the remaining water and anchors indicating good points for mooring.

Size of the original: 64 × 87 cm. Image courtesy of the Cartothèque, Institut géographique national, Saint-Mandé (chem. 258, feuille 8).


FIG. 821. DETAIL FROM THE "CARTE DES CÔTES DE BRETAGNE DEPUIS LE MONT-SAINT-MICHEL JUSQU'À L'ÎLE DE NOIREMOUTIERS." This manuscript map by the *ingénieurs géographes* comprises sixty-one sheets surveyed between 1772 and 1778 on the geometric framework established by Etienne-Nicolas Calon. This detail from sheet ten extends from the coast to fifteen kilometers inland and shows the Bay of Saint-Brieuc on the northern coast of Brittany.
Size of the entire original: ca. 113 × 82 cm; size of detail: ca. 59 × 82 cm. © Service historique de la Défense, Vincennes (Vincennes, J 10 C 289, feuille 10).

public. With editions also printed in 1803 and 1813, the *Spectacle* defined and codified the representation of all categories of features found on large-scale maps.

The works of Dupain de Montesson existed alongside other manuals, such as the indispensable courses in mathematics of Bernard Forest de Bélidor, Charles-Étienne-Louis Camus, and Étienne Bézout, several times reprinted. The book trade thus contributed to the diffusion of cartographic practices and the establishment of codification of conventional signs. This codification, developed from the principle of imitation, was fixed by conventions of execution that allowed a draftsman who had never visited an area to make fair copies of maps with confident consistency.

By the second half of the eighteenth century, after the creation of specialized schools, all civil and military engineers received complete training (including drawing, architecture, and foreign languages). After the suppression of the Jesuits (1773) and the closure of their *collèges*, the reorganization of the Écoles royales militaires in 1776 bore witness to a revolution in thought: the French language received priority; some pupils abandoned Latin altogether. At the École royale militaire de Sorèze (maintained by the Benedictines), for example, in addition to fundamental instruction, students could choose from optional subjects or exercises, including physics, chemistry, agriculture, natural sciences, basic naval principles, foreign languages, music, dance, art drawing, architecture, and mapmaking (Julia 2001, 79–84). Topography was taught by "a very good professor, M. Fleuret, [having come] from Paris and remaining long at the École Militaire" (letter from a student, 10 March 1776, Archives de l'École de Sorèze).

This revolutionary instruction, reinstituted by the Assemblée Constituante (1789–91), focused on the personal development of the individual, a reflection of the period. The ideas of Isaac Newton were made fashionable by famous men and women of letters (e.g., Voltaire, Émilie Du Châtelet). High society was strongly drawn to experiments and *cabinets de physique*. Nature was viewed as a place where tensions and forces were practiced, and whose field of action was tested. Men capable of drawing topographic maps were expected to know mathematics as well as fine arts and mechanics. Even if the principle of the imitation of nature remained the foundation of cartographic representation, measurement assumed considerable importance. D'Hérouville, for example, in instructions given to *ingénieurs géographes* charged with drawing a map of the coasts of the ocean in 1771 (Service historique de la Défense, Vincennes, 3M 277) wanted to show "the locale better than one could do with an ordinary map aided by a boring report" and to make the maps as instructive as possible (Berthaut 1902, 1:46–48). He suggested, among other things, the addition of numerical data in different colors to give the height, breadth, and depth of rivers and the nature of the river bottom. Such instructions could not be executed at the requested scale (1:14,400), but they already reveal a tendency toward abstraction.

While *l'agriculture nouvelle* (the new agriculture) developed and physiocratic thought—by which the circulation of goods and the development of agriculture were the pillars of the wealth of nations—grew, engineers also became actors in local and regional development. They drew anticipated improvements and projects on topographic maps, where the eye might not distinguish fiction from reality. For engineers, these maps argued on behalf of their projects of agricultural development, irrigation, canal building, and land reclamation (fig. 822).

Engineers mastered territory with maps. At the initiative of the *intendant* Daniel-Charles Trudaine, the principal roads of the realm—thought of henceforth as the framework for the circulation of goods indispensable to the new agriculture—were surveyed between about 1740 and 1780 by the engineers of the Ponts et Chaussées. The surveys were refined in several exemplars to form the famous atlas series of the roads of France, known as the "Atlas de Trudaine," in which the cities and countryside of the *généralités* of the realm of France stretch out alongside roads, at a scale of 1:8,640. The maps must *parler aux yeux* (speak to the eyes) so effectively that they became an essential element in dossiers displayed to potential patrons (Dupain de Montesson 1813, 114). Thus, the archives were filled with such projects presented by nonspecialists to the local *intendant*, supporting Voltaire's statement concerning this shift in public attitude: "Around the year 1750, the nation, sated with verses, tragedies, comedies, operas, novels, fantastic stories, moral reflections still more fabulous, and theological disputes on grace and convulsions, began finally to argue about grain" (Voltaire 1771–72, 3:112 [s.v., *Bled ou Blé*]). Like other European cities, all the large French cities furnished themselves with *académies* that passed on new ideas, and their municipalities ordered magnificent geometric plans that valorized their activities and improvements.

In 1777, not long after the accession of Louis XVI (1774), a series of reforms profoundly reorganized society, exacerbating group rivalries and discontent. Some wanted to secure the status and tasks of engineers, whose social role was in full flower. Competition among members of the corps of engineers led to emulation. The printing trade, as described above, played a significant role. Dupain de Montesson, Georges-Louis Le Rouge, and others published model representations, which, in an effort to be as exhaustive as possible even included overseas territories. Only the representation of mountains defied consensus: some preferred to indicate


FIG. 822. DETAIL FROM "PLAN DU BAFFIN D'ARCACHON ET DE SES ENVIRONS," 1776. Surveyed geometrically at ca. 1:28,800 by Clavaux, an engineer and officer of the Dragons de la Légion Dauphiné. This manuscript map of Arcachon Bay presents the projects of colonization of the Compagnie Nezer, including established or projected patterns of settlement and salt flats planned and already created.
Size of the entire original: ca. 108.5 × 86.5 cm; size of detail: ca. 51.5 × 72.0 cm. © Archives nationales (France) (CP/F/14/10276/dossier 2/pièce 2).

variation in relief by hachuring or with shading, with light coming from the northwest; others, suggested using perspective to show differences in height and highlight summits, as did painters like Louis-Nicolas de Lespinasse (1801). No matter what method, it remained necessary to measure the differences in height.

Although imprecise, the trigonometric estimation of heights by sightings with an astrolabe, graphomètre, plane table, or other instrument long remained the most common method. During the Peru expedition (1735–39), Pierre Bouguer and Charles-Marie de La Condamine used this method to determine the height of the Andean chain. Beginning in 1750, other instruments appeared, including the quadrant and the octant, which improved angular measurements (Verkaven 1811, 93–122). Barometers were used to take direct but rough measurements of the heights, although corrections had to be made for atmospherical refraction in order to estimate distances obtained by sightings. In 1774, Gaspard Monge and Jean Darcet tested the variations of mercury. While ascending the peak of Ayré (Pyrenees), they marked reference points with a surveyor's rod every ten toises of altitude change; on the descent, they observed these same reference points with the barometer (Broc 1991, 86).

In addition to the difficulties of estimating differences in altitude, the mode of representation remained problematic. It was common practice to show a succession of summits in perspective, while representing the valley floors two-dimensionally in plan. From 1749 to 1754, the military officer Pierre-Joseph de Bourcet produced the first precise maps of the Dauphiné at a scale of 1:14,400, with reductions at a scale of 1:28,800. He chose to use a zenithal point of view, but he used a


FIG. 823. DETAIL FROM THE MANUSCRIPT MAP OF THE ALDUDES REGION AND OF THE VALLEY OF VALCARLOS. Surveyed and mapped at ca. 1:7,200 under the direction of Mr de Grandpré and M. de Ricardosby of the Ingénieurs géographes des camps et armées, 1768–69.
Size of the entire original: ca. 163 × 88 cm; size of detail: ca. 49.0 × 32.5 cm. © Service historique de la Défense, Vincennes (Vincennes, J 10 C 1344/2 feuille 2).

semiperspective viewpoint to draw the mountain chains and their terracing. The geographic engineers chose a zenithal viewpoint for shading with color wash for their 1768–69 map of the Aldudes (contested frontier between upper and lower Navarre) (fig. 823). A similar mode of representation—fine hachuring—was chosen for the Cassini *Carte de France*. However, this technique was not satisfactory because it eliminated the possibility of placing height values directly on the map. As soon as more precise and systematic measurements of slopes became available, it was necessary to find a more appropriate method of representation. One was established by the Commission topographique in 1802 after an animated debate regarding "the lines of the steepest slope." Like hydrographers who transposed soundings into lines joining equal depth readings, topographers could indicate relief with *courbes de niveau,* or contour lines, but this method was not universally practiced (Dainville 1986, 452). The debate around contour lines allowed for the establishment, at smaller scales, of a system of hachures spaced proportionally to the slope that functioned like shading; at larger scales, contour lines could be used ("Topographie" 1803, 37). The carte de l'État-Major would be born. All that remained to be established was a zero reference point.

Planimetry and the determination of height and depth were no longer disassociated. "All topographic operations were reduced to three kinds of measurements: the measurement of distances, the measurement of angles, and the measurement of altitude or differences in level," wrote Pierre Larousse in his article "Topographie" in the *Grand dictionnaire universel,* vol. 15 (1876, 305, col. 2). Topographic representation surrendered to sections and profiles, abstract visions of relief that created an entirely different mental image of the landscape.

CATHERINE BOUSQUET-BRESSOLIER

SEE ALSO: *Carte de France*; Cassini Family: Cassini (III) de Thury, César-François; Commission topographique of 1802; France; Heights and Depths, Mapping of; Military Cartography: France; Ponts et Chaussées, Engineers and École des (School of Bridges and Roads; France)

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***Topographical Surveying in New France.*** The majority of large-scale topographical maps produced in New France reveal a fundamental need to better understand principal routes of communication. In the colonial environment, these channels were primarily lakes and watercourses, the most important being the Saint Lawrence River, the Great Lakes, and the Mississippi River. More detailed maps also showed roads, relief, cultivated lands, and buildings. Mapmakers, especially the military engineers concerned to plan for defense and development, initially focused on mapping the main colonial cities. All their work remained in manuscript, although the results were sometimes incorporated into the printed smaller-scale maps of the period.

The first precise maps of the Saint Lawrence River were produced at the end of the seventeenth century, responding to high stakes, since the growth of the colony depended on precise navigation of the river, which offered the sole connection to the metropole. In 1685, the *seigneur* and merchant Louis Jolliet presented to the *ministre de la Marine* a large manuscript map of the Saint Lawrence estuary, produced after forty-six trips by boat and canoe. The map included capes, islands, sand bars, and anchorages, together with the courses recommended for avoiding reefs and shoals (Palomino 2007, 196–97). In the same year, Jean Deshayes disembarked in Quebec, sent by the king to map the Saint Lawrence River. Thanks to his observation of an eclipse of the moon and his comparison of times with observations in Paris, he calculated the longitude of Quebec with heretofore unequaled precision. Deshayes mapped and sounded the Saint Lawrence estuary, making notable use of triangulation techniques. He used up-to-date scientific instruments, notably an assemblage that included a cross staff, a compass, and a telescope (Pritchard 1979).

Several royal engineers were sent to the colony to establish or rebuild military constructions. Robert de Villeneuve, one of the first engineers to sojourn in Canada at the suggestion of Sébastien Le Prestre, marquis de Vauban, left several beautiful manuscript plans of Quebec and its surroundings, notably a topographic map revealing the extent of clearance and deforestation along the Saint Lawrence River as well as the locations of lands and houses with a list of inhabitants (fig. 824).

Other talented engineers besides Villeneuve would likewise depict Quebec, Montreal, and other fortified locations in New France. In Acadia, the engineer sieur de Labat drew a map of the surroundings of Port Royal (1710), which had fallen into the hands of the English. While showing the extent of destruction inflicted by the enemy, he also gave an excellent idea of the agricultural landscape alongside the Rivière du Dauphin (Annapolis River) (Litalien 2007a, 166–67).

The engineer Gaspard-Joseph Chaussegros de Léry most influenced topographical mapping in New France. Sent to the colony in 1716 to reexamine the fortifications of Quebec and Montreal, over the course of nearly forty years he prepared an impressive number of manuscript maps and plans (including some plans in relief), which allowed him to describe the topography of particular locales (Charbonneau 1999).

Engineers and draftsmen in Louisiana also described watercourses and their banks in addition to cities and forts. For example, in 1740 Ignace-François Broutin, Bernard Devergès, and François Saucier produced a manuscript map at medium scale showing the Mississippi, the Mobile, and their principal tributaries. The "Carte particuliere d'une partie de la Louisianne ou les fleuve et rivierre onts estés relevés a l'estime & les routtes par terre relevées & mesurées aux pas" (Vincennes, Service historique de la Défense, Recueil 69, no 15) indicates the land paths leading to the region of the Chicachas, an Amerindian nation inimical to the French. Another map (ca. 1726), whose author is anonymous, precisely delimits the indigo plantations of Chapitoulas (a village situated about ten kilometers upstream from New Orleans), while also indicating the location of principal buildings, roads, dikes, and canals for drainage (Litalien 2007b, 177).

The French also mapped the territories occupied by the Amerindians, with varying degrees of precision. Before its destruction in 1650, *Huronia* (the land of the Hurons) had been represented by Father Francesco Giuseppe Bressani (1657) and other Jesuits. Iroquois territory had also been mapped, notably by Jean Baptiste Louis Franquelin, probably in anticipation of a military campaign led by Governor Jacques-René de Brisay de

Denonville in 1687. The cartographer signaled the emplacement of Iroquois villages, the number of huts that composed them, and the paths that linked them to one another (fig. 825).

Although the French had not described their colony in a systematic fashion, the British took on the task after the fall of New France. After British troops had subdued the cities of Quebec and Montreal, General James Murray began in late 1760 to coordinate the survey of the Saint Lawrence Valley, resulting in more than forty large-scale manuscript maps covering most of the seigneurial area in Canada (see fig. 838) (Murray 2006, 37–47). Thanks to this painstaking work, British soldiers acquired a better knowledge of the topography of conquered areas. In addition to being helpful tools for administration and planning, these maps helped to guarantee close military control of the colony. Thanks to the military intervention, the British managed to establish a foundational topographic map, something that the French had never undertaken, probably because of the paucity of colonial population and the small number of mapmakers capable of performing precise surveys, combined with the lack of sustained interest and provision of resources from France (Dujardin 2008).

JEAN-FRANÇOIS PALOMINO

SEE ALSO: Franquelin, Jean Baptiste Louis; New France

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FIG. 824. ROBERT DE VILLENEUVE, "CARTE DES ENVIRONS DE QUEBEC, EN LA NOUVELLE FRANCE, MEZURÉE TRES-EXACTEMENT," 1688. Manuscript map, ca. 1:28,000, of the area around Quebec showing the contemporary state of the clearing of wood and field and the placement of cultivated lands and houses, with a keyed and numbered list of inhabitants.

Size of the original: ca. 75 × 112 cm. © Archives nationales (France) (MAR 6JJ/61 pièce 32).

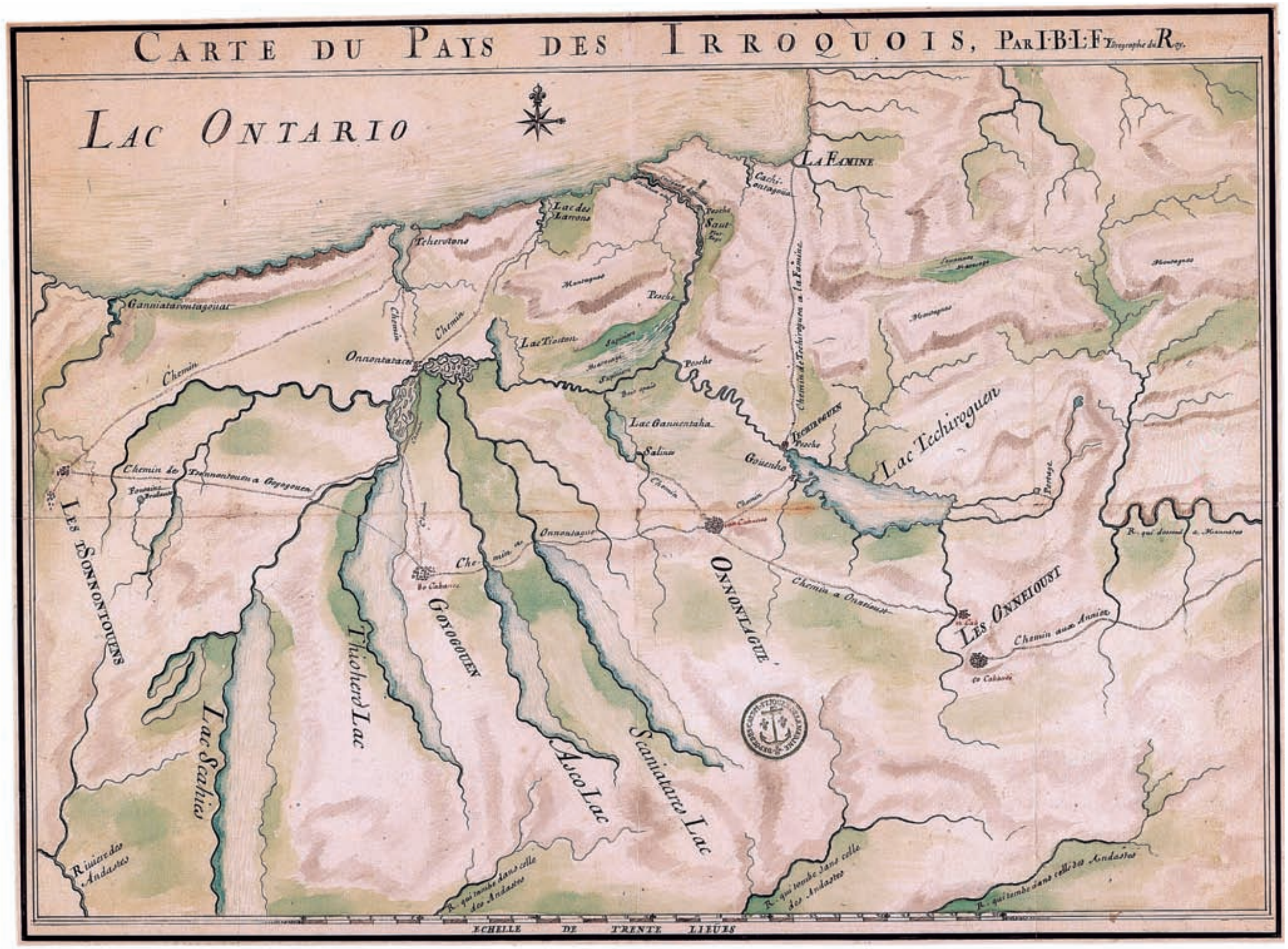


FIG. 825. JEAN BAPTISTE LOUIS FRANQUELIN, "CARTE DU PAYS DES IRROQUOIS," CA. 1687. This manuscript map, ca. 1:465,000, anticipated the military campaign led by the French against the Tsonnontouan (Seneca), south of Lake Ontario, in the summer of 1687. Although the map bears Franquelin's initials, it is unclear if he was in the field or if he based it on someone else's sketch.
Size of the original: 33 × 45 cm. © Service historique de la Défense, Vincennes (MV/71/67-66).

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***Topographical Surveying in the French West Indies.*** Large-scale topographical mapping of the French possessions in the Caribbean really began with the work of Amédée-François Frézier, director of the fortifications of Saint-Domingue from 1719 to 1725, whose work on that island provided important new source material for Paris geographers. His "Nouvelle carte de l'isle de S$^{t}$ Domingue" (1721) and his other manuscript and published maps of coastlines and the outgoing channels of the island, of the Île-à-Vache and the Saint-Louis plain, were used by Paris geographers Guillaume Delisle (*Carte de l'isle de Saint Domingue*, 1725), corrected later by Philippe Buache; by Jean-Baptiste Bourguignon d'Anville (*Carte de l'isle de Saint-Domingue*, 1730, and *Carte de la partie de Saint-Domingue habitée par les françois* included in Pierre-François-Xavier de Charlevoix's *Histoire de l'isle Espagnole ou de S. Domingue*, 1730–31); and by Gilles Robert Vaugondy (*Isles de Saint Domingue* *ou Hispaniola, et de la Martinique*, 1750). Within the Dépôt de la Marine, Jacques-Nicolas Bellin compiled and corrected many maps and memoranda concerning the West Indies, published in *Le Neptune françois* (2d ed., 1753), the *Hydrographie françoise* (1756), and the *Petit atlas maritime* (1764). Despite the criticism of their uncertain longitudes, Bellin's maps were frequently used as annexes to memoranda on the colonies.

Only after the Seven Years' War (1756–63) were topographic maps of the French West Indies prepared that were based on systematic observation and measurement as specifically required by the ordinance of 24 March 1763 that reorganized the defense and administration of the islands (Bousquet-Bressolier and Pelletier 1998, 52). The preparation of these topographic maps was entrusted to the *ingénieurs géographes* attached to the Dépôt de la Guerre, following principles laid out in the "Projet de travail à faire faire pendant la paix par les ingénieurs géographes" (Paris, Bibliothèque nationale de France [BnF], Cartes et plans, Ge GG 13290–292) by the head of the *corps*, Jean-Baptiste Berthier, in 1762, for the ministre de la Guerre, Étienne-François, duc de Choiseul, based on his wartime instructions for the Armées du Rhin. Engineers were to make topographical surveys of the interior of the islands as well as coastal surveys including reefs and barriers on a scale of ca. 1:14,000. Their maps were to show the hydrographic network, types of vegetation and land use, types of human habitation, and topographic information including elevation, soil use, and possibilities for roads. Engineers also were to write accompanying *mémoires* providing further information on the land with tables showing local sovereignties, resources, census, and commerce (Bousquet-Bressolier and Pelletier 1998, 64–65). Their surveying methods were described in *L'art de lever les plans* (1763) by the engineer Louis Charles Dupain de Montesson, who had served in Guadeloupe, and details of how the maps rendered the landscape were described in the same author's *Le spectacle de la campagne* (in *La science de l'arpenteur,* 1775 ed. and later) (Bousquet-Bressolier and Pelletier 1998, 76–85).

On 28 April 1763, twenty-four engineers were assigned to the West Indies: three to Guadeloupe, three to Martinique, two to Sainte-Lucie, and sixteen to Saint-Domingue (Glénisson 2004, 18). Such a comparatively large number of engineers was necessary for Saint-Domingue because the colony, very mountainous and wooded, was much larger (about 26,000 sq km, compared to nearly 1,700 km for Guadeloupe and roughly 1,100 km for Martinique) and far less occupied by settlements than the other French islands. The *ingénieurs géographes* had trained in the Seven Years' War or in the recently formed École du Génie de Mézières for military engineers (1748) or École des Ponts et Chaussées for civilian engineers (1747), or had experience on the survey teams of the Cassini *Carte de France*. In the Caribbean the *ingénieurs géographes* reported to the *directeurs des fortifications*, Henri Philippe Joseph de Rochemore for the Windward Islands and Jean-Jacques Du Portal for the Leeward Islands, to whom they were to deliver their drawings together with descriptive memoranda.

As early as January 1764, Rochemore complained of the poor discipline of the engineers and demanded the return of some to France. Mainly preoccupied with defense work, he wanted to limit the maps to the depiction of coastal areas, sufficient for establishing defensive plans. Notwithstanding these limitations, the large-scale maps of Martinique and Guadeloupe (ca. 1:14,400) were based on triangulation work started in 1764 and finished in 1769. On Martinique, the triangulation survey was run by Claude Loupia de Fontenailles, who also wrote the accompanying *mémoire* for the map. Loupia de Fontenailles received help from Louis Gense and René Moreau du Temple, but it was Moreau du Temple who in 1770 signed the copy of the large manuscript map that was sent to Paris ("Carte géométrique et topographique de l'jsle Martinique," BnF, Cartes et plans, GE SH 18 PF 156 DIV 2 P 17). The map shows the interior and land use of the island but no coastal soundings. By contrast, the Guadeloupe map, completed in 1769, shows no detail of the "inaccessible mountains completely covered by forest" in the center of Basse-Terre, but does display hydrographic soundings along the coast (quoted in Pelletier 1984, 24). The soundings were reported on the topographical map by order of the governor, Pierre Gédéon, comte de Nolivos, who, as early as 1766, wanted a complete map to prepare the defense of the colony (Pelletier 1984, 26).

The situation was more complicated in Saint-Domingue, where the death of three of the engineers forced Du Portal to reorganize the work. In March 1765, faced with financial cutbacks and problems of insubordination, he sent most of the engineers back to France, keeping only four to map the colony. From February to June 1766, the governor, Charles-Henri d'Estaing, requisitioned three of them to prepare nautical charts of the coast, for the defense of the colony, which were later copied and collected into the "Encyclopédie de St Dominigue," presented by d'Estaing to the *ministre de la Marine* in 1766 (there are two copies at Aix-en-Provence, Archives nationales d'Outre-Mer, and two copies at Vincennes, Service historique de la Défense). Nonetheless, these hydrographic soundings were not incorporated into the final topographic map.

In 1769, Du Portal's "three most accurate *ingénieurs géographes*," Sigisbert Mansuy, Antoine-François Sorrel, and Jean-Baptiste Moreau, finished drawing the coast and "perfecting the interior drawing of Saint-Domingue" (quoted in Glénisson 2004, 21). Sorrel prepared maps of

FIG. 826. DETAIL FROM ANTOINE-FRANÇOIS SORREL, "PARTIE DE LA CÔTE ENTRE LA PLAINE DE LEOGANE & LE PORT AU PRINCE," 1767. From the topographical survey of Saint-Domingue by the *ingénieurs géographes*. Manuscript; scale, 1:14,400. Size of the entire original: 47 × 150 cm; size of detail: ca. 33.0 × 55.5 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, SH pf 151 div 3 pièce 10 B).

the coast between Port-au-Prince and Cape Dammarie, especially remarkable for their precise rendering of the topography near the coast, showing different kinds of land use and elevation of the terrain inland (fig. 826). Du Portal had planned for the reduction of the drafts made by the engineers to a general map in seven and a half sheets, at a scale of ca. 1:57,600. Only five of these sheets are known, covering the north, the northwest, and the extremity of the southern peninsula. As they were not based on a triangulation survey, these maps contain important distance and location errors; there is little detail of the interior of the country with topography shown only along the coastlines. Interrupted by Du Portal's departure in July 1769, this general map was probably completed later and may have been used by General Donatien-Marie-Joseph de Vimeur, vicomte de Rochambeau, during the 1802 military expedition (Glénisson 2004, 22–23).

JEAN-LOUIS GLÉNISSON

SEE ALSO: French West Indies

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***Topographical and Geodetic Surveying in the German States.*** As the treaties of the Peace of Westphalia of 1648 elevated the German *Landesherren* and other governors of imperial estates to the status of sovereign rulers, they initiated their own foreign and domestic policies, with many German princes becoming absolutist rulers after the model of France's Louis XIV (r. 1643–1715). This development exerted a varied but considerable impact on large-scale cartography in the individual German states between 1648 and 1806. Due to the sheer number of independent territories of diverse size (over 200 imperial estates, 51 autonomous cities, and 1,500 tiny estates), no comprehensive topographical survey covered the German Holy Roman Empire as occurred in other regions. Thus, only the most important geodetic and topographical surveys of larger territories are described here.

Although Wilhelm Schickard began the first topographical survey based on triangulation in Germany in Württemberg from 1624–35 (Lindgren 2007, 485, 487, 494, 502), it was not until the second half of the eighteenth century that most of the German states were mapped using the principles of geodetic surveying. The intellectual impetus for this effort came from France and the work of the Cassini family on the *Carte de France*. This method of mapping was introduced in many southern German states (Torge 2009, 72) and was motivated by military concerns. The Seven Years' War (1756–63) exposed the lack of large-scale maps of Germany; maps that depicted roads, vegetation, and relief were needed to plan major troop movements and military operations. This dearth led many armies in the German states to establish engineering corps and academies where officers were trained in topographical surveying and were able to lead the often secret surveys. During his occupation of the German states from 1800 to 1813, Napoleon Bonaparte (r. 1799–1814) continued topographical surveys begun at the end of the eighteenth century and commissioned new ones.

In southern Germany, the Principality of Bavaria profited from French experiences when the Bayerische Akademie der Wissenschaften commissioned César-François Cassini (III) de Thury in 1761 to perform a triangulation and topographical survey of Bavaria; from 1765, his colleague, the French *ingénieur géographe* Henri de Saint Michel, continued the work until he was dismissed in 1769. Only two plates were completed and published (1:86,400), depicting the region between Munich and Ingolstadt (Seeberger 2001, 8). Only after Napoleon's victory over Austria and Bavaria in 1800 was the baseline surveyed under the direction of the French engineer and geographer Colonel Charles-Rigobert Bonne. A topographical bureau was founded in 1801, and the first printed plate of the *Topographischer Atlas von Bayern* appeared in 1812.

The "Theatrum belli Rhenani" (1713/15; ca. 1: 130,000) by Cyriak Blödner depicts the entire area of southwestern Germany in twenty manuscript sheets drawn on parchment and also includes regions of the Alsace and northern Switzerland (see fig. 562). The representation of the terrain is noteworthy for its use of shaded relief (Musall and Sperling 2010). Blödner was an officer and engineer in the imperial army and familiar with the current surveying methods. During the War of the Spanish Succession between France and Austria, he prepared maps for the defensive line on the Upper Rhine, an experience he drew on to create the "Theatrum," produced in three copies: two for the Austrian army (Vienna, Kriegsarchiv) and one for the Duke of Württemberg (Budapest, Hadtörténelmi Levéltár); all three share the same catalog designation (Sign. HIII d 344 M).

During the First Coalition War of Austria and the German princes against France (1792–97), Austrian surveyors mapped southern and southwestern Germany from 1793 to 1797 under the direction of *Generalquartiermeister* Johann Heinrich von Schmitt. This work, called the "Schmitt'sche Karte," was considered secret and remained in 198 manuscript sheets (ca. 1:57,600) depicting the territories of Salzburg, Pfalz, Württemberg, Baden, and Hesse-Nassau (Schmitt 1977–). The framework of the map manifests considerable distortions since it was not based on triangulation but was compiled in part from both existing maps and new surveying with a plane table using the baseline method.

Beginning in 1782, Ignaz Ambros von Amman, who held the position of surveyor to the Bishopric of Augsburg, worked single-handedly for a decade on a triangulation of the bishopric using a sextant. In 1793, the theologian and astronomer Johann Gottlieb Friedrich Bohnenberger began to triangulate the Duchy of Württemberg. Beginning in 1798, Amman and Bohnenberger worked together on what would become the detailed topographic *Charte von Schwaben* (62 sheets, 1:86,400; reprinted in Fischer [1988–95]). This covered the Swabian Imperial Circle by including both Württemberg and the Bavarian territories; the map was only completed in 1823, but Amman himself published a single sheet in 1802 that showed the triangulation network and baselines (fig. 827). Both men published books on methods for determining the geographic position of places: Bohnenberger, *Anleitung zur geographischen Ortsbestimmung* (1795); Amman, *Geographische Orts-Bestimmungen im östlichen Schwaben und dessen Nachbarschaft* (1796) (Wolfart 2008).

The smaller states in western Germany are exemplified by the landgraviates of Hesse-Kassel, Hesse-Darmstadt, and Kurpfalz (Electoral Palatinate). Some of these territories were mapped by commissions from sovereigns, while other topographical surveys were based on the private initiatives of scholars and officers. The landgraves of Hesse had promoted mapping in the Landgraviate of Hesse-Kassel since the sixteenth century, particularly under the rule of Landgrave Karl I (r. 1670–1730). Military engineer Johann Georg Schleenstein, who was responsible for fortress building and artillery, obtained the commission to make a topographical map of Hesse-Kassel in 1698. He based his map on the cadastral surveys that had already begun in 1680 and compiled twenty manuscript maps on a scale of 1:52,629. These *Inselkarten*

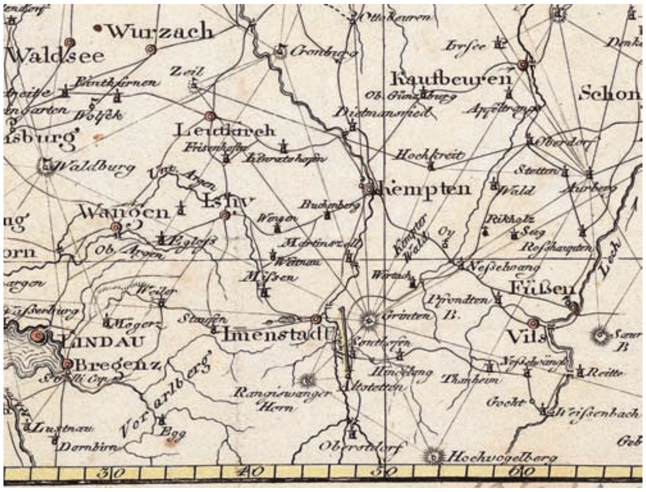


FIG. 827. DETAIL FROM *TRIGONOMETRISCHE CARTE VON SCHWABEN, ZUR ÜBERSICHT DER BERECHNUNGEN, AUF WELCHE SICH DIE NEUEN CARTEN GRÜNDEN,* BY IGNAZ AMBROS VON AMMAN (DILLINGEN, 1802). Copper engraving; ca. 1:830,000. This detail shows the triangulation network on which the 1823 map of Swabia was based. Amman measured the north-south baseline just east of Imenstadt in 1783; it was 3,730 Augsburgische Schuh (some 9700 m) in length. The nearby mountain, Grünten (1,783 m; labeled "Grinten" on the map) was a primary node in the system of triangles.
Size of the entire original: 24.5 × 35.5 cm; size of detail: ca. 8.0 × 10.5 cm. Image courtesy of the Württembergische Landesbibliothek, Stuttgart (Signatur: 19Cg/107).

(isolated maps) depict either a district (*Amt*) or a precinct (*Bezirk*), though their contents often broadly overlap. The direction of river flow is shown with arrows; state and district borderlines as well as the main roads receive the most prominent treatment with relief depicted using graphic shading (Schleenstein 1991).

The Landgraviate of Hesse-Darmstadt was also surveyed by a military officer, Johann Heinrich Haas, whose *Militärische Situationskarte* (1789–1804; 24 sheets, 1:30,400) was initially a project of private entrepreneurship from 1786. His survey was subsequently sponsored by Landgrave Ludwig X (later Ludwig I, r. 1790–1830) and based on plane table surveying by the baseline method using a compass and walking along the line segments (reproduced in Haas 1979) (fig. 828).

The Palatinate of Kurpfalz is represented by the *Charta Palatina* (ca. 1780; 2 sheets, 1:75,000) by Christian Mayer, who had worked as an astronomer with Cassini III on the measurement of a degree of latitude. He was therefore familiar with the methods of triangulation, which he had executed from Strasbourg and Basel to Frankfurt with a quadrant in 1763 and 1772 (Torge 2009, 80–81).

Further west, the Duchy of Kleve and the counties of Ravensberg and Mark were incorporated into the Principality of Brandenburg in 1614. They later formed the western exclaves of the Kingdom of Prussia. In the county of Mark, the pastor Friedrich Christoph Müller initially carried out a survey with a measuring chain and compass in 1775. However, the resulting district map at 1:96,000 had major positioning errors and did not satisfy his own stated goals, so using an English theodolite by John Dollond, he executed a noteworthy triangulation in 1789–90 for his *Die Grafschaft Mark* (1791, 1:187,000).

In northern and eastern Germany during the three Silesian Wars, Prussian king Friedrich II (r. 1740–86) ordered Lieutenant Colonel Carl Friedrich von Wrede to prepare a military map of Silesia between 1747 and 1753, resulting in the "Kriegskarte von Schlesien" (195 sheets, 1:33,333). The manuscripts (Staatsbibliothek zu Berlin) have been reproduced in microfiche with an accompanying text (Wrede 1992). Although Friedrich II recognized the usefulness of good maps for conquering new territories, he had deep reservations about mapping the Prussian heartland, fearing that the maps would fall into the hands of the enemy to be used in a campaign against Prussia. Despite the king's fears, in 1763 Captain Friedrich Wilhelm Carl von Schmettau, the son of Samuel von Schmettau, began to map Prussia on his own initiative. The survey comprised the Prussian territories east of the Weser, eastern and western Prussia, Silesia, and parts of Hesse, Thuringia, and Saxony.


FIG. 828. DETAIL FROM SHEET 4 (LANGEN) OF *MILITÄRISCHE SITUATIONSKARTE IN XXIV BLÄTTERN VON DEN LÄNDERN ZWISCHEN DEM RHEIN MAIN UND NECKAR NEBST ANGRÄNZENDEN GEGENDEN*, BY JOHANN HEINRICH HAAS (FRANKFURT AM MAIN, 1789–1804). Copper engraving on twenty-four sheets, 1:30,400. This detail shows a brickworks and the paths in the gardens of Schloss Wolfsgarten, built as a hunting lodge.
Size of the original sheet: 47 × 63 cm; size of detail: ca. 10 × 13 cm. Image courtesy of the Universitäts- und Landesbibliothek, Darmstadt (H180 4r).


FIG. 829. DETAIL FROM SHEET 89 (BELITZ) OF THE "SCHMETTAUSCHE KABINETTSKARTE," BY FRIEDRICH WILHELM CARL VON SCHMETTAU (1767–87). Manuscript; 1:50,000. Roads, individual buildings, and land cover are shown, with relief indicated by hachures and shading, in the area around Seddiner See, south of Berlin. Size of the original sheet: ca. 56.5 × 91.5 cm; size of detail: ca. 21.0 × 21.5 cm. Image courtesy of the Staatsbibliothek zu Berlin–Preußischer Kulturbesitz (Kart. L 5420, Blatt 89).

Completed in 1787, the "Schmettausche Kabinettskarte des Preußischen Staates östlich der Weser" was not based on a triangulation network but was composed of large-scale district and forest maps carefully fitted together. Although Schmettau lost favor with the king and was dismissed from the army in 1778, he continued his work thanks to the sponsorship of Crown Prince and later King Friedrich Wilhelm II (r. 1786–97) and his minister Friedrich Wilhelm Graf von der Schulenburg-Kehnert. The result was 270 manuscript maps on a scale of 1:50,000 (fig. 829). Schmettau also published the maps for the Duchies of Mecklenburg-Strelitz (1780/82; 9 sheets, 1:35,000) and the *Topographisch oeconomisch und militærische Charte des Herzogthums Mecklen-*

*burg Schwerin und des Fürstenthums Ratzeburg* (1788; 16 sheets, 1:50,000) (reproduced by Jäger 1984–2001). The surveys were primarily based on the work of Carl Friedrich von Wiebeking (Flint and Jordan 2009).

Prior to the Schmettau and Wiebeking surveys, there existed a complete map compilation of every district in Mecklenburg dating from around 1700 and authored by Bertram Christian von Hoinckhusen. The collection comprised twenty-two colored manuscript sheets on a scale of approximately 1:100,000; the originals are in the Mecklenburgisches Landeshauptarchiv (Hoinckhusen 1995). Swedish surveyors had covered the occupied territories of Pomerania from 1692 to 1709, resulting in a total of 1,737 cadastral maps as well as a district map at 1:8,333. For these the Swedes had combined the plane table and baseline methods with cadastral surveying; each map depicts an isolated individual district with property limits (Busch et al. 2015).

The Kurhannoversche Landesaufnahme, carried out from 1764 to 1786 by the Hannoversches Ingenieurkorps under the direction of officer Georg Josua Du Plat and Johann Ludewig Hogrewe, was one of the first and most significant topographical surveys of the Principality of Braunschweig-Lüneburg, also known as the Principality of Hannover. The initial impetus was a civil canal project between the Rivers Weser and Ems to enable a settlement on the moor. From 1765 the project was extended to the entire state since the Prince of Braunschweig-Lüneburg, also King George III of England (r. 1760–1820), had a military interest in it. The topographical survey was conducted with plane tables along a baseline, ten kilometers long, with no subsequent triangulation. The baseline served to join the plane table sheets, which were oriented toward magnetic north. The astronomer and physicist Georg Christoph Lichtenberg determined the longitudinal and latitudinal coordinates for the astronomical orientation of the map in 165 sheets at 1:21,333⅓ (fig. 830). They have been reproduced at full scale in black and white (Engel 1959–62) and in color at 1:25,000 (Bauer 1993).

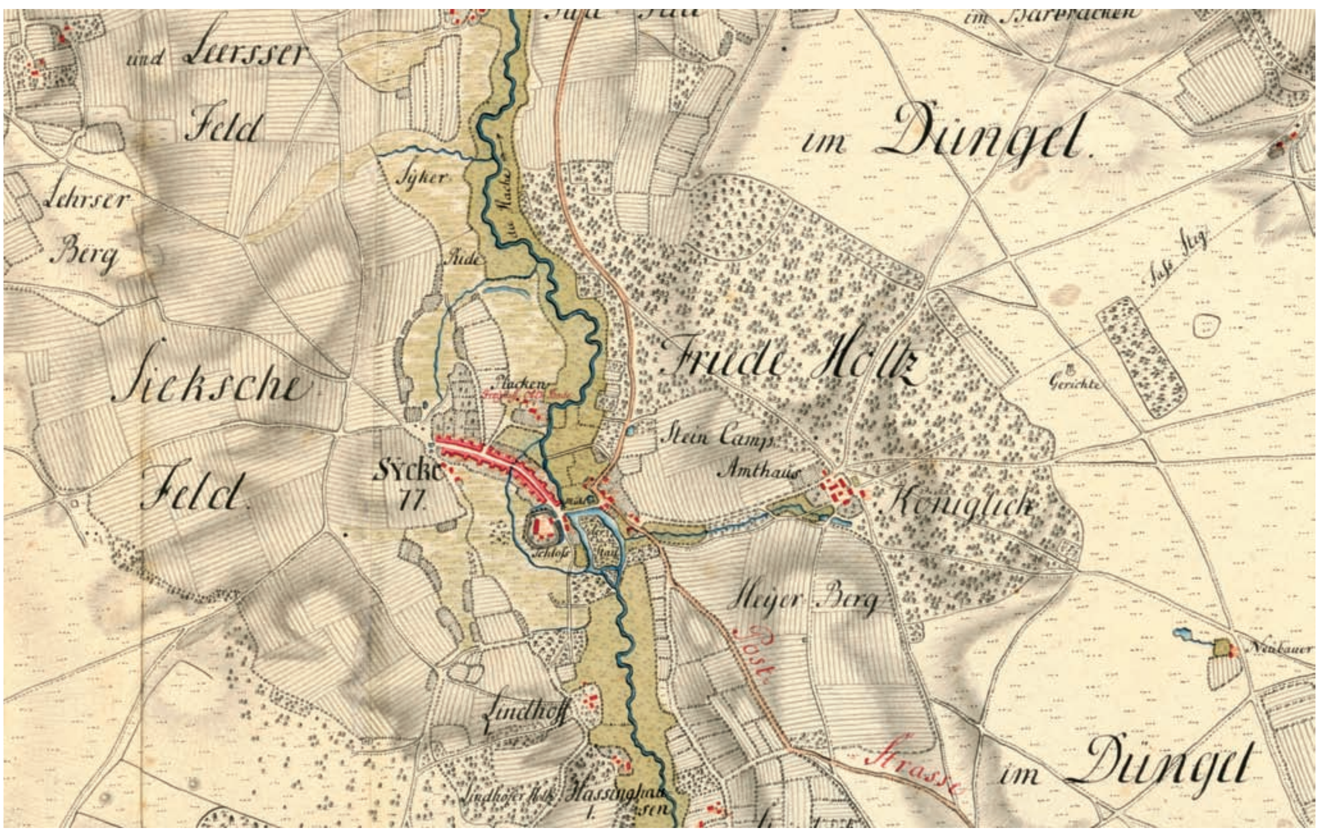


FIG. 830. DETAIL FROM HANNOVERSCHES INGENIEURKORPS, KURHANNOVERSCHE LANDESAUFNAHME, 1773, SHEET 41. Manuscript; 1:21,333⅓. This detail centered on the village of Syke ("Sycke" on the map) shows field patterns, field names, individual buildings, footpaths, a mill, and a gibbet (*Gerichte*). Size of the original sheet: ca. 60 × 99 cm; size of detail: ca. 16.0 × 25.5 cm. Image courtesy of the Staatsbibliothek zu Berlin–Preußischer Kulturbesitz (Kart. N 25564).

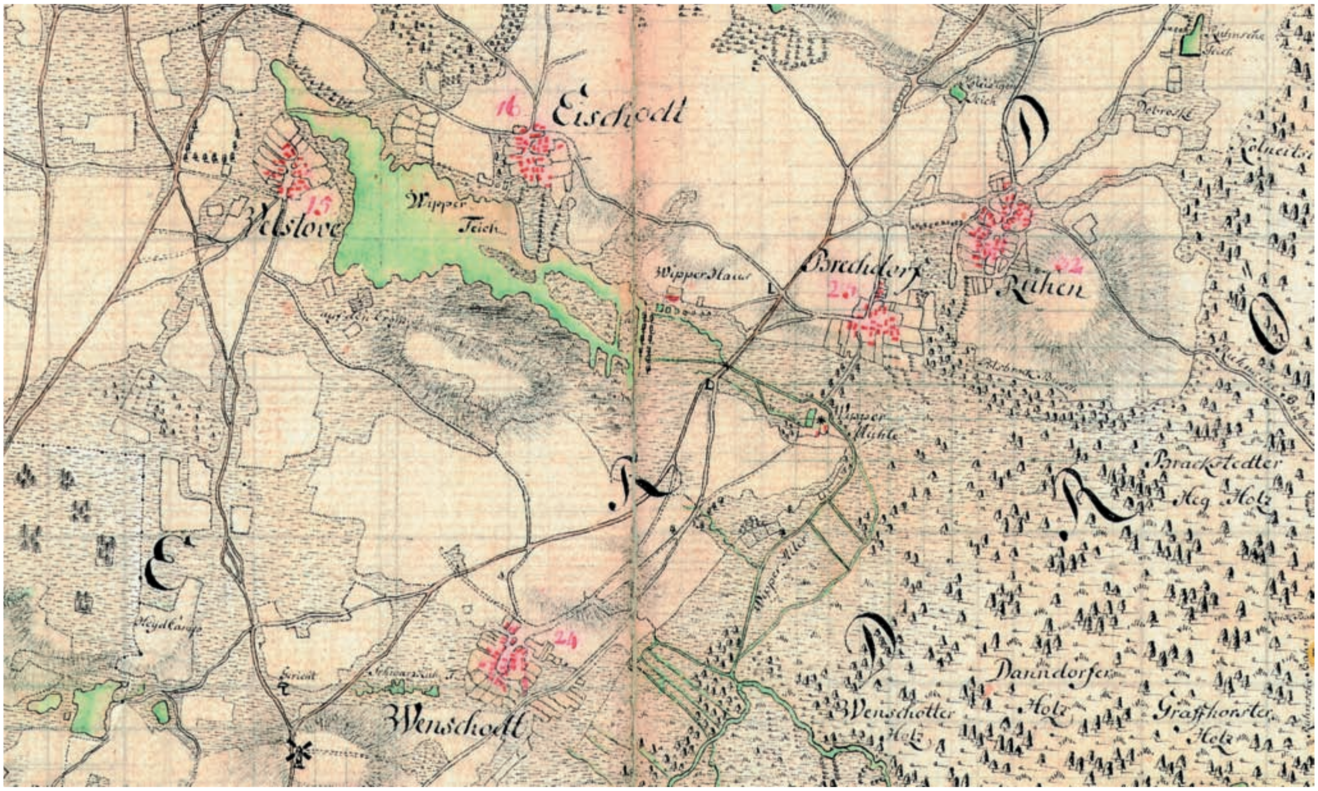


FIG. 831. DETAIL FROM "PLAN DER SCHÖNINGISCHEN-DISTRICTS ZUM HERZOGTHUM BRAUNSCHW. WOLFENBÜTTEL," BY JOHANN HEINRICH DANIEL GERLACH. Manuscript map of the Duchy of Brunswick (1764–70) in six sheets; 1:42,000. The maps include a wealth of detail, including pathways, bridges, post offices, custom houses, inns, forest and hunting lodges, mills, iron, copper, and tin foundries, various types of quarries, abandoned settlements, and field names. The Wipper Teich, a pond south of Eischott, was drained in 1841.
Size of the original sheet: 83.8 × 102.3; size of detail: ca. 10.5 × 18.0 cm. Image courtesy of the Niedersächsisches Landesarchiv–Standort Wolfenbüttel (STAWO K 3, Blatt 2a).

The sheets served as a basis for a military map later in the nineteenth century.

To the east in the Duchy of Braunschweig-Wolfenbüttel, communal forests had been surveyed from 1675 to 1680, followed by cadastral mapping from 1746 to 1784 in forty-eight sheets at 1:4,000. These forty-eight sheets were redrawn (1956–64) at the scale of 1:25,000 and overlaid on contour lines from a modern map; the resulting sheets are available from the Niedersächsisches Landesarchiv, Wolfenbüttel (Kleinau, Penners, and Vorthmann 1956). The original maps served military engineer Captain Johann Heinrich Daniel Gerlach in the production of the "Gerlach'sche topographische Karte" (6 sheets, 1:42,000) between 1763 and 1775, on behalf of Karl I von Braunschweig-Wolfenbüttel (Wolfenbüttel, Niedersächsisches Landesarchiv) (first published in Gerlach 2006) (fig. 831). Although the surveys of the two Braunschweig principalities were not based on triangulation, to the north the maps of the Duchy of Oldenburg were reworked from earlier surveys using an astronomically fixed triangulation network established by Georg Christian Edler von Oeder in 1781–88. After Oeder's death, several other surveyors working under the direction of Dietrich Christian Römer filled in topographical details with plane table surveys between 1791 and 1799, resulting in forty-seven so-called Bailiwick maps (*Vogteikarten*) at 1:20,000 (Harms 1961) (fig. 832). Major Gustav Adolf von Varendorff surveyed the Duchy of Holstein in the far north from 1789 to 1796, resulting in sixty-eight map sheets at 1:26,293, which have been reproduced at 1:25,000 (Varendorff 1999).

In central Germany, pastor Adam Friedrich Zürner was ordered in 1713 by Prince Friedrich August I (later August II, r. 1694–1733) to map the Principality of Saxony. He worked with great diligence until his death in 1742, creating two manuscript copies of the "Atlas Augustæus Saxonicus" each of approximately a hundred sheets of which thirty-seven are *Ämterkarten* (district maps) at 1:120,000 to 1:130,000 (see fig. 954). The atlas also included thematic overview maps and descriptions of the surveying methods, which confirm that they were not based on a triangulation network. The baseline


FIG. 832. DETAIL FROM THE WEST SHEET OF *VOGTEI MOORRIEM I*, 1797, BY HINRICH CARSTEN BEHRENS. Copper engraving; 1:20,000. The long strip farms, each with its own homestead, are formed by the drainage ditches that carry water from the marshlands to the Hunte River.
Size of the entire original: 62.2 × 44.3 cm; size of detail: ca. 31.5 × 25.5 cm. Image courtesy of the Niedersächsisches Landesarchiv–Standort Oldenburg (K-ZE, Best. 298 Vogteikarte Nr. 12a).

method was used with the aid of a special surveying instrument, the *Zollmannsche Scheibe* (Zollmann's disk), which was similar to a theodolite except that the horizontal angles were not read off and recorded as numbers but rather drawn on replaceable paper disks. In effect, each disk replicated a station point in a plane table survey. By placing the disks representing the two ends of a baseline on a large piece of paper, the cartographer would establish the scale of the finished map (which might be much larger than any plane table); graphic intersection would enable the placement of other disks representing other stations (fig. 833). After Zürner's death the district maps served Amsterdam publisher Petrus II Schenk as masters for his *Atlas Saxonicus novus*, which appeared in 1754.

The first triangulation of the state of Saxony took place from 1780 to 1806. Prince Friedrich August III (r. 1763–1827, later Friedrich August, king of Saxony) commissioned the Saxon engineer corps under the direc-

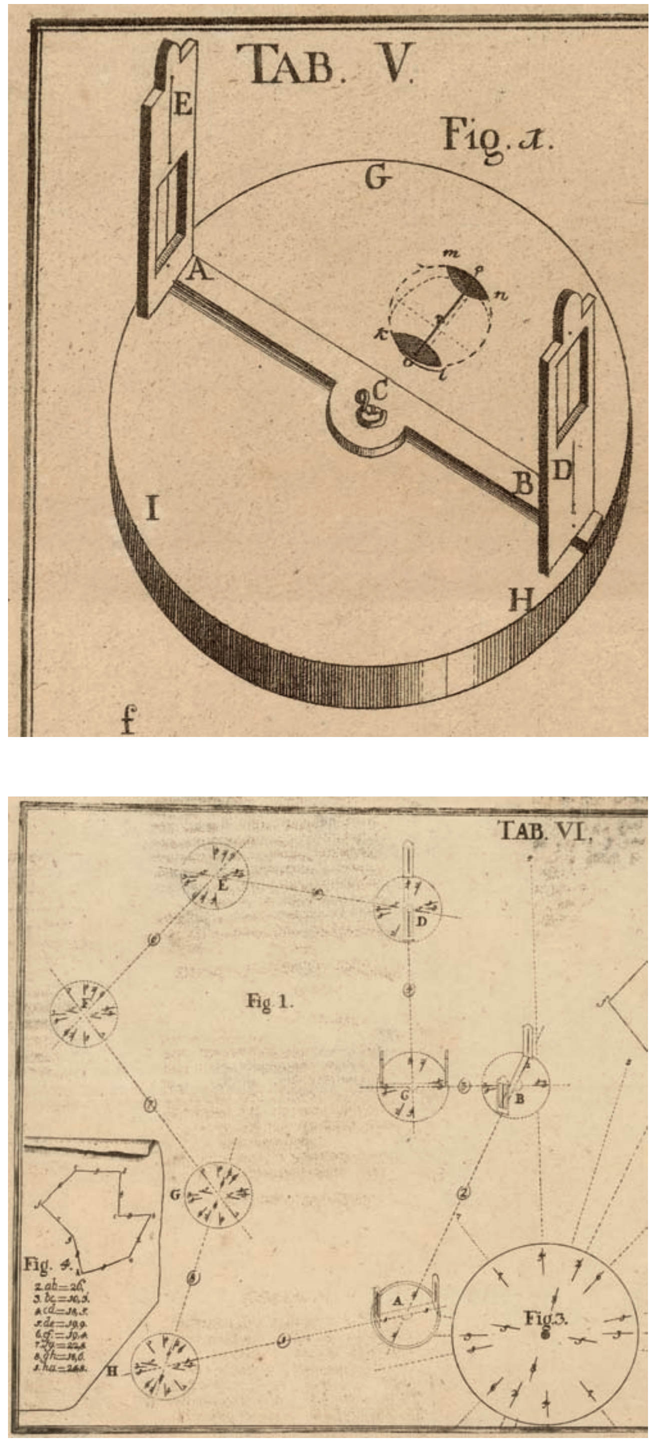


FIG. 833. THE *ZOLLMANNSCHE SCHEIBE*. From Johann Wilhelm Zollmann, *Vollständige Anleitung zur Geodæsie oder practischen Geometrie* (Halle: Renger 1744), details from plates V and VI. The body of the instrument (top) would be oriented by the built-in compass, a circular paper disk laid over it, and the sighting vane or alidade laid atop the disk; the surveyor drew lines on the disk to distant features. The marks on the disks, one per survey station, would then be used to plot bearings in reconstructing the survey on paper (bottom).
Images courtesy of the Bibliothèque nationale de France, Paris.

tion of Major Friedrich Ludwig Aster. He carried out a first-order triangulation with the sides of the initial triangles ten to fifty kilometers long. The baseline at the city of Pirna was 4.2 kilometers long. The main triangulation network was condensed by a second-order network for the plane table survey. The *Hofmechaniker* (court mechanic) Johann Sigismund Mercklein used a theodolite especially constructed for this purpose to measure the angles. A new instrument by the Saxon instrumentmaker Johann Gotthelf Studer was substituted for it in 1798. The coordinates were calculated by plane trigonometry formulas. The sheet lines are at right angles to the baseline, resulting in a northwest orientation for the map. The Napoleonic Wars interrupted the topographical surveying in 1806, but it continued under Napoleon himself and afterward until 1825, resulting in 445 map sheets on a scale of 1:12,000. They were dubbed *Meilenblätter* (mile sheets) since each map sheet depicts a square with sides one *kleine sächsische Meile* in length. The mile sheets exist in three manuscript copies, preserved in Dresden, Berlin, and Freiberg (Brunner 2002) (see fig. 355).

There was no comprehensive sovereign territory for the region of Thuringia but rather numerous small duchies and principalities and exclaves of neighboring states. In the eighteenth century, for instance, the dominion of Schmalkalden was part of the landgraviate of Hesse-Kassel and large regions of the Thuringian basin around Langensalza belonged to the Principality of Saxony; this fragmentation prevented comprehensive topographical surveying of the region. The regions mentioned above were included in the map compilations of the Hessian and Saxon topographical surveys. However, the cadastral survey of the independent Principality of Saxe-Weimar, carried out by Johann Wilhelm Zollmann from 1726 to 1744, is noteworthy (Graf 1918, 38–75). In his *Vollständige Anleitung zur Geodæsie oder practischen Geometrie* (1744), Zollmann describes the angle-measuring instrument and measuring method named after him that Zürner used for the surveys in Saxony. In contrast to Zürner's work, Zollmann's large-scale field survey of Saxe-Weimar was at a scale of 1:1,600. A castle fire in Weimar in 1774 destroyed many of his maps and only a few copies survived in municipal and state archives of Thuringia. Wiebeking, already active in the Duchy of Mecklenburg-Schwerin, also worked in Thuringia from 1785 on the state map compilations for the independent small duchies of Saxe-Gotha and Saxe-Weimar as well as the Hessian dominion of Schmalkalden on a scale of 1:25,000.

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SEE ALSO: Academies of Science: German States; German States; Military Cartography: German States; Wiebeking, Carl Friedrich von; Zürner, Adam Friedrich

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***Topographical Surveying in Great Britain.*** Topographical surveying comprises the representation, at large to medium scales, of the physical and cultural character of a particular place or region. Typically in Great Britain in the eighteenth century, the scale adopted by surveyors and map publishers was one inch to one mile (1:63,360), although there were some local variations. Technologies of topographical mapmaking were both scientific and artistic; maps were produced by direct observation and techniques of measurement closely allied to geodetic surveying with relief interpreted impressionistically rather than measured (although Christopher Packe used barometers to measure heights above sea level in eastern Kent). Eighteenth-century British topographical mapmaking was characterized by developments in multiple settings: individual and institutional, private and military, and local and national.

Mapmaking in Great Britain received a new impetus with the marked economic expansion that followed the end of decades of civil war in 1660. The London map trade responded energetically to growing public demand, but without financial assistance from the Crown and with relatively few subscriptions from the map-buying public, many projects remained unfulfilled. John Ogilby's atlas of English county maps (1675) and John Seller's *Atlas Anglicanus* (1675–81), for example, failed to be completed. With the exception of Ogilby's survey of roads, *Britannia* (1675) (see fig. 866), William Petty's atlas of Ireland, *Hiberniæ delineatio* (1685), and the county maps from Edmund Gibson's reworking of William Camden's 1586 *Britannia* (1695), the topographical mapping of Great Britain had not advanced much by the beginning of the eighteenth century. Revised editions of Christopher Saxton's sixteenth-century maps were still relied on for depictions of English counties; for Scotland, Willem Jansz. Blaeu's fifth volume of the *Atlas novus* (1654), drawing on the sixteenth-century survey work by Timothy Pont, remained the leading authority; for Wales, the only worthy sources were the two maps of north and south Wales in Gibson's edition of *Camden's Britannia* (Walters 1968; Harley 1972; Harley and O'Donoghue 1975; Smyth 2006, 166–97; Stone 2007, 1686–90).

The eighteenth century, however, proved to be highly significant in the large-scale mapping of Britain


FIG. 834. VIGNETTE OF PERAMBULATOR, PLANE TABLE, AND OTHER SURVEYING INSTRUMENTS FROM A CARTOUCHE ON HENRY BEIGHTON'S MAP OF WARWICKSHIRE (1728). Beighton surveyed Warwickshire from 1722 to 1725 (*A Mapp of Warwick-shire . . . Actually Survey'd in the Years 1722, 1723, 1724, 1725*). The wheel of the perambulator shown here appears much smaller than that for which Beighton had advocated.
Size of the entire original: ca. 123 × 116 cm; size of detail: ca. 12.5 × 11.5 cm. © The British Library Board, London (Cartographic Items Maps K.Top.42.78.8 Tab End).

(Delano-Smith and Kain 1999, 81–111). The first published one-inch-to-one-mile county map—of Cornwall by Joel Gascoyne—appeared in 1700, and George Yates's map of Glamorgan (1799) was the last to be issued in the century (Walters 1968; Ravenhill 1991). There was, however, a significant difference in the development of regional mapping between the first and second halves of the century, with the latter period proving more crucial and distinctive. In the first half of the century, no official support for plans proposed by county mapmakers was forthcoming. The fact that Gascoyne succeeded in completing his fieldwork and publishing his map where others failed owes much to the support of a map-minded patron, Charles Bodville Robartes, then lord lieutenant of Cornwall (Ravenhill 1991, 7). Another noteworthy map was made of Warwickshire (1728) by the surveyor Henry Beighton. The map was based on a methodical survey using a perambulator to measure distances (fig. 834) and provided economic and social data about the changing face of the county in the early years of industrial development (Harvey and Thorpe 1959, 19–35). One further exception was *A New Philosophico-Chorographical Chart of East-Kent* drawn by Packe at a scale of one-and-a-half inches to one mile (1:42,240) and published at his own expense in 1743. Richard Gough (1780, 1:492) describes the chart as a "curious performance," showing the countryside within a sixteen-mile radius of Canterbury "wherein are described the progress of the vallies, the directions and elevations of the hills, and whatever is curious both in art and nature that diversifies and adorns the face of the earth." Packe included a wealth of information concerning the cultural landscape of Kent, with the exception of roads.

The period from the 1750s to 1800 was one of remarkable progress in the private mapping of Britain. Notwithstanding the improvements made by local enterprises and the role of the London map publishers, probably the greatest national incentive for stimulating the remapping of Britain was the decision by the Society of Arts to offer money prizes for new county surveys after 1759 (Harley 1963–64, 43–46). In September 1755, William Borlase wrote to Henry Baker, a fellow of the Royal Society, to suggest that the Society of Arts ought to support cartography: "I would submit to you as a friend, whether the state of British Geography be not very low, and at present wholly destitute of any public encouragement. Our Maps of England and its counties are extremely defective." Improvement, he continued, would require the support of government. In the meantime, he suggested that the society, among its premiums for drawings, ought to offer some reward for "the best plan measurement and actual Survey of city or District" (quoted in Harley 1963–64, 43). Doing so would attract public notice and might induce the government to support a national survey. In 1759, the society accordingly offered a premium of £100 for an original county survey on a scale of one inch to one mile; this offer was repeated in 1762 and then intermittently until 1810. Awards were made only after each map was carefully assessed by the society and its accuracy vouched for by residents of the counties; after 1787, surveyors were also required to submit "Certificates of Accuracy," signed by members of the county gentry (Harley 1963–64, 43–46; 1965).

Response to the awards was moderate. Between 1759 and 1801, twenty-three mapmakers submitted claims for awards but only eleven were awarded prizes; a further two awards were made in 1803 and 1808 (Williamson and Macnair 2010, app. 1). The potential for an award attracted a wide variety of people to undertake or supervise the surveys, such as Benjamin Donn, a "teacher of mathematics and natural philosophy on the Newtonian principles" (Devon, 1765), Andrew Armstrong, a retired soldier, with his son Mostyn John Armstrong (Northumberland, 1769), John Prior, a clergyman and schoolmaster (Leicestershire, 1779), and Richard Davis, a farmer, enclosure commissioner, and agricultural writer (Oxfordshire, 1797), in addition to trained surveyors. Several people mapped more than one county. The Armstrongs, for example, surveyed in Scotland in the 1770s, producing maps of Berwickshire (1771), the Lothians (1773), and Ayrshire (1775) before returning south to survey Lincolnshire (1779) and Rutland (1780) (Harley 1963–64, 120, 270–73; 1965, 60–64; 1968).

It is perhaps surprising that at least three experienced mapmakers and publishers failed to receive awards: John Rocque, Isaac Taylor, and Thomas Jefferys. Rocque had surveyed and published maps of Middlesex and Shropshire before 1759, but the Society of Arts deemed his survey of Berkshire (1761) to be ineligible because it had been started several years before the award was first advertised; Rocque died before he could submit further maps of Oxfordshire and Buckinghamshire. Taylor, an estate surveyor, had authored maps of Herefordshire (1754) and Hampshire (1759); his map of Dorset (1765) was rejected, possibly, according to Gough (1780, 1:328), because it was "very faulty in the places names." Undeterred by the decision, Taylor went on to complete surveys of Worcestershire (1772) and Gloucestershire (1779). Jefferys employed some of the best surveyors of the day to map many counties, but never received a society award himself (Harley 1963–64, 121–23; 1966, 42–44).

Not all county surveys were undertaken, however, in the hope of gaining awards; some were the result of local enterprises, funded occasionally by powerful nobles or more commonly by subscriptions. In 1796, for example, John Cary, engraver and mapseller, announced his intention to produce a map of Cardiganshire "under the patronage of Thomas Johnes, Esq.," which was duly published in 1799 (Walters 1968, 144). Subscriptions—upward of two hundred per survey—were sought from the nobility, gentry, and clergy within the county concerned or in adjacent counties. It was not always possible to raise sufficient subscriptions; Peter Perez Burdett failed to do so in Lancashire before successfully surveying Cheshire (1777) (Harley and Laxton 1974). Most, although not all, of the new county surveys were engraved, printed, and colored in London workshops and sold from the same premises. As the first-edition copperplates came up for sale, London publishers often made bids for them; by 1822, at least twenty-eight of the eighteenth-century county surveys were owned by William Faden (Harley 1965, 67). The county maps were not always commercial successes; the necessarily high level of capital investment drove Jefferys into bankruptcy in 1766 (Harley 1966).

In nearly all these county surveys, there was a marked improvement in surveying methods that reflected a


FIG. 835. DETAIL FROM *THE THIRD SHEET OF AN ACTUAL TOPOGRAPHICAL SURVEY OF THE COUNTY OF SUSSEX* ([LONDON], 1783) BY THOMAS YEAKELL AND WILLIAM GARDNER. First state; copper engraving on four sheets; two inches to the mile; the area around Lewes is shown. Known as the Great Survey, the map "[if] executed agreeable to the specimen . . . will be the most masterly performance of the kind which has appeared in this country" (Gough 1780, 2:298).
Size of the entire original (four sheets): 73.5 × 90.5 cm; size of detail: ca. 13 × 24 cm. © The British Library Board, London (Cartographic Items Maps 183.o.2.[2]).

European scientific culture. The key to the new cartography was triangulation. The maps published by Jefferys, for example, included an explanation stating that during the survey of a county, "the great Angles were taken by the Theodolite, & the Roads were measured by the Chain & Transcribed on the Plain Table in the Field" (quoted in Harley 1966, 44). Yates inserted a triangulation diagram on his map of Lancashire "to gratify the curious in Geography; and in some degree to Convey an Idea of the Labour and precision with which this Survey has been carried on and completed" (quoted in Harley 1968, 11); Joseph Hodskinson followed suit on his map of Suffolk (see fig. 875). By 1800, the majority of England, north Wales, and parts of lowland Scotland had been surveyed (albeit in varied styles) by county mapmakers. Each map conformed to a standard scale, achieving greater accuracy with the adoption of trigonometrical survey and the use of astronomical observations to fix precise latitudes and longitudes and provide detailed coverage of both natural and man-made features through topographical infilling (fig. 835). These enterprises in county surveying, combined with developments in British military cartography during the eighteenth century, eventually gave rise to a national survey of Great Britain.

The work of military topographers largely paralleled that of the commercial surveyors. The cartographic duties of military engineers were first defined in 1683 when they were instructed to take "surveys of land" (Harley and O'Donoghue 1975, vii). From these foundations, a scientific corps was built under the aegis of the Board of Ordnance. Between the Royal Military Academy (established in 1741) and the Ordnance Drawing Room at the Tower of London, surveyors and draftsmen were provided with the necessary instruction in geometry, measurement, and art to represent military landscapes. Of particular importance in their education was the drafting and copying of fortification plans and military topographical maps that underpinned a tradition of topographical surveying in British military mapmaking (Harley and O'Donoghue 1975).

One of the first military surveys to be undertaken was of mainland Scotland (1747–55). The survey, undertaken in the aftermath of the 1745 rebellion, was conceived by Lieutenant-Colonel David Watson, quartermaster general in North Britain; Watson directed the survey, but it was executed primarily by his assistant, William Roy. After 1749, Roy was joined in the field by several junior engineers and civilian surveyors and artists, notably Paul Sandby. The finished maps, in their methods of survey and in the conventions employed in drawing the fair copies, represent a British variant of European map culture. The survey parties constructed a geometrical framework from road and river traverses, while hills and other landscape details were sketched in by eye (see fig. 221). Relief was drawn using hachured lines to indicate the direction and gradient of slope; relatively few symbols were used—stylized representations of trees, tilled fields, moorland, and sands and shoals. Notably, the maps were not graduated for latitude and longitude (see fig. 745). In its representation, the military survey of Scotland reflected the Enlightenment understanding that surveying was both a mathematical practice and a painterly pursuit, which had close connections with landscape painting. For the Highlands, it was the only relatively large-scale topographical map in existence in the eighteenth century.

For the remainder of the eighteenth century, the topographical work of British military surveyors turned to other geographical areas where, owing to military and colonial aspirations, the focus of British policy was concentrated. One such area was Ireland. In 1776, Charles Vallancey, then director of engineers in Ireland, secured the king's agreement for a military survey, the most elaborate cartographic project attempted in Ireland since the Down Survey of 1655–59. Directed by William Petty, the Down Survey was the most extensive of the many surveys of Irish plantations. In addition to recording boundaries of forfeited townlands and estates, its maps at ca. 1:10,000 to 1:20,000 contained an inventory of cultivatable lands and areas of bog, mountains, and woods (Smyth 2006, 166–97; see fig. 418). Petty compiled his maps at a reduced scale for his *Hiberniæ delineatio* (1685), which in turn formed the basis for most maps of Ireland produced during the eighteenth century (Gough 1780).

Vallancey's goals and structure for his survey changed repeatedly. His initial plan was to map and describe in a military itinerary the roads and crossroads in southern Ireland, divided into five districts that would eventually be combined into a single map. By 1778, he was mapping large blocks of territory at two inches to the Irish mile (1:40,233). In 1779, Vallancey was redeployed and work on the survey did not resume until 1789, when the Limerick–north Kerry section was mapped. Other than some small extensions into east Limerick and south Clare in 1796, no further work was done on the survey. The fact that the military survey of Ireland did not extend to the north of the country explains why mapmakers only stopped relying on Petty's Down Survey in the second half of the nineteenth century, when it was finally replaced by the Ordnance Survey. Vallancey's techniques were the same as Roy's in Scotland. The final maps provided a strong representation of relief and major lines of communication—a result of measuring traverses and sketching from observation (fig. 836). Unlike the county surveys of the time, however, there was no general triangulation, no latitude or longitude shown, and no evidence of any astronomical observations (Andrews 1966; O'Reilly 2006).

The last decade of the eighteenth century brought together the work of private mapmakers and military surveyors. By this time, Roy had completed the measurement of the baseline on Hounslow Heath and the triangulation to the southeast coast, to connect the Greenwich and Paris observatories. At the command of the Duke of Richmond, master general of the Ordnance, a trigonometrical survey of Britain was begun that would give rise to the first printed Ordnance Survey, a one-inch map of Kent published by Faden in 1801. By the close of the century, a transitional era in county mapmaking had commenced. Private mapmakers availed themselves of the published trigonometrical data provided by the Ordnance Survey, marking the beginning of modern geodetic mapping in Britain. Much of the topographical content, however, was still rooted in an older kind of mapmaking. The incorporation of estate surveys, the copying of published works, the predominant use of road traverses and sketching, all perpetuated traditional methods used throughout the eighteenth century. Additionally, London mapmakers remained the predominant publishers of maps until the Ordnance Survey was fully established in the nineteenth century (Harley 1966).

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SEE ALSO: Great Britain; Irish Plantation Surveys; Jefferys, Thomas; Military Cartography: Great Britain; Packe, Christopher; Roy, William; Scotland, Military Survey of (Great Britain)

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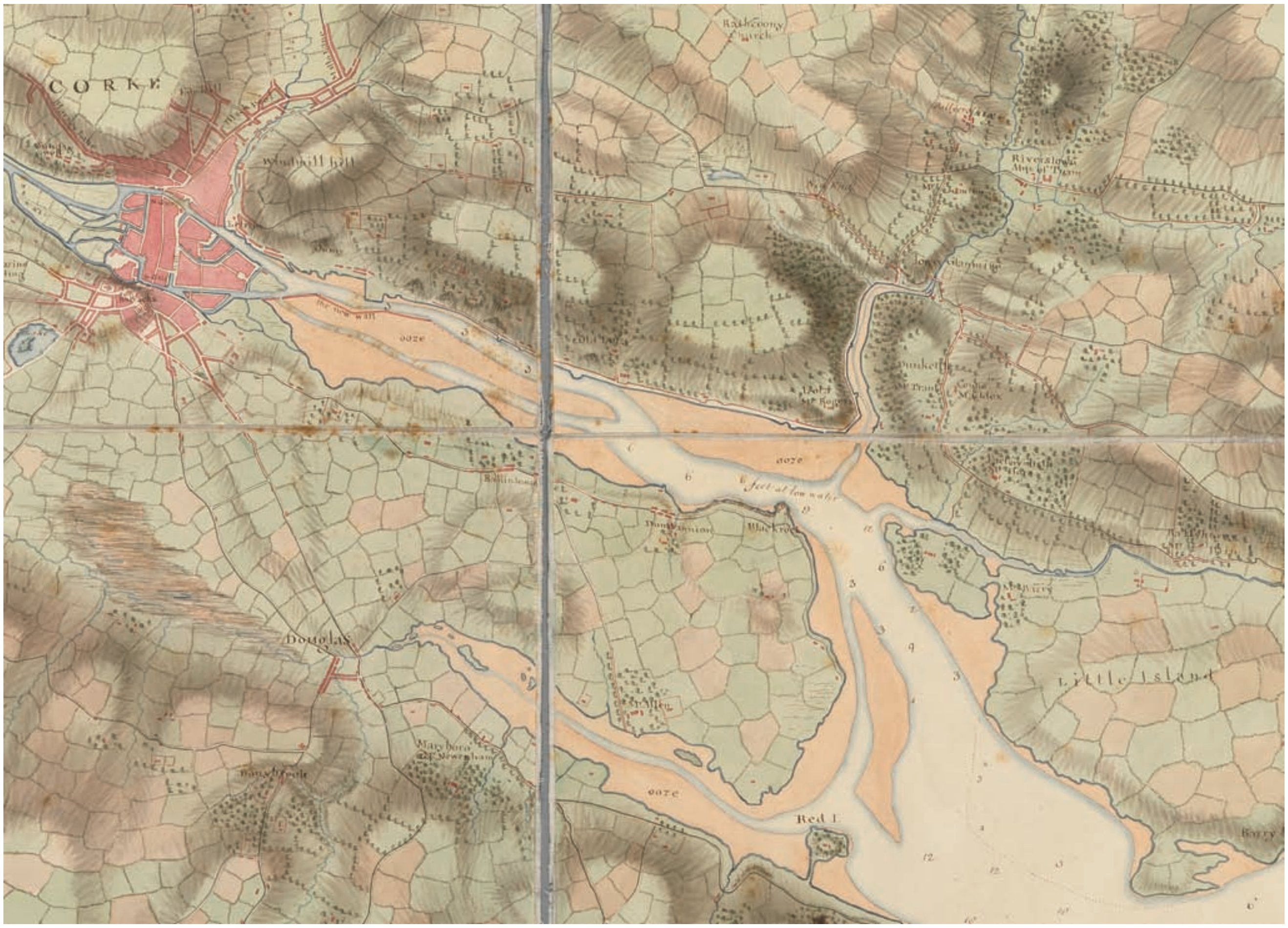


FIG. 836. DETAIL OF THE MILITARY SURVEY OF SOUTHERN IRELAND. Vallancey gave several sets of his work to George III: three volumes of reports with maps and itineraries (1776–78), three cases of plans (dated 1782–90), and a brief treatise on military surveys. This detail of the harbor of Cork, one of several deep harbors in southwestern Ireland in which Vallancey was especially interested because of the risk of invasion, was produced as part of his 1778 survey of coastal areas. Other copies of his work are now housed in the Royal Irish Academy.
Size of the entire original: 213 × 168 cm. © The British Library Board, London (Cartographic Items Maps 6.TAB.37).

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***Topographical Surveying in British America.*** Topographical surveys were only sporadic in British America before the mid-eighteenth century and have not drawn the attention of historians. One of the more sustained topographical efforts, for example, remains unstudied: that of Colonel Wolfgang William Romer, a Dutch-born military engineer who had accompanied William of Orange to England in 1688, inspected, rebuilt, and mapped a series of fortresses across the northern frontier of British settlement both in New York and along the east coast of New England between 1698 and 1706. In addition to detailed plans and views of fortresses, Romer also produced some maps of the environs of forts (fig. 837). The French and Indian War (1754–63, the North American


FIG. 837. WOLFGANG WILLIAM ROMER (ATTRIBUTED), PLAN OF CASCO BAY, MAINE, 1699. Prepared as part of Romer's 1699–1700 tour of the fortifications along the Maine coast. Size of the original: 50 × 34 cm. Image courtesy of The National Archives of the U.K. (TNA), Kew (CO 700/MAINE 3).

theater of the Seven Years' War) introduced larger armies into British America together with European-style military tactics (Marshall 1976). The sustained interest in the details of landscapes led to more topographical mapping, both in association with the French and Indian War (Schwartz 1994) and also during the American Revolution (Harley 1978; Marshall and Peckham 1976). Moreover, after 1760, the London authorities gave orders for several extensive topographical surveys, mostly of the colonial littoral, as part of the General Survey (Hornsby 2011). The primary repositories for these later topographical maps are the King George III Topographical Collection in the British Library, London, and The National Archives of the U.K., Kew, and many have been reproduced both photographically (Hulbert 1904–15) and, more recently, digitally.

The active promotion of the southern mainland colonies led their authorities to sponsor medium-scale general surveys as early as the 1720s. William Mayo's *A New & Exact Map of the Island of Barbadoes* (1722), followed by Edward Moseley's *New and Correct Map of the Province of North Carolina* (1733), represented serious attempts to depict coastal and interior regions. In particular, Moseley's map showed European settlements as far as eighty-five miles inland and detailed the numerous tributaries of major rivers; further inland, it depicted Native American villages and a major trading road (Cumming 1998, 235–37). William Gerard De Brahm's surveys for the governments of both South Carolina and Georgia led to his *A Map of South Carolina and a Part of Georgia* (1757), which not only shows the coastal topography in great detail, but uniquely features a cross-section of the topography of South Carolina's northeastern frontier (see fig. 194).

The French and Indian War permanently established topographical mapping in British America. In 1756, the 60th Regiment of Foot, or the Royal Americans, was dispatched to the American theater. The regiment included several European-trained engineers, including John Montresor, Samuel Holland, J. F. W. Des Barres, Charles Blaskowitz, Bernard Ratzer, William Furness Brasier, and Dietrich Brehm. Together, these soldiers were largely responsible for introducing conventions of military engineering to drafting surveys, including the use of standard scales, colors, and perspectives, and hachures and shading to express contours of elevation (Marshall 1976; Hornsby 2011). One of the first regional military surveys based on careful measurement and observation was Brasier's of Lake Champlain in 1759–62, which was then a critical theater in the conflict; this work was published in London by Robert Sayer and John Bennett in 1776. Starting in late 1760, General James Murray coordinated several surveyors, led by Montresor and William Spry, in the detailed mapping and census taking of the recently annexed St. Lawrence Valley, at 1:24,000. The so-called Murray Map, or Survey of Canada, comprised four large medium-scale maps covering the former New France and an atlas of more than forty smaller detailed maps (fig. 838). It took two years for seven manuscript copies of the total work to be created; the work was never published (Hornsby 2011, 26–30).

Holland's work on the Murray Map informed his 1763 proposal to the Board of Trade for a General Survey of British North America. This systematic program to map British America was financed and directed by the Board of Trade and ran from 1764 to 1775. This was the most intense period of topographical surveying in the colonies (Johnson 2017). Its ambitious goal was to create a general map of all British possessions east of the Mississippi River by incorporating existing works and by the careful creation of new surveys. For the latter, the colonies were divided into northern and southern districts, directed respectively by Holland and De Brahm. Both surveyors general were entrusted with recently fashioned surveying equipment from London with which they executed a finely detailed coastal survey extending two miles inland. From 1765 to 1770, De Brahm's surveys of the east coast of the Floridian peninsula were conveyed in a series of manuscripts and presented to George III in 1773 (De Brahm 1971). The published epitome of the southern survey was Bernard Romans's *Part of the Province of East Florida* (1774) (see fig. 301), issued by De Brahm's former deputy. Holland's priority was to survey the Gulf of St. Lawrence and New England, a particular challenge given the irregular coastlines and highly variable topography of the area (fig. 839). Holland and his team also made detailed surveys of particular islands (see figs. 26 and 374), and of the interior of New Hampshire (published by William Faden in London in 1784). Some of the surveys were separately published, as with Blaskowitz's *A Topographical Chart of the Bay of Narraganset* (1777) (Pedley 2005, 119–55), also printed by Faden in London, but most were combined with other coastal surveys within Des Barres's *The Atlantic Neptune* (1774–82), a work that captured topographical features with particular subtlety through the use of aquatint (Hornsby 2011; Johnson 2017, 239).

While the American Revolution effectively ended the General Survey and other British civilian surveying programs in America, many important topographical maps were published in London by the likes of Faden, Sayer and Bennett, and Andrew Dury. These maps include Montresor's *A Plan of the City of New-York & Its Environs* (1775), Ratzer's *The Province of New Jersey, Divided into East and West* (1777), Henry Mouzon's *An Accurate Map of North and South Carolina* (1775), and Claude Joseph Sauthier's *A Chorographical Map of the Province of New-York* (1779). Moreover, during the war British officers occasionally conducted topographical surveys of areas that were safely behind British lines, for example, Blaskowitz's "A Plan of New York Island, and Part of Long Island, with the Circumjacent Country," 1777 (Richard H. Brown Revolutionary War Map Collection, Norman B. Leventhal Map Center, Boston Public Library). Even after the loss of the thirteen colonies, the British continued to survey their possessions in Canada and the West Indies into the next century.

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SEE ALSO: British America; De Brahm, William Gerard; Holland, Samuel (Johannes)

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FIG. 838. ONE OF JOHN MONTRESOR'S DETAILED PLANS FROM THE MURRAY MAP OF CANADA. "Plan of that Part of Canada and the River St. Lawrence which Lies between Point du Lac and Repentigny on the North Shore & Nicolet and Varrenes on the South," 1761; map has an inset of Montresor's route in July 1761 from the Chaudière to the Kennebec rivers.

Size of the original: 49.0 × 71.3 cm. Image courtesy of the William L. Clements Library, University of Michigan, Ann Arbor (Atl 1761 Mu sheet 16).

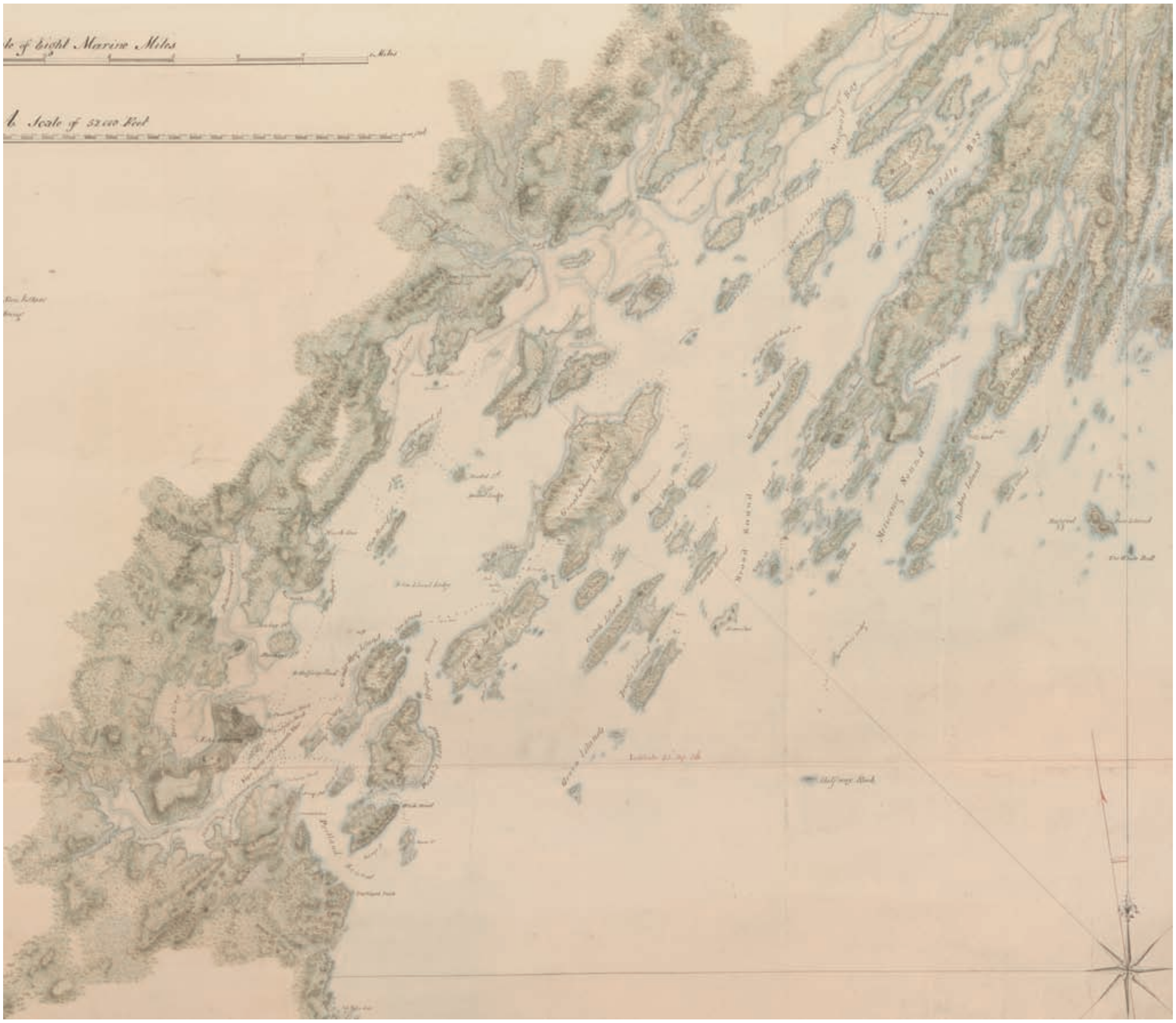

FIG. 839. DETAIL FROM GEORGE SPROULE, "A PLAN OF THE SEA COAST FROM CAPE ELIZABETH, TO THE ENTRANCE OF SAGADAHOCK, OR KENNEBECK RIVER, INCLUDING CASCO BAY," CA. 1772. Sproule was one of several surveyors working for Holland on the survey of the northern district; this detail of the very large manuscript map covers much the same area as figure 837.
Size of the entire original: ca. 253.5 × 159.0 cm; size of detail: ca. 61.0 × 70.5 cm. © The British Library Board, London (Cartographic Items Maps K.Top.120.19).

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***Topographical Surveying in the Italian States.*** Chronologically and geographically, large-scale topographical maps produced in Enlightenment Italy defy description with a simple pattern of development; the inadequacy of that approach is demonstrated by maps made during the early Renaissance, based on instrumental measurements, which appear as innovative in content as cartographic works from the late Enlightenment. Examples are Leonardo da Vinci's well-known map of Imola (1502), Leonardo Bufalini's equally well-known map of Rome (1551) (Ballon and Friedman 2007, 682–85), and the topographical maps of southern Italy commissioned by its Aragonese rulers around the mid-fifteenth century (Valerio 1993, 34–42).

The methods for creating large-scale topographical depictions of cities and larger territories varied and alternated according to subjective factors. Cultural models played a role, along with codes of figurative representation, mechanics of visual perception, and the mapmaker's own technical and scientific ability. However, other factors included "the demands [made of such maps] by the practical requirements of the public" or the representatives of the political-economic powers "for whom the representation was intended"; urban maps displayed notable preference for an "image that gave the illusion of actual appearance" (Nuti 1996, 12)—that is, for renditions constructed using perspective views. These might involve a depiction from an artificially raised point of view, the equally artificial combination of two points of view (one oblique, one raised), or a panoramic representation as seen by a spectator from one particular spot.

Generally the point of view employed by large-scale terrestrial mapmaking fell between the two extremes: a zenithal point of view (as in marine charting) and a horizontal point of view (e.g., coastal elevations or the outline of landscape). Large-scale maps tended more often toward a bird's-eye perspective, which could depict territory obstructed from view in a panorama. Thus, the same drawing or map often combined azimuthal or geometric projections (used to depict the hydrography and coastline) and perspective views (rendering mountain elevations, inhabited areas, and vegetation) (Quaini 1994). The graphic language of mapping gradually moved away from artistic, pictorial representations typical of the Renaissance in part because of the foundation of a centralized corps of military (and, more rarely, civil) mapmakers. This shift was consolidated during the course of the eighteenth century as various Italian states began constructing cadastral maps that embodied geometrically based depictions of specific parcels of land.

A contribution to this process came from large-scale mapping of landed estates in the so-called *cabrei*, documents that not only played a role in the economic administration of property but were also a symbolic reaffirmation of the ideology of an ancient model of power, as can be seen from the fact that during the course of the seventeenth and eighteenth centuries there was an increasing taste for *cabrei* to include decoration, starting with the landowner's heraldic crest (Sereno 1990, 60). Although *cabrei* predate cadastral maps, they continued to be produced after the creation of the geometrically based cadastral maps in the middle of the eighteenth century (Sereno 2002b, 143–44). Their success in Italy is largely explained by their combination of pictorial depiction with geometrical land surveying based on simple triangulation.

> The rural landscape as depicted in the cartography of the *cabrei* is essentially a two-dimensional landscape. Rigorously to scale, the terrain depicted by the land surveyor lies on a plane defined by measurements of length, width, and area. But the *cabrei* further embodied a more subtle significance, which required that on this skeletal framework the configuration of the landscape should also be rendered—watercoloring and bird's-eye perspective being used in accordance with the rule of beauty as an imitation of nature. Thus, from a cartographic point of view, the *cabreo* map is a hybrid document, part geometrical survey, part pictorial rendition. (Sereno 1990, 61)

During the eighteenth century, measurements based solely on ad hoc visual evaluations slowly fell into disuse due to the gradual introduction of techniques of instrumental measurement (Galliano and Miroglio 2001, 219). Their ability to use these instruments distinguished the new land surveyors from the old, with many states laying down specific rules requiring practitioners to be skilled in such techniques and in the application of trigonometry in measurement. Nevertheless, up to the middle of the eighteenth century even the best small- or medium-scale maps were based more on empirical procedures of land surveying than on the dictates of astronomy and geodesy as sciences. In other words, it was only with regard to topography that such maps could be said to have "some geometrical basis, the representation of the forms of terrain were purely indicative, that is drawn up in accordance with a system known as *alla cavaliera* [providing a "horseman's view"] of mountains seen in semiperspective and with a total disregard for precision altimetry. . . . All such maps were drawn on a simple plane, with no account taken of the spherical form of the earth. Similarly, there was no standardized network of degrees, no attempt to pinpoint the location of sites on the earth's surface through the use of suitable astronomical points of reference" (Mori 1903, 19). The one exception in the seventeenth century appeared in the Piedmont House of Savoy when, in 1680, the state engineer Giovanni Tommaso Borgonio published his *Carta generale de stati di sva altezza reale* (ca. 1:190,000), constructed both from available official cartography and specific on-site surveying (see fig. 108) (Sereno 2007, 848–52; Massabò Ricci and Carassi 1987, 277).

Various Italian states witnessed the foundation of official mapmaking institutions during the Enlightenment. In the Kingdom of Sardinia, a military corps of topographical engineers was set up in 1738, specializing in surveys for military purposes and also in the representation of entire areas of territory; a similar corps of military engineers had already been established in Genoa between 1710 and 1717 to apply more advanced techniques toward the supervision of the state's defenses and borders. In the 1760s the Duchy of Parma founded a corps of military engineers in conjunction with the preparation of a geometrically mapped cadastre. In the Grand Duchy of Tuscany, the corps of military engineers, headed by Colonel Odoardo Warren, was founded in 1739 but was concerned almost exclusively with fortifications until its disbandment in 1777. The other civil offices of state administration continued to use practitioners who received in-house training provided by the public administration. Naples had no specific body trained for cartography until Giovanni Antonio Rizzi Zannoni created the core of the Officina Topografica in 1781–84, which produced a number of innovative cartographic works from the late eighteenth to early nineteenth century. In Lombardy, the first body responsible for cartography was established in 1798 by the French occupying forces, the Bureau topographique del Comando dell'Armata d'Italie, initially staffed exclusively by French engineers under the command of Captain Léopold Berthier; in 1805, the Bureau became the Deposito Generale della Guerra del Regno d'Italia (Cantile 2007, 32–38; Quaini 1983, 26).

Though these attempts aimed at centralizing cartographic production as well as subordinating it to political requirements, by the end of the eighteenth century "production [within each Italian state] was still far from achieving standardization in procedures for the gathering and handling of geographical information and in the formats and techniques of representation. Such uniformity would become a concrete reality only after the unification of Italy" (Cantile 2007, 38).

Military maps were the newest and most expert form of the cartography produced at the time. They were distinguished by

> a spatial rendering of the "landscape" that was represented figuratively in painting, their topography being based on a network of points not organized in relation to one specific point of view. . . . This is true both of the geometrical maps, based on measurements, and of "illustrational" maps, not infrequent even in military topography, which were based on rule-of-thumb visual assessment with no resort to a geometrical frame of reference. The legibility of such a territorial model, or *tipo,* as the map was called, required that the representation include a rendering of the landscape . . . understood not as a panorama as such but rather as a combination of territorial forms, depicted in outline and color. Not yet abstract in conception, neither were these maps pictorial representations. However, they did share the naturalism of contemporary landscape painting by drawing on both the latter's techniques of representation and even the methods of preparing watercolors. (Sereno 2002a, 96n48)

Certainly from the middle of the seventeenth century, thanks partly to the work of Galileo Galilei and the experimental approach he championed, there were developments within the field of optics, which led to gradual improvement in both the precision of information and the techniques used in rendering it cartographically. The old sighting tools and instruments using pinnules were replaced by telescopes with lenses equipped with right-angled grids that allowed ever more precise measurements. At the same time, the use of the plane table became widespread and the application of trigonometry meant that surveying procedures were simplified; it was no longer necessary to measure so many distances directly (Sturani 2002, 106). Although high costs initially restricted its use to scientists, the precursor to the modern theodolite, an avant-garde instrument from England that combined a quadrant and eyeglass with a half-circle for vertical measurements, slowly became widespread from the mid-eighteenth century (Sturani 2002, 109).

The progress of large-scale mapping during the Enlightenment, particularly in the measurement of private landed estates and the establishment of state borders, was partly linked to growing government legislation regarding the professional qualifications required of public land surveyors. Around Milan, the duties of both architects and land surveyors had been subject to definition as early as 1497, with a corporation (*collegio*) of such professions active in the sixteenth century. Here, as elsewhere, the "family dynasty" principle was soon established in the craft as technical know-how passed from father to son (Palmucci 2002, 50). The pattern in Lombardy was repeated in similar forms in other Italian states.

In the seventeenth-century, Italian engineer-architects and land surveyors practiced measuring angles, distances, and heights in order to survey fortifications, cities, and state boundaries and to map landed estates. Measuring instruments exploited Pythagorean and Euclidean theorems regarding right triangles and other geometrical figures: a prepared right-angled grid helped to calculate distances and surface areas (Sturani 2002, 104–7). The government of the Duchy of Savoy exerted control over these technicians through the *Misura general* (or *perequazione* [reform]), legislated in 1677 and enacted from 1698 to 1711. The entire operation produced only descriptive data (based on both measurements and estimates of distances and areas), relying on the work of dozens of urban and rural land surveyors, expert and loyal individuals who employed topographical techniques and instruments that were innovative for their day. Nevertheless, the results exposed the errors and failings of many of the technicians involved, revealing the need to establish "the bases for the professional definition of a new type of technician" (Palmucci 2002, 50–51). Hence, the *Regolamento per gli ingegneri civili siano architetti, e militari, e misuratori ed estimatori* of 1724 was enacted, which instituted a professional register with exams for admission to the distinct professional categories of engineer-architect and land surveyor.

In the early eighteenth century, large-scale projects for a geometrically based cadastral register (initiated in Austrian-ruled Lombardy in 1718 and in Savoy-ruled Piedmont in 1739–40) provided engineers, architects, and land surveyors with a task that progressively challenged their professional abilities—even if many technicians found themselves in difficulties due to their lack of familiarity with the plane table (*tavoletta pretoriana,* an instrument more advanced than the more familiar *squadro agrimensorio*), the level, and the compass (Palmucci 2002, 50–54).

During the eighteenth century, topographical mapping in Italy began to mirror the situation elsewhere in Europe with regard to both techniques for constructing maps and the greater role of maps in determining or applying territorial policies. With increased frequency, maps began to consist of a geometrical representation that eschewed pictorial figuration; the mapmaker increasingly had to conform his abilities as a craftsman to the demands of an abstract and impersonal geographical knowledge that was becoming the new model of truth that maps were expected to respect. However, even though maps were no longer constructed on a rule-of-thumb visual assessment but by means of instruments used to calculate angles, distances, and sometimes even heights, perspective-pictorial depictions continued to coexist with horizontal projection during the first part of the century. For example, Matteo Vinzoni, a gifted and prolific cartographic engineer who worked for the Republic of Genoa from 1710 to 1770, produced very effective depictions that combined horizontal projections with the *alla cavaliera* perspective—a mix that became completely outmoded only at the beginning of the nineteenth century, when a system of horizontal projection also depicted mountain formations. Vinzoni's substantial output offers a paradigm for how the language of cartographic draftsmanship and the level of technical-professional ability developed throughout the Italian states during the century of Enlightenment.

Panfilio Vinzoni, Matteo's father and first teacher, had also worked for the Genoese Republic and had been appointed to map its territorial boundaries. However, his work embodied a sort of flat *vedutismo* on which Matteo innovated by striving to "include within a perspective view of the mountains a representation of the hidden side of such ranges, creating new systems of depicting mountain relief that made a more ample use of hatching and color" (Quaini 1986b, 92). The first signed cartographic work by the young Matteo was the so-called "Carta della Selva della Pertegara," 1711 (fig. 840). It clearly shows "progress . . . not so much in the rendition of settlements and vegetation as in the use of perspective drawing to render elevation, with pen-drawn hatching and shading created in black and red, the two colors that—as the legend points out—are also intended to distinguish between the territories that fall under the two jurisdictions [of Genoa and Tuscany]" (Quaini 1986b, 93). The map also used planimetry to depict the largely cultivated areas at the bottom of the valley cut by the River Vara.

Nevertheless, Vinzoni's first drawings are still of the rule-of-thumb visual type rather than geometrical renditions: "measurements are almost entirely absent and, as a result, so is any sort of scale; in this particular case ["Carta della Selva della Pertegara"] there is also no indication of orientation" (Quaini 1986b, 96). And though in his large "Carta del Capitanato di Levanto" (1712) (Genoa, Archivio di Stato [AS], Mappe e tipi cartografici vari, B. 10) Vinzoni gives a detailed account of settlements and watercourses (all named), he is still operating within the parameters of the pictorial view (Quaini 1986b, 102). It is no accident that the map lacks a scale and a wind rose. By 1714 the young man's work had matured substantially, as evidenced by a number of maps with a graphic scale, which embody "a move toward geometrical cartography, after beginning in a more freely pictorial mode" (Quaini 1986b, 98). Such works were, in fact, the fruit of direct on-site measurements and of reliance on guides who were familiar with the terrain in question (Quaini 1986b, 103–4).

The greatest problem facing Italian mapmakers before the nineteenth century was the depiction of relief and elevation. Renaissance mapmakers had resolved the difficulty of rendering complex orography by filling the space with conventional images of cones or "mole hills," dotted more or less equally. During the seventeenth century, brushstrokes and variations in shades of color rendered mountains more expressively and approximated the actual variation in the appearance of mountains. However, with the exception of a few prototype works in the late part of that century, in the eighteenth century cartographer-engineers increasingly resorted to fine, pen-drawn hatching and shading, the latter usually oblique. In short, in the second half of the seventeenth century it was the exception for mountains and hills to be rendered in a sort of frontal or perspective view; in the following century it became the general rule. This approach, which obviously created opportunities for imprecision, remained predominant until the century's end, the era of Napoleonic rule. Though susceptible to inaccuracies, the method did provide a visually immediate and relatively effective account of orography, as can be seen in a 1679 map of the territory of Piedmont that shows a projected road system extending from Turin to Nice (fig. 841) in which alpine uplands are rendered in perspective view, with fine hatching and raking light from the west. Only toward the end of the eighteenth century did orography begin to be rendered differently "from an azimuthal point of view, with some resort to careful shading to give a sense of elevation and relief" (Carassi 1984, 94), such as displayed in the mili-


FIG. 840. "CARTA DELLA SELVA DI PERTIGARA," BY MATTEO VINZONI, 1711. Manuscript, ink and watercolor on paper, no scale given. Within the constraints of the perspective view, Vinzoni attempts to represent the hidden slopes of the mountain area using more intense hatching and color, demonstrating the evolution of a graphic language tied to the increased skills required.
Size of the original: 31.2 × 42.4 cm. Image courtesy of the Archivio di Stato, Genoa (Confinium, 190). Su concessione dei Ministero dei Beni e le Attività Culturali.

tary topographical map drawn by L. Bergalli in 1795 (fig. 842). By the late eighteenth and early nineteenth centuries, the French had adopted a method of using zenithal projections to construct contour lines, based on earlier techniques developed by the versatile mapmakers Luigi Ferdinando Marsigli and Nicolaas Samuelsz. Cruquius. In Italy, Pierre-Antoine Clerc, a leading figure in Napoleon's military bureaucracy from 1809 to 1814, introduced the contour system into the cartography of eastern Liguria and other areas of northern Italy (Rossi 2007, 65–73; Quaini 1983, 25–26, 32–34).

By the middle of the eighteenth century, large-scale topographical maps achieved the relatively rare honor of being printed with the appearance of works noteworthy for their content and metrical accuracy. Foremost was Andrea Chiesa's topographic map of the area around Bologna (1742 and 1762; ca. 1:30,000), prepared for administrative purposes in 1740–42 and based on surveys and measurements carried out from 1732 to 1738 using a plane table (fig. 843). The map "depicts, with noteworthy precision and careful detail, the entire territory that stretches from the hill of Bologna to the boundaries of the provincial area. . . . Despite the fact that it does not indicate crops and cultivated land . . . , this is one of the first real topographical maps in Italy" (Barbieri 1949, 38; see also Catolfi 2006, 65–66; Giacomelli et al. 1992).

Other administrative maps of a high standard include the manuscript "Carta della Riviera di Ponente di Genova" (1746–47) (Turin, AS, Carte Topografiche segrete, A 15 nero), prepared from on-site surveys by the Piedmont military engineers Giovanni Giacomo Cantù, Antoine Durieu, Francesco Antonio Garella, Giambattista Sottis, and Coloniato (Quaini 1986a, 48). It displays orography (with shading and fine hatching), the network of watercourses and rivers, settlements and


CARTA COROGRAFICA
Dove dimostrativamente son segnate le strade, e Colle, che d'ordine di M.R. furono visitate l'anno 1679 a fine di render carreggiabile in tutte le stagioni, se il possibile la volesse, una strada da Cuni a Nizza


FIG. 842. "CARTA TOPOGRAFICA MILITARE DALLE SPONDE DEL MARE, DA VENTIMIGLIA SINO A DEMONTE," L. BERGALLI. Manuscript, ink and watercolor on paper, no scale given. The orography is rendered from an azimuthal view with careful shading, which gives a sense of the relief, a technique in widespread use only at the end of the eighteenth century.
Size of the original: 64.3 × 117.3 cm. Image courtesy of the Archivio di Stato, Turin (Corte, Carte topografiche segrete, Ventimiglia 22 BIS a VII rosso).

roads, woods and tree-lined areas of cultivation. The *Topografia del Monte di Brianza* (Milan), drawn and published by Paolo Antonio Sirtori in 1763, exploits the material available in cadastres (Pirovano 2001, 190).

After 1737 the Grand Duchy of Tuscany was ruled by a European dynasty open to innovations in territorial surveying and determined to construct geometrically based topographical cartography on an urban and territorial scale—that is, maps that could be used for urban, environmental, economic, and administrative reforms. The anonymous manuscript map of Florence (fig. 844) evinces the prolific workshop of the Giachi brothers (Antonio, Francesco, and Luigi, active from the 1750s to the 1790s in the service of the grand duke's administration). However, its original content may be the work of the mathematician and engineer Ferdinando Morozzi, whose works were reproduced by the Giachi *atelier*. Drawn after 1765, it shows the entire territory around Florence, clearly distinguishing the plains from the hills. The mathematician Leonardo Ximenes produced one of the first truly modern topographies of Tuscany. His "Carta topografica generale del lago di Castiglioni" (1758–59, Florence, AS, Miscellanea di Piante, 56), later published in Florence in 1769, was based on accurate measurements and on-site observations. The mathematician Pietro Ferroni supervised the "Carta corografica del Valdarno di Pisa," ca. 1:34,000, drawn by his young pupil Stefano Diletti in 1774 (Prague, Národní Archiv, Rodinný Archiv Toskánsckých Habsburk [NA, RAT Map], 215), which depicts the lower plain of the Arno, outlining the Pisa and Livorno hills using a planimetric layout. The territory is rendered with great precision, including indications of land use. In Tuscany, the map was unsurpassed until the appearance of the maps based

(*facing page*)
FIG. 841. "CARTA COROGRAFICA DOVE DIMOSTRATIVAMENTE SON SEGNATE LE STRADE," 1679. Manuscript, ink and watercolor on paper, ca. 1:23,000. This map shows relief with a frontal or perspective representational technique, that is, azimuthal, which predominated until the Napoleonic era. Though imprecise, it offers an immediate and relatively efficacious perception of the orography in the region north of the Ligurian coast, using fine hatching and raking light to render mountain relief. Local routes are shown in red and yellow (much faded).
Size of the original: 143.0 × 95.5 cm. Image courtesy of the Archivio di Stato, Turin (Corte, Carte topografiche per A e B, Nizza n. 8).

FIG. 843. *CARTA DEL BOLOGNESE*, BY ANDREA CHIESA (BOLOGNA, 1742). Engraved on copper by Giuseppe Benedetti; ca. 1:30,000.

Size of the original: 198 × 192 cm. Image courtesy of the Archivio de Stato, Turin (Carte topografiche e disegni, Carte topografiche serie IV, mazzo 8).

on information gleaned from the geometric cadastral maps drawn up for the Lorraine administration in the 1820s.

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SEE ALSO: Italian States; Officina Topografica (Topographical Mapping Office; Naples); Rizzi Zannoni, Giovanni Antonio

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FIG. 844. "PIANTA DEI CONTORNI DELLA CITTÀ DI FIRENZE," POST-1765. Manuscript, ink and watercolor on paper, ca. 1:30,000. Though this map of the area around Florence is attributed to the *atelier* of the Giachi brothers, the content may be the work of Ferdinando Morozzi. Size of the original: 89 × 93 cm. Reproduced with permission of the Istituto geografico militare, Florence (inv. N. 3650, Tordi n. 5) (authorization n. 6934 dated 03.15.2017).

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***Topographical Surveying in the Netherlands.*** See Military Cartography: Military Cartography and Topographical Surveying by the Netherlands

***Topographical Maps in the Ottoman Empire.*** Although topographical depiction occupied a long-standing place in Ottoman cartography, by the seventeenth century the number of examples incorporating the particular features of this style drastically decreased. During the seventeenth and eighteenth centuries, topographical depiction was largely restricted to urban views, reproduced from the classical works of the sixteenth century. Only in the first half of the eighteenth century did a clear divergence between panoramic projection and mapping emerge in the Ottoman Empire. European artillery officers, engineers, and mapmakers in the service of the Ottoman government attempted to gather topographical maps pertaining to different regions of the empire, albeit without a geodetic purpose. It was not until the beginning of the twentieth century that Ottoman engineers took the initiative to create a complete topographical survey of the empire.

The seventeenth- and eighteenth-century copies of the "Kitāb-ı baḥriyye" (Book of maritime matters) contain some maps that are not scaled; they may be primarily identified as panoramic or schematic images of documentary rather than cartographic value. There is limited information about the artists who drew these illustrations, such as the seventeenth-century map of the island of Crete (İstanbul Üniversitesi Kütüphanesi [İÜK], Nadir Eserler 6605, f. 347a) and the eighteenth-century map of the castle and gulf of Thessaloníki (Istanbul, Süleymaniye Yazma Eser Kütüphanesi, Ayasofya 2605, f. 15b), neither of which contains detailed information. These same copies of the "Kitāb-ı baḥriyye" include maps of Istanbul and Cairo that show typical iconic features and are replete with iconic details. This same style was employed on itinerary maps for certain pilgrimage journeys. Manuscripts with titles such as "Menāsik-i Ḥacc," in which the sacraments of the Islamic pilgrimage are shown, include schematic maps of the halting places en route and holy places, particularly the cities of Jerusalem (Ḳudüs), Mecca (Mekke), and Medina (Medīne). (For the Mecca and Medina drawings in an anonymous manuscript recopied in 1146/1734, see İÜK, Nadir Eserler 6757, f. 3a–4a).

Among the works of the renowned Ottoman intellectual Muṣṭafā ibn ʿAbdullāh Kātib Çelebi, the first and second drafts of the "Cihānnümā" and his translation of the *Atlas minor* of Gerardus Mercator and Jodocus Hondius ("Levāmiʿü'n-nūr fī ẓulmeti aṭlas minur") are especially abundant in topographical maps. The author's copy of the first draft of "Cihānnümā" (Vienna, Österreichische Nationalbibliothek, Cod. Mixt. 389) is adorned with rather simple maps in which towns, fortresses, rivers, hills, and bridges are marked by name; these are mostly placed in the margins of the page, sometimes contained in a circle. Among these are maps of Andalusian towns (f. 36a-40a); the Ottoman cities of Edirne (f. 47b), Sarajevo (f. 94b), and Belgrade (f. 99b); the residential/architectural plan of Mecca (f. 182a); and Azov and its surroundings (f. 220a). The maps of Rumelia in the "Cihānnümā" are much more detailed in the later copies, and some new maps in color are added, elaborated with further topographical details, such as the map of Szeged (copy date 1163/1750, Süleymaniye, Esad Efendi 2043, f. 111a). The author's copy of the second draft of the "Cihānnümā" included a number of topographical sketches as well (e.g., Istanbul, Topkapı Sarayı Müzesi Kütüphanesi [TSMK] R. 1624/1, f. 112b).

The rolled-up (scroll) maps of the courses of the Tigris and Euphrates Rivers of the mid-seventeenth century provide a thorough depiction of the holy places and sanctuaries along the pilgrimage route. By the same token, the scroll map of the Nile River (copy date


FIG. 845. *ŞEKL-I ḪALĪC-I ḲOṢṬANṬINIYYE*, THE BOSPORUS AND THE GOLDEN HORN OF ISTANBUL. Printed map bound between pages 671 and 672 of the *Cihānnümā*, probably compiled and certainly published by İbrāhīm Müteferriḳa in 1145/1732. It depicts the coastline of two sides of the Bosporus with considerable accuracy and especially emphasizes promenades along the coast.
Size of the original: ca. 25 × 35 cm. Image courtesy of the Süleymaniye Yazma Eser Kütüphanesi, Istanbul (Hamidiye 931, 671–72).

1097/1685) using a topographical illustration method covers the area from the spring up to the river's outlet at Alexandria (Karamustafa 1992, 222–25, figs. 11.16, 11.17). The presumed connection between this latter map and the Ottoman traveler Evliyā Çelebi, who in his multivolume work, "Seyāḥatnāme" (Book of travels), stated that he had prepared many maps and topographical sketches, remains highly speculative. Still, in the "Seyāḥatnāme," he made room for the graphic depiction of the town of Anaboli and the castle of Lepanto (VIII, TSMK B. 308, f. 279b, 338a). In an anonymous colored atlas dated to the seventeenth century (Kayra 1990b, 76), all gates, places of worship, and districts of Istanbul are numbered up to sixty-three and shown with their names and symbolic figures.

In his translation of the *Atlas maior* of Joan Blaeu, the Ottoman geographer Ebūbekir ibn Behrām ed-Dımaşḳī supplemented the maps with numerous topographical elements in accordance with current tradition. More importantly, he drew fourteen topographical maps/sketches in his addendum "Cihānnümā," almost all of them describing Anatolian cities. These maps are the first known examples of towns in Anatolia drawn by an Ottoman artist.

The map of the Bosporus and the Golden Horn appended to Kātib Çelebi's *Cihānnümā* by İbrāhīm Müteferriḳa, who also printed the manuscript in 1145/1732, is probably Müteferriḳa's own creation. The map is equipped with a delicate compass rose and shows the eleven gates of the inner city on the Golden Horn (Ḫalīc-i Ḳoṣṭanṭıniyye) side, five on terra firma, and two along the Marmara Sea coast. It indicates the line of the coast and represents the two sides of the Bosporus with considerable accuracy compared to the contemporary coastline and displays special emphasis on promenades (fig. 845).

The water supply maps of the eighteenth century offer the best examples of the characteristics of the topographical approach of Ottoman cartography. In the Ottoman world, water supply maps were treated very seriously; they portrayed the route of a network of pipelines and aqueducts that ran from the water's source to its final destination. Typically drawn on scrolls, the maps had their own peculiar scales and were drawn with the utmost attention to detail in order to demonstrate clearly the spatial distribution of geographical and environmental elements that lay within the water distribution system. Therefore it is possible to find in these maps the illustrations of villages, farms, gardens, roads, fountains, wards, bridges, docks, mountains, streams, and hills together with several religious, military, and civil institutions that comprise water gauges, water tanks, arches, mosques, tombs, and madrasas along with mansions of notables along the water distribution network. A very detailed map is that of Beylik Suyu, the stream that supplies the Topkapı Sarayı, dated to 1161/1748. The map is drawn on a roll 75 centimeters high (TSMK A. 1815). A red and yellow scale drawn on the first section of the map is applied to subsequent sections; each colored unit corresponds to 75.8 meters (100 ells). According to the figures provided on the map, the quantity of water supplied to sixty-three fountains, thirteen wells, and fourteen baths, as well as many pools and little fountains in the palace, amounted to 266 cubic meters per day (Çeçen 1991b, tipped in at back).

The schematic and nonscaled map of the Üsküdar (Scutari) aqueduct constructed by Nevşehirli İbrāhīm Paşa was supplemented with additional information up to 1177/1763–64 (Istanbul, Türk İslam Eserleri Müzesi Kütüphanesi [TİEM], ms. 3336). Similar to the examples already mentioned, it marks the locations and designates the names of religious and civic structures. The illustrations of Kavak Sarayı and Şeref-ābād Kasrı are particularly important for modern audiences, because those structures have not survived to the present day. Among the undated and mostly schematic water supply maps, the Köprülü maps from the latter half of the seventeenth century (Istanbul, Köprülü Yazma Eser Kütüphanesi, 2441/1 and 2441/2) distinguish themselves by their abundant structural illustrations (Çeçen 1991b, 99–104), whereas the Süleymāniye water supply map from the second half of the eighteenth century (TİEM, ms. 3337) draws attention by its scarcity of place-names; the Nūruoṣmāniye water supply map from the reign of ʿOṣmān III (r. 1754–57) shows an unusual route (İstanbul Vakıflar Başmüdürlüğü, no. 334).

The Bāyezid II water supply map prepared by engineer Ḳule Ḳapılı Seyyid Ḥasan in 1812–13 with the aid of a plane table is considered an early topographical map of Istanbul drawn by the Ottomans in conformity with European surveying techniques (fig. 846). It represents approximately half of the historical peninsula of Istanbul, namely the northern section of the inner city, and uses a scale of 100 kulaç or ca. 1:25,000 (1 kulaç = 1.895 m); furthermore, the ziraʿ-i miʿmārī (architect's cubit) used by Seyyid Ḥasan in his calculations corresponded to ca. 0.76 m. The map has some explanatory notes on how to use it and comprises all topographical elements with special attention to each structure. The unsigned and undated *isāle* (water delivery) map of the same water system (TİEM ms. 3338), which encompasses the zone from Edirneḳapı to the Bāyezid complex, is presumably also drawn by Seyyid Ḥasan. In general, water supply maps include two-dimensional images combining pictures with physical properties (Çeçen 1997, 30–51).

European experts and officers hired by the Ottoman government or artists and architects serving on diplomatic missions in Istanbul had an indirect effect on Ottoman cartography because they were interested in purchasing maps of Ottoman lands. Among these, the engineer-mapmaker François Kauffer was appointed state chief engineer in 1793 and paid by the central government regularly from 1 Muharrem 1215/25 May 1800 (Istanbul, Başbakanlık Osmanlı Arşivi, Cevdet-Maarif 2073/9152). In 1776 he prepared the first topographical map of Istanbul (scale 1:10,000) to cover the inner city, Golden Horn, Pera, Üsküdar, and Kadıköy and revised it ten years later with Jean-Baptiste Le Chevalier's *Carte de la ville de Constantinople / Plan de la ville de Constantinople* (1786). This early detailed topographical map of the Ottoman capital, based on European-style surveying to scale, served as a prototype for subsequent Istanbul maps that appeared in print in Europe until 1840. It also marked a qualitative milestone for European mapmakers who had been drawing Istanbul in view, panoramic or bird's-eye, and would now render the city in plan (Pedley 2012).

As part of its effort to provide military assistance to the Ottoman state, the French government sent André-Joseph Lafitte-Clavé to Istanbul, where he prepared plans of and reports on the conditions of Istanbul fortifications. He then thoroughly investigated the

(*facing page*)
FIG. 846. SULTAN BĀYEZĪD II MANUSCRIPT WATER SUPPLY MAP, CA. 1812–13. Ottoman water distribution maps treated a precious resource along a network of pipelines and aqueducts from source to destination and used European surveying techniques. This is one of four pieces.
Size of the original: 188 × 104 cm. Image courtesy of the Türk ve İslam Eserleri Müze Müdürlüğü, Ankara (No. 3339).

FIG. 847. MANUSCRIPT MAP OF ISTANBUL AND THE BOSPORUS BY KOSTANTI (KONSTANTIN) KAMINAR. The former dragoman of Morea presented this map to Sultan Maḥmūd II. Original name: "Bu taṣvīr olunan resminin güzelliğinden maʿlūmdur ki Āsitāne-i 'aliyye'nin resmidir"; dated 23 Zilkaʿde 1228/17 November 1813. For a detail of Istanbul from this map, see figure 917.
Size of the original: 98 × 210 cm. Topkapı Sarayı Müzesi Kütüphanesi, Istanbul (H. 1858).

topography of the coast of the Black Sea, from which survey he composed his "Mémoire topographique sur les côtes de la Mer Noire" (1784) (Lafitte-Clavé 1998), including thirty-five plans and three maps, which he submitted to the French ministry of defense. At the same time, he lectured on topography at the Mühendisḫāne, the imperial engineering school, where he taught students such as Ṣāliḥ Efendi, who helped him prepare the plans for the "Mémoire topographique."

The topographical map of the Bosporus (1791) by Egya Endazyan, a Mechitarist priest of Venetian origin, was published in Venice using Armenian characters for the Turkish language. The map uses symbols for religious and civic buildings and residential areas in Istanbul and marks the twenty-six gates of the inner city with Roman numerals and the twelve gates in the Galata district with Arabic numbers. Another unusual feature of the map is that it indicates the locations of fish weirs along the Bosporus shore. The scale provided on the map to estimate distances uses the Turkish mile, corresponding to 1,895 meters. A smaller-scale map may be found in the *Descrizione topografica dello stato presente di Costantinopoli* (1794) by Kozmas Kömürciyan of Istanbul, also known as Cosimo Comidas de Carbognano, the Ottoman-Armenian dragoman who worked at the Sicilian and Spanish embassies. The map, presented in Italian, depicts Istanbul and the Bosporus on a scale of 2 leghe/ligs, and provides only a meager number of illustrations and place-names.

There are also some anonymous Ottoman topographical maps drawn on silk cloth or preserved in manuscript. Among these is a map of Istanbul and the Bosporus dated before 1800 (TSMK A. 3624), which assigns a number to each of the twenty-six gates of the capital and includes a legend. It also names some of the residences along the Bosporus but mostly omits geographical elements. Another anonymous example from the same period is a manuscript map (TSMK R. 1818) delineating the territory from Baghdad to the *ṣancāḳ* (district) of Kirkuk in the north. It includes the gates, tombs, and cemeteries belonging to the city of Baghdad. Another such map is related to the Caspian (Hazar) Sea and the natural and urban areas surrounding it (TSMK A. 3622). Although Ottoman castle plans and maps usually include many topographical details, they are considered military maps because of the context of their production and use.

The manuscript map of Istanbul and the Bosporus by former dragoman Kostanti (Konstantin) Kaminar prepared on 23 Zilkaʿde 1228/17 November 1813 is furnished with a compass rose, and it uses small illustrations in red ink to plot the gates, cemeteries, docks, castles, citadels, lighthouses, bridges, residential districts, timberlands, and cultivated areas of Istanbul (fig. 847). Two more maps by Kaminar, charcoal drawings from the same year, delineate the Dardanelles strait with its environs (TSMK H. 1845) and the city of Bursa with the surrounding towns (TSMK H. 1846) in which the localities subject to extraordinary levies are designated by shaded zones. The latter map displays the Bursa Ulu Cāmiʿi/Grand Mosque, the mosque of Çelebi Sulṭān Meḥmed, the Keşīş Mountain (Uludağ), and the Dut valley in Bursa and thus may be regarded as one of the earliest examples of the topographical maps of that city.

The military campaigns of Napoleon Bonaparte in Syria and Egypt (1798–99) initiated a process of map collecting in Ottoman lands, particularly for the Black Sea and the Mediterranean, that were advanced by British and Russian interests. However, only in the first quarter of the nineteenth century did the Ottomans begin to practically assess these topographical maps and translate a few of them into Turkish for common use.

FİKRET SARICAOĞLU

SEE ALSO: Ottoman Empire, Geographical Mapping and the Visualization of Space in the

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***Topographical Surveying in Poland.*** Large-scale mapping of the military fortifications of towns and siege plans in late seventeenth-century Poland as a response to threats from the Scandinavian north and the Ottoman south has been discussed in volume 3 of *The History of Cartography* (Török 2007). Evidence for the practices of topographical surveying in Poland during the Enlightenment is scarce and not thoroughly researched. The efforts of military surveyors and civil engineers, the usual practitioners of large-scale mapping, have so far not been studied except in the contexts of urban mapping and maps of mines, particularly salt mines. The Polish Crown relied heavily on the revenue from salt. At the very end of the reign of Sigismund III Vasa (r. 1587–1632), the famous Wieliczka salt mines were surveyed by Marcin German, who made maps of three levels of the mine and a plan of the town all at the scale 1:1,260. At the order of Władysław IV, Willem Hondius made copperplates and printed German's maps in 1645 at a scale of 1:3,800 (Jodłowski, Walczy, and Gawroński 2005). Throughout the eighteenth century surveyors continued to map the Wieliczka salt mines, among them the Germans Jan Gottfryd Borlach (1718), Jan Friedrich Müller (1742), and Jan Gottfryd Gebhard (1752), the Pole Jan Stolarski (1762), and the Austrian Antoni Fridhuber (1768) (Rastawiecki 1846, 145–50). All of these maps remained in manuscript.

In the eighteenth century the desire to create a large-scale map of the entire country, a truly national map, resulted in at least five projects. The Catholic Church assembled material on the diocesan level, and both King Stanisław August Poniatowski and Prince Józef Aleksander Jabłonowski energetically pursued a national topographic map. Other even more ambitious projects were proposed. Jabłonowski, who busied himself with a variety of scientific and literary endeavors and was firmly opposed to the kingship of Stanisław August, began work on a comprehensive map of the Commonwealth in about 1740. By the mid-1750s he had completed what must have been a quite elaborate map, based on more than forty other maps and with corrected latitudes of many places, but it has now been lost. In 1760, Jabłonowski engaged Hungarian engineer and cartographer Franciszek Florian Czaki, who had been touring Poland making maps for almost twenty years, perhaps under the sponsorship of Hans Moritz von Brühl, a privy councilor to the kings of Saxony who was reportedly working on an "atlas of Sarmatia" in 1753. Czaki worked for Jabłonowski for five years before being hired


FIG. 848. DETAIL FROM GIOVANNI ANTONIO RIZZI ZANNONI, *CARTE DE LA POLOGNE DIVISÉE PAR PROVINCES ET PALATINATS ET SUBDIVISÉE PAR DISTRICTS* (PARIS, 1772). Copper engraving on paper, twenty-four sheets, 1:692,000. Although published in the year of the first partition, the map shows Poland as it was at its greatest extent. This detail from sheet 23 shows the course of the Dniester from Raşcov to Dubăsari in present-day Moldova. Many place-names on the Ottoman borderlands are also written in Turkish script.
Size of each sheet: ca. 49 × 55 cm; size of detail: ca. 11.0 × 8.5 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge DD 2987 [3127.23]).

away by King Stanisław August in 1765 and taking all his manuscript maps with him (Buczek 1982, 85–87). Jabłonowski protested to the king, and the maps were returned to him. With the Czaki maps as a basis and additional material supplied by Father Théodore Waga, Jabłonowski hired Italian cartographer Giovanni Antonio Rizzi Zannoni, then resident in Paris, to compile the *Carte de la Pologne* (1772) in twenty-four sheets at a scale of 1:692,000 (Buczek 1982, 95). With its rich detail (the map key includes fifty symbols denoting types of settlements, churches, factories, mines, and land cover) and considerable mathematical accuracy, it remained for decades the largest printed map of the country and was considered the best (fig. 848).

King Stanisław August, a great map lover and collector, wanted nothing more than to produce a large and accurate map of his kingdom along the lines of the Cassini *Carte de France*. Toward this end, even before being crowned, he had hired the German-born cartographer Charles (Herman Karol) de Perthées. Perthées was soon joined by the military engineer Jan Bakałowicz and the aforementioned Franciszek Florian Czaki (later assisted by his son, Franciszek Kajetan Czaki), who was made a captain in the Polish army and remained in royal service for the rest of his life (Buczek 1982, 86–87). In order to provide the precise locations required for a large-scale topographic map, the king engaged two Jesuit astronomers, Marcin Poczobutt-Odlanicki and Alexandre Rostan, who, with their assistants, determined latitudes (and even some longitudes) of many places in the Grand Duchy of Lithuania and Courland (Buczek 1982, 100). The king later set up an observatory at the royal palace in Warsaw under the direction of Jowinus Fryderyk Bystrzycki, ordered the latest instruments from London, and consulted with notable scientists from elsewhere in Europe. Despite all his efforts, which were gathering strength even as his kingdom was being reduced by partition, Stanisław August was never able to complete his elaborate and comprehensive survey, remarking in a letter of 1777, "I have encountered constant obstacles in this enterprise; it seemed that the earth itself rose up in opposition so as not to be measured" (quoted in Buczek 1982, 102). Perthées, meanwhile, acting as *géographe de cabinet*, was diligently gathering maps of all kinds and editing them into ever larger and more comprehensive manuscript maps of the country. The largest of these, "Polonia secundum legitimas projectionis stereographicae regula" (48 sheets, 1:934,000) was completed in 1770 (Madej 1987, 58–63) and survives only in a photographic copy, the original having been destroyed during World War II. Perthées was able to cram thousands of place-names into his map, and despite the differences in scale, Perthées's "Polonia" and Rizzi Zannoni's *Carte de la Pologne* invite detailed comparison (Buczek 1982, 102–3).

There was no lack of plans for a detailed map of the country. In 1777, the architect and curator of the royal collections, August Moszyński, presented to the king a "Projet pour faire une carte géographique exacte de la Pologne," for which a special government office would be set up (Sawicki 1968, 338–39). In 1787, Józef Kromer, a registered surveyor and professor of mathematics at the Jagiellonian University in Kraków, proposed a uniform topographic map of the country to be based on triangulation and with the work to be done by army engineers (Stoksik 2013, 186–90). Two years later the Sejm established a *pułkownik kart geograficznych* (colonel of maps) within the corps of engineers, Korpus Inżynierów, to coordinate topographic mapping in peacetime (Sawicki 1968, 341). Finally in 1790, mathematician and rector of the University of Wilno, Jan Śniadecki, presented a detailed plan for a national topographic map, à la Cassini, to a committee of the treasury. The plan was well developed and had the full backing of the commission on national education, Komisja Edukacji Narodowej, and the great reformer Hugo Kołłątaj. Had it been brought to fruition, the plan would have placed Poland at the forefront of countries with a detailed national map (Olszewicz 1932, nos. 177, 233–34, 238, 246). Unfortunately, all of these efforts were too late.

Ironically, the partitions of the country provided a springboard to detailed topographic mapping of Poland, albeit by foreign powers. Even before the first partition, Theodor Philipp von Pfau, a captain-quartermaster in the Prussian army, published *Regni Poloniæ, Magni Ducatus Lituaniæ nova mappa geographica, concessu Borussorum regis* (1771–72) in twenty-five sheets. The Prussians seem to have acquired a number of Polish cartographic sources, including some of those available to Jabłonowski, to use in compiling this map. Its relatively large scale of 1:525,000 allows the presence of a great many place-names, but no roads are shown. Its striking characteristic is the use of hachuring to indicate relief in the more mountainous parts of the country. After the second partition of the Commonwealth, the Prussian army undertook five major topographic surveys in Poland (1796–1805), one of them at a scale as large as 1:33,300, resulting in hundreds of manuscript map sheets. These maps had all the topographical details required for military use, employed hachures to indicate relief, and some of them even had trigonometric bases. But they rendered place-names in German rather than Polish and remain in manuscript (Buczek 1982, 94–95) (Staatsbibliothek zu Berlin–Preuβischer Kulturbesitz). Reduced-scale versions (1:150,000) of three of these maps were published soon after the turn of the century: *Special Karte von Südpreussen* (13 sheets, 1802–3) by David Gilly; *Karte von Ost-Preussen nebst preussisch Litthauen und West-Preussen* (25 sheets, 1802–12) by Friedrich Leopold von Schrötter; and *Topographisch Militärische Karte vom vormaligen Neu Ostpreussen oder dem jetzigen Nördlichen Theil des Herzogthums Warschau* (15 sheets, 1808), by Daniel Friedrich Sotzmann.

Immediately after the first partition in August 1772, military cartographers of the Austrian Habsburg Empire began a survey of their new kingdom of Galicia and Lodomeria, which comprised a large part of what had been southern Poland, including the salt mines of Bochnia and Wieliczka. Under the leadership of the Jesuit Joseph Liesganig, Austrian troops measured baselines and erected a triangulation network covering Galicia and Lodomeria. The resulting map, in seventy-nine sheets at 1:72,000, remained in manuscript, but a reduced version at 1:288,000 was engraved in Lviv and published in Vienna: *Regna Galiciæ, et Lodomeriæ Iosephi II. et M. Theresiæ* (1794) (Paldus 1916, 428–33) (see fig. 439). An even more detailed survey was undertaken in 1779–82 commanded by kaiserlicher Oberstleutnant Friedrich von Mieg as part of the Josephinische Landesaufnahme, resulting in 413 sheets of the so-called "Karte des Königreichs Galizien und Lodomerien" covering Galicia at the scale of 1:28,800 (Sawicki 1920, 81 [no. 1074]). All manuscript sheets are preserved in Vienna (Kriegsarchiv, Österreichisches Staatsarchiv) (Bukowski, Dybaś, and Noga 2012–) (fig. 849). The Austrian Jesuit mathematics professor Georg Ignatz von Metzburg directed work on a topographic survey of west Galicia based on triangulation in 1796–99. The resulting manuscript map, in twenty-seven sheets at a scale of 1:72,000, showed all the usual cultural features as well as woods and fields, but lacked any indication of terrain (Sawicki 1928, 30–42). A printed version of this map appeared in reduced form (1:880,000) as *West-Galizien* (1799) (see fig. 629). All these Austrian maps strictly maintained the use of Polish place-names and orthography. Russia began to undertake detailed mapping of its new Lithuanian lands only after the turn of the nineteenth century.

LUCYNA SZANIAWSKA

SEE ALSO: Poland

FIG. 849. DETAIL OF SEIBUS (GERMAN) OR ŻYWIEC (POLISH) FROM SEC. 7 "THEIL DES WIELICZKER KREIS" OF FRIEDRICH VON MIEG'S TOPOGRAPHIC MAP (VIENNA, 1779–82). Manuscript, ink and watercolor on paper; 1:28,800. A detail from one of the 413 map sheets of the Josephinische Landesaufnahme covering Polish Galicia. All individual buildings are located, relief is shown by shaded hachures, and Polish place-names are used (with their German equivalents, when available).
Size of the entire original: 47 × 73 cm; size of detail: ca. 11.0 × 13.5 cm. Image courtesy of the Kriegsarchiv, Österreichisches Staatsarchiv, Vienna (Kartsammlung B IX a 390).

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***Topographical Surveying in Portugal.*** Until the end of the eighteenth century, topographical surveys in Portugal addressed mainly military concerns. They were neither well structured, nor did they follow general uniform rules. Under the direction of the *engenheiro-mor* (principal engineer), who defined and supervised surveys, the few national engineers available at that time were insufficient in number for all necessary jobs, including the survey of the huge colonial territories of South America, Africa, and Asia. Therefore, from the seventeenth century until the end of the eighteenth century, Portugal relied on foreign officers, mathematicians, and astronomers. In 1750, João V recruited engineers and astronomers from many countries, in addition to Portugal, for the important expeditions to survey and establish the boundaries in South America. On completion, some returned to Portugal, such as the Italian Miguel António Ciera, who later joined others on the newly created mathematics faculty, a result of the reform of the Portuguese University in Coimbra in 1772.

In Portugal, the training of military engineers, established in 1647 under Luís Serrão Pimentel, was expanded to the overseas territories. After the training reforms of 1693, the number of military engineers was fixed and the first corps of engineers was constituted. In 1701 ever-growing needs led to the creation of new academies for fortification in many regions beyond the capital, but only the academy in Minho functioned well (Moreira 2012). Even though changes were reinitiated in 1732 as part of the plan of the *engenheiro-mor* Manoel de Azevedo Fortes, lasting reform was only achieved by the creation of the Academia Real de Fortificação, Artilharia e Desenho (1790). The Real Corpo de Engenheiros, established at the same time, was charged with mapping Portugal and of the overseas territories, as well as military and civil engineering works appropriate to the corps.

In 1722, Azevedo Fortes formulated mapmaking principles for engineers to follow in his *Tratado do modo o mais facil, e o mais exacto de fazer as cartas geograficas*, a small treatise written at the request of the Academia Real de História Portugueza. As *engenheiro-mor*, Azevedo Fortes supervised the topographical surveys of Portugal and the overseas territories, and the goal of his treatise was the uniformity of these maps (fig. 850). This initiative spurred increased topographical surveying in Portugal in the first half of the eighteenth century. During the 1760s and 1770s, Sebastião José de Carvalho e Melo, marquês de Pombal, the minister of King José I, initiated the next stage with the development of mathematical studies. Also important were the activities of Count Wilhelm de Schaumburg-Lippe, who commanded the Anglo-Portuguese forces at the end of the Seven Years' War. During his brief stay in Portugal (1762–64), Schaumburg-Lippe reorganized the army and promoted military reconnaissance and several surveys (fig. 851). A final burst of topographical energy occurred toward the end of the century with the start of a geodetic survey and the foundation in 1798 of the Sociedade Real Marítima, Militar e Geográfica. Had the society enjoyed a longer life, its engraving and printing workshop would have solved one of the biggest problems of Portuguese cartography: its lack of publishing capabilities.

These general conditions allowed and encouraged surveying and detailed topographical representations not only of battlegrounds and their environs and key coastal areas, but also of the terrestrial frontiers, mainly in Beira and Alentejo, two very sensitive regions for the defense of Portuguese territory. But it is not easy to study these documents today for several reasons: they are mostly in manuscript and there is a dearth of inventories; they were dispersed for political reasons (their transfer to Brazil at the time of the French invasions and the simultaneous pillage of Portuguese archives and libraries); and many were lost due to catastrophes (notably the disastrous earthquake in Lisbon in 1755).

By the end of the eighteenth century, the outlines of the first detailed and uniform topographical map began


FIG. 850. *CARTA TOPOGRAFICA DO TERMO DE LISBOA ATHE A VILLA DE MAFRA E DE TODOS OS CAMINHOS QUE HA PARA A MESMA VILLA* [CA. 1718]. This printed map, ca. 1:90,000, was probably authored by Manoel de Azevedo Fortes and José da Silva Pais, based on the area represented and compared to another map by them at the Real Academia de la Historia, Madrid (C-003-011).
Size of the original: 25.5 × 32.5 cm. Image courtesy of the Biblioteca Nacional de Portugal, Lisbon (C.C. 30 P2).

with the triangulation of the entire country in 1790. But this was only after some fruitless trials under the aegis of the Academia Real das Sciências de Lisboa (1779). The Academia had initially proposed a survey for a regional map to be carried out by counties on a scale similar to that of the *Carte de France* of the Cassinis and accompanied by descriptive memoirs. It was decided that the astronomers would simultaneously determine the geodetic points to support the topographical surveys. As a model, the Setúbal Peninsula south of Lisbon was chosen; German officer Jacob Crisóstomo Pretorius, a member of the Academia, supervised the work from 1789. However, it soon became clear that this work could not be completed in the context of the Academia due to the unwieldy structure and the large expense required. After two years, and with only the Setúbal region surveyed, this work was stopped.

The geodetic work initiated in 1790 by government order and under the direction of Francisco António Ciera was carried out over a few years by several military engineers performing the topographical surveys for the "Carta geral do reino," executed with a plane table at a scale of 1:10,000. From the field surveys carried out north of Lisbon, only a small number of sketches were completed, since the work was suspended in 1804. However, the geodetic and astronomic positions of the most important coastal points were determined, as were the triangulation and sounding of the mouth of the Tagus River at Lisbon. Although the maps of this area were taken from the Arquivo Militar during the French invasions, Marino Miguel Franzini was able to prepare a new manuscript "Plano hydrografico do porto de Lisboa, e costa adjacente até ao Cabo da Roca" (1803–8, ca. 1:40,000) based on survey data of 1802 and later published at a smaller scale with the plans of other Portuguese harbors (1811).

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SEE ALSO: Portugal


FIG. 851. LOUIS D'ALINCOURT, "CARTE MILITAIRE DE LA PROVINCE DE BEIRA, DIVISÉE EN HAUTE ET BASSE," [1762–64]. Manuscript, ca. 1:200,000. D'Alincourt was a French officer who came to work in Portugal in 1757 under Schaumberg-Lippe, along with his brother Francisco d'Alincourt in 1760. The map extends to the south and connects to the "Carte militaire d'une partie de l'Alentejo" made by Francisco at the same time.
Size of the original: 86 × 80 cm. Image courtesy of Portugal/Gabinete de Estudos Arqueológicos da Engenharia Militar/Direção de Infraestruturas do Exército (1865-2-22A-109).

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***Topographical Surveying and Urban Mapping in Portuguese Africa.*** Large-scale Portuguese cartography of the African continent focused on coastal locations along the maritime routes of the Atlantic and Indian Oceans that connected the Portuguese to their commercial interests in the interior. In the majority of cases these maps include graphic representations of small urban centers, maritime ports, military defenses, and the surrounding area. In this context, military, hydrographic, and civil architectural surveys were instruments used to plan the occupation, defense, and expansion of colonial power in Morocco, Guinea, Cape Verde, São Tomé, Angola, and Mozambique. As strategic documents, these cartographic examples remained—almost without exception—in manuscript and are housed in central archives in Portugal, but regional governors could always keep copies in their own archives (Vasconcellos 1904; Dias et al. 2005). Generally speaking, the mapmakers were military engineers and pilots trained in Portugal or in Portuguese colonies who acted on orders of the Crown.

In the middle of the eighteenth century, the last outpost of Portuguese colonization in Morocco was the city of Mazagan (Mazagão; today El Jadida). Given its strategic position and relative isolation, this strongly fortified city suffered numerous attacks, which prompted various cartographic studies such as those by João Tomás Correia and Simão dos Santos from the first half of the century (Lisbon, Biblioteca Nacional de Portugal [BNP] and Direção-Geral do Território). Regarding the final Moroccan siege of the city in 1769, five views and surveys are known, either in original form or as copies, in different public and private archives (Mattoso 2010, 85–96) (fig. 852). The city was then abandoned, and the Portuguese population moved to the mouth of the Amazon, where they founded Nova Mazagão in 1773. Different cartographic documents were created for the planning of this new town.

The coastal territory of western Africa, the so-called Rios da Guiné, was an important center of the Portuguese slave trade since the fifteenth century and evoked various maps of the fortress of São José de Bissau, dated between 1765 and 1796, by the military engineers Manuel Germano da Mata, José Luís de Braun, and Bernardino António Álvares de Andrade (Biblioteca Pública Municipal do Porto). The fort's existence and the maps were associated with the creation in 1755 of the Companhia Geral do Grão-Pará e Maranhão, which controlled commerce and navigation connected to Brazilian captaincies in the Portuguese South Atlantic. The fort provided a strategic defensive outpost near the mouth of the Geba River, around which grew Bissau, the future capital of Guinea-Bissau.

The existing urban maps of Cape Verde are limited to two cities that functioned as capitals of the archipelago: Ribeira Grande and Praia, both on the island of Santiago. A group of military maps by António Carlos Andréis dated between 1769 and 1778 (Lisbon, Arquivo Histórico Ultramarino [AHU]) depicts Ribeira Grande by presenting the city's defenses, cathedral, and port, all of which were the focus of repeated pirate attacks that eventually caused the transfer of power to Praia. The development of this new capital was slow. The "Planta da Villa da Prayia de S.ta Maria" (ca. 1778) by Andréis was followed in 1808 by additional maps of the military fortifications around the city's port, made in the context of the conflict between Portugal and France (AHU; Viterbo 1988, 1:28–30).

The topographical and urban cartography of the São Tomé and Príncipe archipelago depicted the two principal population centers and their respective ports: São Tomé and Santo António. The decision to move the capital from São Tomé to the small island of Príncipe in 1753 explains the important collection of large-scale maps made by the Luso-Brazilian military engineer José António Caldas in 1757 (AHU). Caldas's charts and plans of the bay, the city of Santo António, and the various existing and projected fortifications were all drawn under the king's orders. A similar collection of maps was made in 1800 by António Ramos de Queiroz, another military engineer; these represented the defense of the harbors and the construction of barracks (AHU). The fortifications of the island were renovated again during the Portuguese-French conflict, with additional maps made in 1809. The mapping of the island of São Tomé was not as prolific. Between 1788 and 1797, two charts were made of the city, its port, and its military defenses: one of Ana Chaves Bay ordered by the governor, João


FIG. 852. "MAZAGÃO," PLAN OF THE CITY AND FORTIFICATIONS DRAWN BY IGNACIO ANTÓNIO DA SILVA, 1802. Manuscript; ink with watercolor. Re-creation of the Moroccan siege of Mazagan in 1769. The city was the subject of numerous cartographic images because of its strategic position, relative isolation, and strong fortifications.

Size of the original: 55.5 × 90.2 cm. Image courtesy of the Biblioteca Nacional de Portugal, Lisbon (D-68-R).

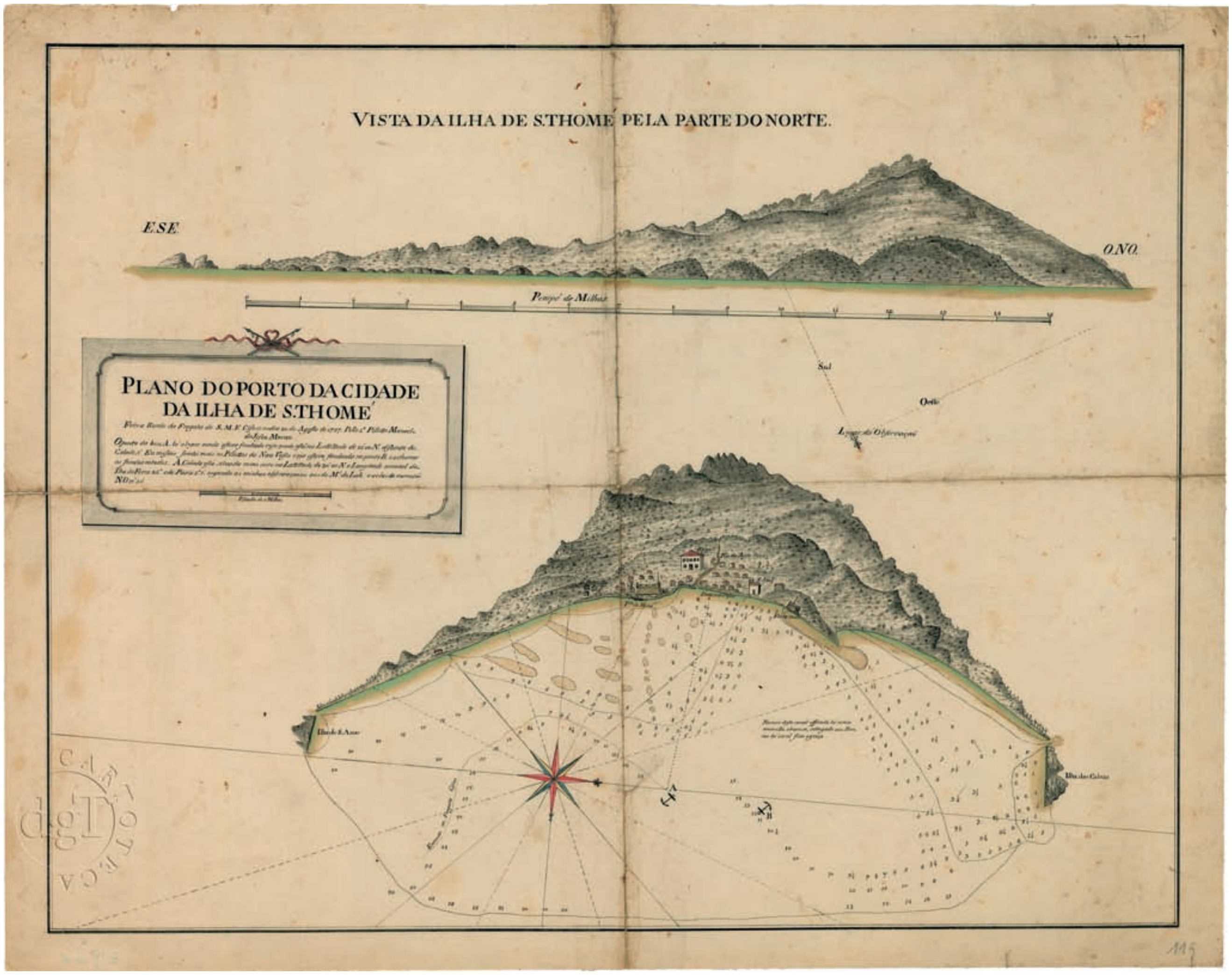


fig. 853. MANOEL DE JESUS MORAN, "PLANO DO PORTO DA CIDADE DA ILHA DE S. THOMÉ," 1797. Manuscript, color added. This chart and view of São Tomé harbor by Moran reflects the persistence in the late eighteenth century of the view from the sea as a graphic depiction of towns and landfalls, but with the addition of latitude and longitude observations, as described in the title cartouche.
Size of the original: 43.4 × 54.4 cm. Image courtesy of the Direção-Geral do Território, Lisbon (CA 568/IGP).

Resende Tavares Leote (AHU), the other depicting São Tomé harbor by the pilot Manoel de Jesus Moran (fig. 853).

Military maps also dominate the existing topographical and urban cartography of Angola. The "Planta do novo forte para o citio do Penedo," in Luanda (1755) by Guilherme Joaquim Paes de Menezes and the "Planta da fortaleza de Benguela" (1758) by Frederico Jacob de Weinholtz, both military engineers, exemplify the strategic importance of the principal cities of the coast, Luanda and Benguela (AHU). The first shows the capital and seat of the bishop, not far from the navigable Cuanza River connecting the coast with rich interior territories. The second shows an important military center with the extensive commercial routes to the interior of the country. Both were ports from which slaves were sent to the Americas and Europe.

The colonial policies of Sebastião José de Carvalho e Melo, marquês de Pombal, and the strategic development for the kingdoms of Angola by Francisco Inocêncio de Sousa Coutinho, governor from 1764 to 1772, redefined the military occupation of the territory and led to the creation of maps on a local scale of areas along the coast (Santos 2005). The occupation of the interior territory because of economic interests is evident in the building plans for Nova Oeiras and the Real Fabrica de Ferro for iron transformation. The maps and plans of this factory created by the military engineer Manuel António Tavares in 1776 are examples of colonial urban planning and civil architecture (BNP and AHU).

During the last quarter of the eighteenth century, hydrographic studies covered the ports and bays of Angola between Cabinda and Angra do Negro (Namibe), such as the "Plano e prospecto das terras adjacentes ao Porto de Mossamedes" (1785) by Luís Cândido Cordeiro Pinheiro Furtado. These marine charts aimed at furthering knowledge of the principal ports and bays north of Benguela (such as Novo Redondo [Sumbe]) and to prepare for the occupation of new coastal sites between Benguela and the Enseada das Areias (Tombua) in the direction of Epupa Falls on the Cunene (Kunene) River.

In Mozambique and the Rios de Sena region, Portuguese projects for occupation or consolidation of strategic ports along the coasts of the Indian Ocean led to the execution of different types of topographical maps and urban, civil, and military plans (Rossa, Araujo, and Carita 2001). These ports served as commercial gateways to the African states in the interior of the continent, like those existing along the Zambezi Valley, which produced gold and ivory among other products.

Because of its strategic position along the maritime routes between Europe and India, Mozambique Island was one of the most often represented places on maps throughout the century. Administratively part of the Portuguese colonial enterprise in the East Indies, this portion of East Africa became autonomous from the viceroy residing in Goa when the territories were reorganized in 1752. The cartographic response included detailed maps of the island and city of Mozambique and its environs completed by Gregório Taumaturgo de Brito in 1752 and 1754. He and João António de Sequeira also completed maps of the port and fort of Sofala south of the mouth of the Zambezi during the same decade (Teixeira da Mota 1973). Between 1786 and 1804, detailed hydrographic charts, military maps, and civil architectural plans related to Mozambique Island were authored by Carlos José dos Reis e Gama, a military official. To the north, in the direction of the Ruvuma River, which became the future border of Tanzania, maps were also made of the fort on the Island of Ibo (1790s) and for the fort of São José de Mossuril at the beginning of the nineteenth century (AHU).

Along the coast of modern-day Kenya, the Portuguese occupied the city of Mombasa between 1593 and 1698. The Omanis regained control for three decades before there was a brief return to Portuguese power in 1728–29. In this period, military engineers José Lopes de Sá and Álvaro de Cienfuegos and naval captain António de Brito Freire, author of travel diaries, designed four detailed plans of the city, emphasizing the strategic importance of Fort Jesus (BNP and AHU). After 1729, however, the Portuguese never recovered this port.

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Jorge Macieirinha Ribeiro

See also: Portuguese Africa

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***Topographical Surveying in Portuguese America.*** Until the late seventeenth century, medium- and large-scale maps of Portuguese America focused mainly on the coastline, including maps produced during the Dutch occupation of the northeast (1630–54) and the atlases of João Teixeira Albernaz the Elder. In Teixeira Albernaz's atlases, abundant place-names and coastal information contrasted with the merely decorative and pictorial treatment of the hinterland; relief and vegetation were drawn in perspective with color shading, a mode of topographic representation that continued in the eighteenth century. More exact and detailed maps of the interior of the colony during this period privileged the Amazon Basin, the home of numerous Jesuit, Franciscan, and Carmelite missions, whose members were largely responsible for these maps. The Jesuit Samuel Fritz was the author of several maps of the Amazon region, including the *Tabula geographica del Rio Marañon o Amazonas* (four sheets, 1690) (Almeida 2003a, 115).

The discovery of gold served as a catalyst for the exploration, occupation, and mapping of the interior regions of Brazil. From the beginning of the eighteenth century, the Crown expressed the need for maps representing the whole colony from the Maranhão to the Río de la Plata, especially regions with mining potential. Faced with a lack of military cartographers in Portugal, João V decided in 1728 to entrust the task to two Jesuits well-versed in mathematics and astronomy, Domenico Capassi and Diogo Soares. They were charged with making observations and measurements in the field and collecting information from the *gente pratica da terra*, primarily the *sertanistas* (people from the *sertão*, or back country) and other colonists who knew local


FIG. 854. JOSÉ JOAQUIM DA ROCHA, "MAPPA DA COMARCA DE VILLA RICA," 1778. Manuscript. Rocha prepared maps of *comarcas* using an equirectangular projection, geographical coordinates, and a scale. His distinctively stylized indigenes and spare flora were characteristic of his work. Size of the original: 39.0 × 68.3 cm. Photograph by Paulo Schettino. Permission courtesy of the Arquivo Histórico do Exército, Rio de Janeiro (n. 05.05.1111; CEH 3184).

geography well. The king also hoped that the cartographers would contribute to the politico-territorial organization of the vast colony, whose size was more than ninety times that of Portugal itself. Their maps were to indicate not only the existing roadways and civil and ecclesiastical boundaries, but also to propose more rational and convenient limits for these jurisdictional zones. Among the drawings attributed to the two Jesuits are representations of coastal and mining regions (see figs. 312 and 756), a map of diamond-bearing rivers and streams, and plans of cities and military works (Almeida 1999). These documents were prepared at scales significantly smaller than their topographical counterparts in Europe, but the vast size of the region explains the scales of ca. 1:1,000,000 to 1:2,000,000 used for these maps. They primarily concerned the southeast and southern regions of Brazil and gave fairly precise indications of longitude, hydrography, relief, and the networks of cities and roads. They did not, however, indicate current boundaries or new and more rational administrative divisions based on topographical features.

It was only in the second half of the eighteenth century, during jurisdictional conflicts among colonial authorities (governors, magistrates, municipal councils, and bishops), that larger-scale topographic and chorographic maps were encouraged by the Crown, since the desire to appropriate space required an understanding of the terrain and the use of natural features to define the territory. The maps of the *comarcas* (judicial areas) of Minas Gerais prepared in 1778 by the Portuguese military cartographer José Joaquim da Rocha exemplify this process, as they were among the early maps of the captaincy employing the *plate carrée* (or equirectangular) projection, geographical coordinates (though without an indication of a meridian of origin), a specific (and quite small) scale (between 1:800,000 and 1:2,300,000), and a standard codification system for habitations (Furtado 2009) (fig. 854; see also fig. 395). The level of generalization and simplification of information did not change much between maps at a small scale (showing the whole of the captaincy) and those at a medium scale (the *comarcas*). It is also important to note that different types of vegetation were not indicated by distinct cartographic signs, but were sometimes signaled with written observations placed near the legend (Santos 2010, 52).

The municipal territories were also mapped by local amateurs of varying degrees of skill, including militia commanders, local notables, artists, and magistrates, who also exploited natural features to establish so-called "incontestable" boundaries, which were essential for the effective collection of taxes. These manuscript maps sometimes contained explicit references to such tax issues (Fonseca 2003). Some municipal maps refer to the measurements made by the Jesuit *padres matemáticos* (priest mathematicians); these municipal maps could be generally considered satisfactory from a topological point of view (the relative position of cities, geographic features, and administrative divisions), but not in geometrical terms because they offered fairly schematic modes of representation. These locally produced maps were rarely considered compelling documents by the central government in Portugal (Fonseca 2003, 321–22). On the other hand, the information furnished by the indigenous inhabitants of Portuguese America was often judged useful by mapmakers from different regions in the colony. The contribution of the indigenous Amerindians is especially recognized today. Although these populations did not leave behind cartographic representations, numerous witnesses (missionaries and governors) attest that native peoples furnished geographical data to the *sertanistas* and other mapmakers by various means: oral descriptions, designs in the sand, and *maquettes* (models) made with knotted rope representing rivers and Indian villages. Moreover, the indigenous peoples served as guides and suppliers to the land and river expeditions organized by local authorities (Kok 2009).

The demand for clear boundary demarcations with Spanish America as required by the Treaty of Madrid in 1750 involved both foreign and Portuguese military engineers (José Custódio de Sá e Faria, Ricardo Franco de Almeida Serra, and José Fernandes Pinto Alpoim) who produced numerous topographic maps, notably in Mato Grosso and in the south, including surveys of river courses and waterfalls as well as plans and views of fortifications. In the second half of the century, diverse expeditions of exploration and conquest of the *sertões*, areas previously ignored by the colonists, were motivated by economic, political, and fiscal goals (Bueno 2009; Fonseca 2010). Organized most often by the governors of the captaincies (notably at São Paulo and Mato Grosso), by local political leaders (such as Inácio Correia Pamplona in Minas Gerais), or by men of science (such as Alexandre Rodrigues Ferreira in 1783–92), these expeditions resulted in numerous representations both cartographic (hydrography, relief, plans of cities, and even of *quilombos*, i.e., hinterland villages of escaped slaves) and iconographic (landscape views) (Costa et al. 2004; Araujo 2010; Bueno 2011) (fig. 855).

The technical aspects of these manuscript topographical maps fall into two categories: finished maps (even those created without respect to established cartographic codes) and preliminary designs and sketches (*borrões*) made with pencil or pen and ink, of which there were often definitive versions, carefully painted, set on a *plate carrée* projection with a *pétipé* (scale) and a grid of meridians and parallels (Bueno 2004, 2009, 2011). Note that military engineers were scarce in Portuguese America, and their tasks were often carried out by other bureaucrats and colonial agents (governors, magistrates, and municipal officers). Even if some of these latter understood the geometrical and astronomical basis of mapmaking, they possessed very few instruments (often only a compass) to carry out surveys of the terrain. Engineers supplied with more modern and effective instruments (theodolites and telescopes) were stationed more often in the frontier zones, which were thus represented in a more exact and detailed way and often at a larger scale. Although it might seem that after 1750 the use of scientific techniques by military engineers became more prevalent in the topographic maps of Portuguese America, one should note the use of the emblems of science. In the case of municipal maps created by local dignitaries and amateurs, these elements often play a purely rhetorical role. Far from contributing to the political neutrality of the map, they could hide willful distortions that served geopolitical objectives (Fonseca 2010; Bueno 2009).

Throughout the eighteenth century, the progress of geographic knowledge concerning Portuguese America was the work not only of scholars but also of untrained colonists. The latter provided itineraries and data to the mapmakers (as did the indigenous population) but also produced drawings and maps themselves. If the geometric quality and exactitude of their maps might be questionable, the historical and artistic value of some of these documents is today widely recognized (Adonias 1993; Fonseca 2003, 2010; Bueno 2011).

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SEE ALSO: Portuguese America

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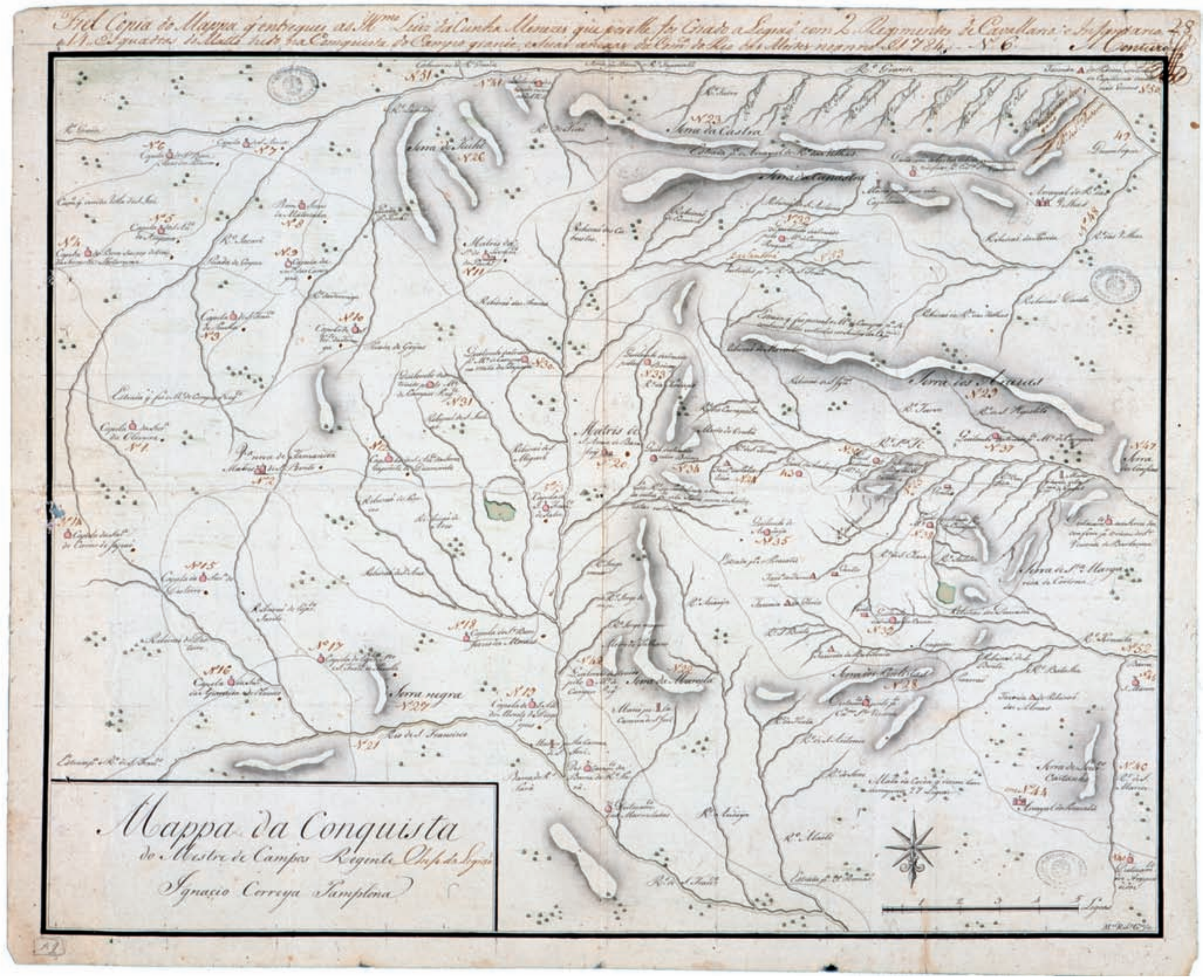


FIG. 855. MANUEL RIBEIRO GONÇALVES, "MAPPA DA CONQUISTA DO MESTRE DE CAMPO REGENTE CHEFE DA LEGIÃO IGNACIO CORREYA PAMPLONA," CA. 1784. This manuscript map of Pamplona's 1769 conquest of the central west territory of Minas Gerais shows the *quilombos*, whose inhabitants were perceived as a possible threat, represented by red circles numbered 30 through 43.
Size of the original: 29.7 × 38.8 cm. Image courtesy of the Arquivo Histórico Ultramarino, Lisbon (AHU CARTm_011, D. 1165).

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***Topographical Surveying in the Portuguese East Indies.*** See Geographical Mapping: Geographical Mapping and Topographical Surveying in the Portuguese East Indies

***Topographical Surveying in Spain.*** During the second half of the seventeenth century, topographical survey in Spain was increasingly linked to warfare, aided by Italian military engineers in the service of the Spanish Crown. For example, the Milanese Ambrosio Borsano prepared the manuscript "El Principado de Cattalvña y condados de Rossellon y Cerdaña" (ca. 1:196,000) in 1687, the most detailed map of Catalonia in this period. Borsano spent twelve years compiling the map by visiting all of Catalonia; the result was an effective design of the Catalan hydrographic and road networks, as well as cities and the fortified towns. Borsano dedicated his map to the Spanish king Carlos II and intended for the Crown to publish it, a goal that was not realized. The map remained in manuscript in Madrid, enjoying limited distribution and little influence on later maps of Catalonia (Buisseret 2007, 1090–91, fig. 39.21; Nadal 2008). Military purposes lay behind the *El Reyno de Valencia* (ca. 1:400,000, 1693) prepared by the Jesuit Francisco Antonio Cassaus and engraved by Juan Bautista Francia (Rosselló 2008, 166–71). This map emphasizes the correct pattern of lakes, such as the Albufera of Valencia, but does not display the distribution of the mountains particularly well. Both the Cassaus and Borsano maps were related to military planning during the wars between the Spanish and the French from 1684 to 1697 and a series of peasant revolts.

The establishment of the Bourbon monarchy in 1700 gave new impetus to topographical work. From the 1740s, Zenón de Somodevilla y Bengoechea, marqués de la Ensenada, the foremost representative of the Spanish absolute monarchy, promulgated an active cartographic policy to provide the Crown with a general large-scale map of Spain, a cadastre, and nautical charts of the coastline, all of which would provide detailed cartographic information about the realm. Ensenada, aware of the increasing cartographic backwardness of Spain vis-à-vis France, directed Jesuits Carlos Martínez and Claudio de la Vega to survey a general map of the country. From 1739 to 1743, both Jesuits measured different areas of Spain geometrically, resulting in a general map, "Exposicion de las operaciones geometricas" (see fig. 320). This incomplete manuscript map of thirty-six sheets (ca. 1:445,800) was based on both fieldwork and compilation. The representation of relief was more detailed than on preceding maps, with mountains drawn in gray from oblique perspective and valleys shown in green and yellow (Núñez de las Cuevas 2001).

However, this map did not please Ensenada, who probably desired cartography based on trigonometric surveys and geodetic measurements (Núñez de las Cuevas 2001, 111). Consequently, in 1749 Ensenada ordered military engineer Pedro Superviela to charge the Cuerpo de Ingenieros Militares with the survey of Spain. A few months later, Ensenada received a series of cartographic reports by several Spanish military engineers, including Pedro Martín Cermeño, who proposed the creation of a general map of Spain based on careful observation and measurements. However, the cartographic survey work performed in the old province of La Mancha by several military engineers also fell short of Ensenada's expectations because the engineers lacked good geodetic and topographical tools (Camarero Bullón 1989, 54–62).

In October 1750, Ensenada ordered Jorge Juan and Antonio de Ulloa to prepare precise instructions for surveying the map of Spain. Juan and Ulloa, Spanish scientists who had participated in the geodetic expedition to the Viceroyalty of Peru headed by French scientist Charles-Marie de La Condamine between 1735 and 1745, were well aware of the geodetic and cartographic work of the Cassini family in France. They responded swiftly with the "Instrucción de lo que se ha de observer . . . en la formación de los Mapas generales de España," an undated manuscript in the Real Academia de la Historia, Madrid, attributed to Juan and Ulloa as it specified scientific criteria for such a survey. In addition to these instructions, Juan wrote "Método de levantar y dirigir el mapa ó plano general de España" (1751) and "Reflexîones sobre el método de levantar el mapa general de España," published together in 1809 (Reguera Rodrígues 2000, esp. 476), which planned a survey program less ambitious from a geodetic viewpoint than that described in the "Instrucción," but which proposed several norms regarding topographical issues, such as the representation of mountains. Article forty established that "the representation of the mountains and the valleys [should] be done on paper as if they were seen at an angle of fifteen degrees, the point of view fixed on the southern part of each point or object, and turning north; because in this way the greater height of mountains is perceived in relation to the others" (Reguera Rodrígues 2000, 488). Unfortunately, Ensenada's fall from power in 1754 caused the survey of Spain to be abandoned until 1796, when the monarchy's new first minister, Manuel Godoy (príncipe de la Paz), created the Cuerpo de Ingenieros Cosmógrafos de Estado and the Real Observatorio with the aim of preparing a map of Spain. The astronomer and Escolapian (Piarist) friar Salvador Jiménez Coronado was the head of the short-lived Cuerpo, which ceased to function in 1804.

During the eighteenth century, a rich and diverse regional cartography developed in which topographical features were represented. These maps were not always based on observation but were sometimes compilations, such as the *Nova et accurata regni Aragoniæ* (ca. 1:380,000, engraved by Jean Baptiste Liébaux, 1715), compiled by Aragonese Dominican friar Juan Seyra y Ferrer, and the *Nueva descripcion geographica del Principado de Catalvña* (ca. 1:230,000, engraved by Antoni Sabater, 1720) by the Catalonian geographer Josep Aparici (Burgueño 2008; Galera 2011). Military concerns continued to propel regional mapping efforts. Responding the War of the Spanish Succession (1701–14) between 1708 and 1716, cavalry colonel Oleguer Taverner i d'Ardena, comte de Darnius, prepared the "Carta general del Principado de Cataluña dividida en sus vegueríos" to fulfill military needs of the Bourbon army, a map not sufficiently studied to understand its place in Spanish cartography. Taverner also authored the *Nueuo mapa del Principado de Cathalvña* (ca. 1:400,000, 1726, engraved by Marcos Lomelin) (Montaner 2007).

Observed and measured plans were the focus of the military engineer Antonio Riviere, probably of French origin, who led a commission of military engineers between 1740 and 1743, during the War of the Austrian Succession, to survey the Canary Islands with plane table, alidade, and a cord of hemp for measuring (Tous Meliá 1997). These topographic surveys produced maps of seven islands (Tenerife, 1740; Lanzarote, 1741; La Palma, 1742; Hierro, 1742; Gomera, 1743; Fuerteventura, 1745; Gran Canaria, 1746) drawn on similar scales (ca. 1:72,000). Riviere calculated the height of Pico de Teide on the island of Tenerife and used shaded relief to render the mountains. In 1762, the Canary Islander Francisco Xavier Machado Fiesco, an official of the royal treasury, prepared the "Plano de las Islas de Canaria" (ca. 1:525,000); using similar techniques, military engineer Francisco Llobet compiled the *Mapa del Reynado de Sevilla* (ca. 1:200,000) in 1748.

The repeated transfer of control of the island of Minorca among English, French, and Spanish powers throughout the eighteenth century engendered a focused cartography of the Baleraic islands. Majorca, Minorca's neighbor, attracted the prebendary (later cardinal) Antoni Despuig i Dameto, who supervised the *A S.A.R. la serenisima princesa de Asturias D*r*. Maria Luisa de Borbon, nuestra señora dedica este mapa de la Ysla de Mallorca* (ca. 1:73,000, engraved by Josep Muntaner i Muner, 1785). Despuig collaborated with several scientists including the Capuchin friar Miquel de Petra and geographer Julià Ballester, often considered the true author of this map, which shows the relief of Majorca with shaded profiles and displays for the first time the wetlands of the island, such as the well-drawn Albufera and the Prat de Sant Jordi (Rosselló 2008, 182–84; Ginard Bujosa 2009). In 1795, the Jesuit botanist Antonio José Cavanilles edited the *Mapa del Reyno de Valencia* (ca. 1:525,000, engraved by Tomás López Enguídanos and Josep Asencio), in which the mountain ranges are correctly arranged and represented in a pseudoperspective illuminated from the left (López Gómez 1997; Rosselló 2008, 175–77).

The second half of the eighteenth century saw an increased number of large- and medium-scale topographical maps of several Spanish regions. The majority were manuscript maps prepared for hydraulic works (irrigation, urban water supply, navigation canals), the construction of public roads, and forestry exploitation. They were nearly all executed by military engineers, trained in current surveying and representational techniques, although some were also made by civilian architects and master builders; they illustrate the consequences of enlightened policies of modernization of Spanish territory and economy (fig. 856). Some of this rich cartographic legacy has been reproduced or cataloged in books about Spanish military engineers or on hydraulic works or roads policy (Capel et al. 1983; Sánchez Giménez 1985; Sambricio 1991; Homar 1992; Tous Meliá 1997). Nevertheless, only a few of these maps have been subject to detailed analysis from the point of view of the history of cartography, and a great many remain uncataloged.

The irrigation projects undertaken in Aragon and Navarra, in the region of the Canal Imperial de Aragón, required a specific topographical cartography, especially the accurate rendition of the hydrographic system, while the mountainous relief was shown by rough hachures only: for example, the "Plano general desde el termino del lugar de Luzeni que confina con el de Voquiñeni, ultimo de los que riega la Azequia Ymperial, hasta la villa de Fuentes" (1746) by military engineer Sebastián de Rodolphe and the "Proyecto y plan general que manifiesta la ruta que puede llebar el Canal Ymperial de Aragon y tierras que riega desde Tudela o el Bocal antiguo hasta Sastago" (1774–78) by military engineer Joaquín de Villanova (Sánchez Giménez 1985, 274–75). In Catalonia the several projects related to the construction of the Canal d'Urgel during the eighteenth century by military engineers such as Bernardo Lana and by civil cartographers like hydrographer Sinibald de Mas or master builder Joan Soler i Faneca produced a varied and interesting hydraulic and topographical cartography

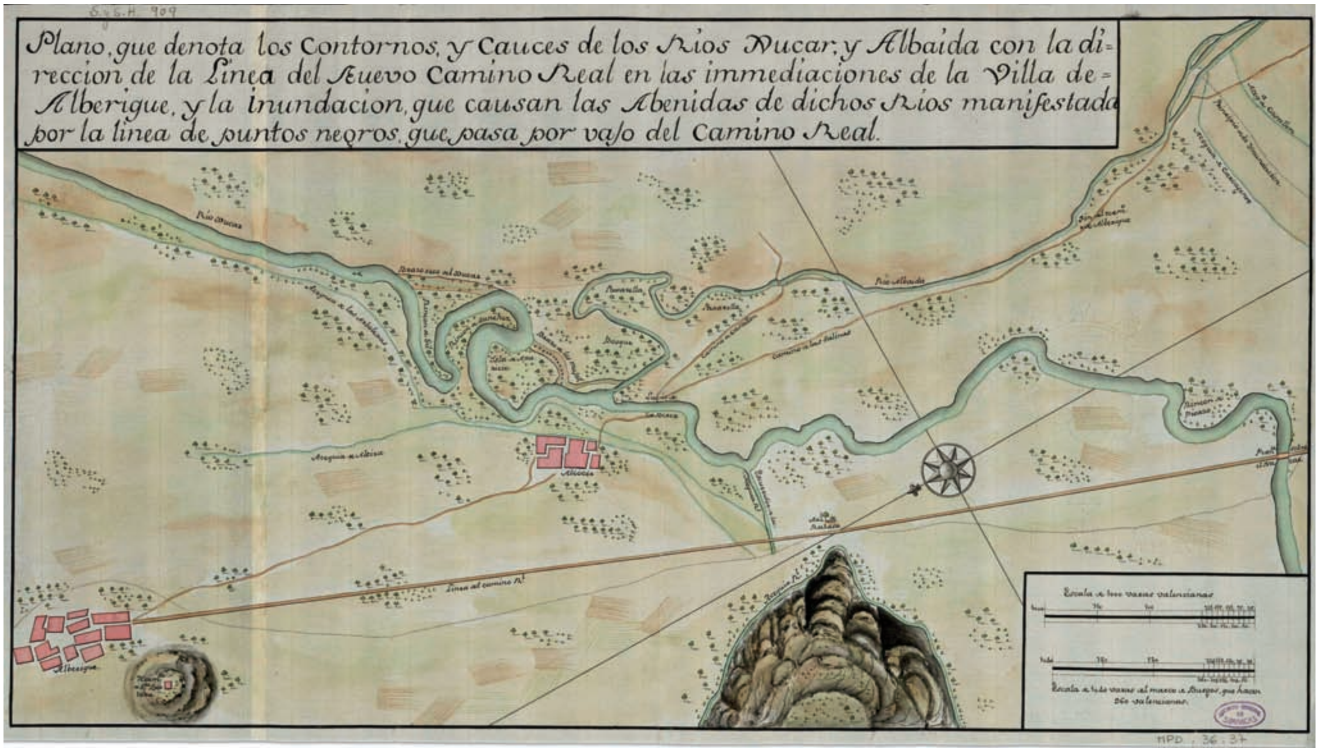


FIG. 856. "PLANO, QUE DENOTA LOS CONTORNOS, Y CAUCES DE LOS RIOS JUCAR, Y ALBAIDA CON LA DIRECCION DE LA LINEA DEL NUEVO CAMINO REAL," 1770. This anonymous manuscript plan, ca. 1:10,000, delineates the course of two rivers and their flood parameters in relation to the design of a new road.

Size of the original: 33 × 58 cm. Image courtesy España, Ministerio de Cultura, Archivo General de Simancas, Valladolid (MPD,36,037).

(Burgueño 2001, 480–89). Irrigation projects around Madrid and in the territory known now as Castilla–La Mancha required similar cartographic work. In 1769, the president of the Consejo de Castilla, Pedro Pablo Abarca de Bolea, conde de Aranda, oversaw an ambitious plan of irrigation of the flat expanse and arable lands of Guadalajara and Alcalá de Henares, which produced large-scale cartography such as the "Mapa de la Campiña de Guadalaxara y Alcala" (1770) by Spanish military engineer Manuel de Navacerrada. Hachures express relief, but the hydrographic system of the Henares River is accurately measured (Camarero Bullón 1989, 72–74).

Urban water supply required maps like the "Mapa de los terrenos desde el confluente o junta de los ríos Lozoya y Jarama en el término de la villa de Uzeda hasta Madrid" (1769) by military engineer Jorge de Sicre y Bejar, who executed the first modern project to supply water to Madrid (Arroyo Ilera 2004, 270–76; Sánchez Giménez 1985, 280). Again, the accurate hydrographic system is accompanied by roughly hachured elevated terrain.

Topographical surveys aided the construction of public roads and communication canals. North of Castile, Rodolphe used his "Mapa ideal en que se demuestran los caminos desde la ciudad de Burgos a las villas de Laredo, Santoña y Santander" (1748) to prepare the public road connecting the city of Burgos with the small harbors of Laredo, Santoña, and Santander along the Bay of Biscay for internal political reasons (Camarero Bullón 1989, 67). The Canal de Castilla, one of the main enlightened projects undertaken in 1751 by Ensenada, required careful preparatory maps made from 1751 to 1755 by two of Spain's best cartographers: Carlos Lemaur and Antonio de Ulloa (Helguera Quijada 1988, 17–33). Lemaur, a French military engineer in the service of Spain, prepared the "Plano general del proyecto ejecutado y por ejecutar de los Canales de Castilla que comprehende desde Olea a la ciudad de Segovia" in 1752 (Sánchez Giménez 1985, 269), while the geodesist Ulloa authored the "Mapa de los canales de navegacíon y riego para los Reynos de Castilla y de Leon," ca. 1755 (Helguera Quijada 1988, 30–31; Sambricio 1991, 1:92–93). Both maps carefully represented the hydrographic system. Similarly, the construction of the Canal del Gran Priorato required the architect Juan de Villanueva to draw the "Plan geographico de las Lagunas de Ruidera y curso que hacen sus aguas sobrantes" (ca. 1:66,800) in 1781 (López Gómez 2004, 430–38).

Large-scale topographical mapping in other regions of Spain has been analyzed in the rich collection of local topographical maps made by Valencian land surveyors during the eighteenth century (Faus Prieto 1995, 224–25). Such local maps again emphasized hydraulic works. The "Plano demonstrativo del Condado de Cosentaina" (1778) by Francesc Aparisi and A. Valor exemplifies this concentration on hydrography to the detriment of mountain relief (Faus Prieto 1995, 346, fig. XV). Other local maps emphasized topography in the depiction of parochial boundaries (fig. 857).

Economic forces also pushed the creation of topographical maps in Catalonia. The search for sources of charcoal led to Juan Gros's "Mapa del terreno, que comprehende los montes, y bosques señalados para la provision de carbon" (1773, ca. 1:210,000), on which relief is shown by means of shading and the use of horizontal curves, serving as a rudimentary contour lines. To show timber suitable for charcoal, the map distinguishes four types of trees: holm oaks, oaks, cork oaks, and beeches (Baig i Aleu 2008). These maps might also be considered thematic cartography, since the display of relief and terrain is subservient to the natural resources highlighted on the map.

Boundary surveying also made a topographical impact. The 1764 agreement between the Spanish and French authorities to mark the boundaries of the area close to the castle of Bellaguarda resulted in the "Plano en que se manifiesta la línea de división de los Reynos de España y Francia por la parte del Ampurdan y Coll del Pertús" (1764, ca. 1:2,200) by Spanish military engineers Miguel Moreno and Carlos Cabrer Suñer and French military engineer Luis de S. Maló. The plan shows relief pictorially, with some heights depicted by color variations and others by shading (Capdevila Subirana 2008, 355–56). Local boundary disputes and urban limits were also depicted in maps by certified land surveyors (*agrimensores* or *geómetras*) and architects (fig. 858).

From the second half of eighteenth century, because of the policy of territorial modernization of Spain undertaken by its enlightened governments, a more detailed and more accurate topographical cartography was created primarily by military engineers (who played a determining role in this process), civil architects, land surveyors, and a few scientists. Spanish military engineers were well trained in mapmaking in the Real Academia Militar de Matemáticas de Barcelona, opened in 1720 (Capel, Sánchez, and Moncada 1988). Even so, the royal academies of art, created in the middle of eighteenth century, also played a very important role in improving the skills of Spanish land surveyors in rendering topography, as the academies like the Real Academia de Bellas Artes de San Carlos in Valencia supported the shift from an apprentice-based training to an institutionalized approach, based on examination and certification (Faus Prieto 1995, 107–29; Astizaraín 1987).

FRANCESC NADAL

SEE ALSO: Spain

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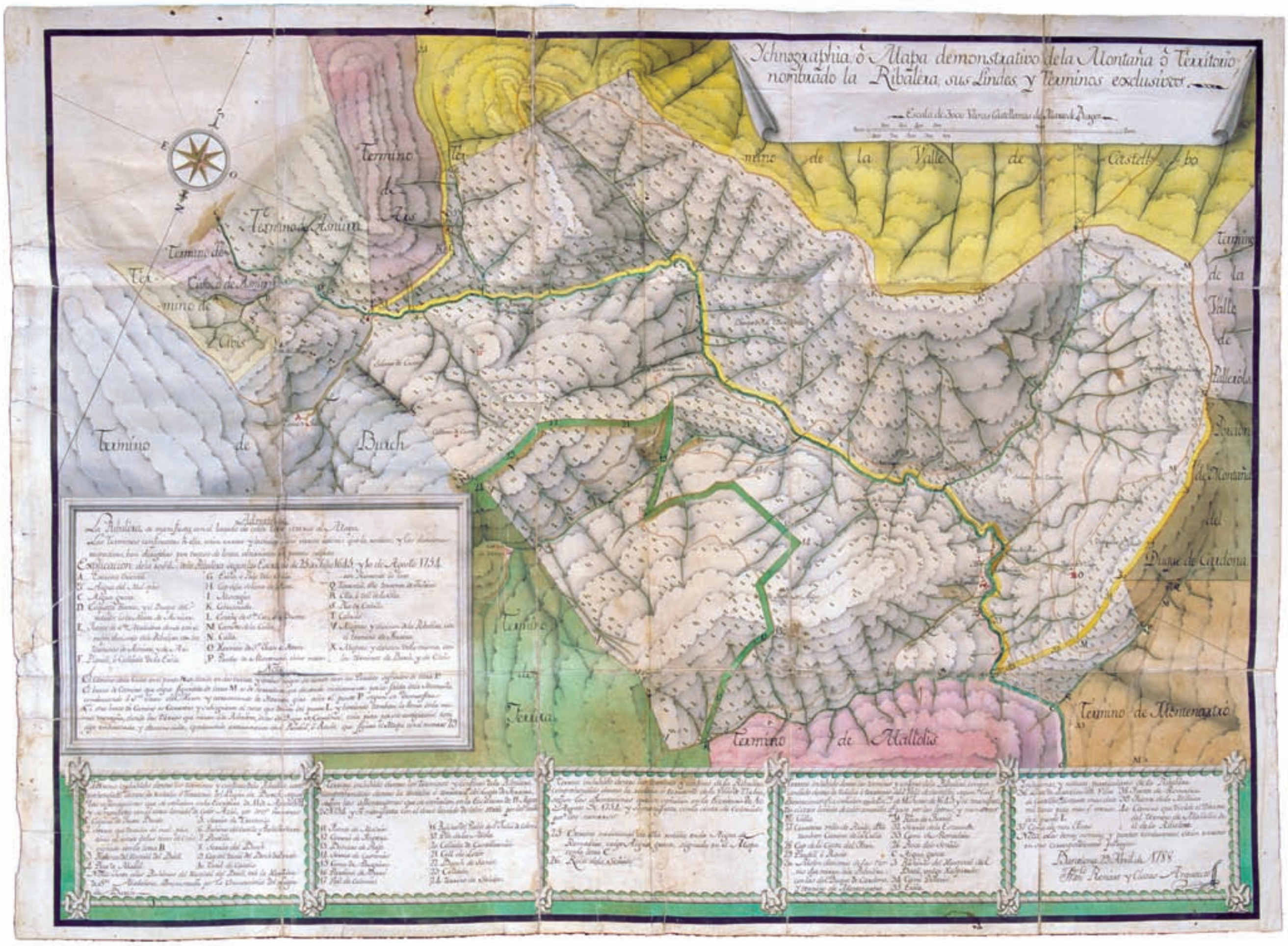


FIG. 857. "YCHNOGRAPHIA Ó MAPA DEMONSTRATIVO DE LA MONTAÑA O TERRITORIO NOMBRADO LA RIBALERA, SUS LINDES Y TERMINOS EXCLUSIVOS," 27 APRIL 1788. Manuscript map, ca. 1:9,000, made by the Catalan civil engineer Francisco Renart Closas, as part of the resolution of a conflict between several municipalities (colored variously on the map) of the Catalan Pyrenees.
Size of the original: 68 × 92 cm. Ministerio de Educación, Cultura y Deporte, Archivo de la Corona de Aragón, Barcelona (ACA, Collecciones, Mapas y planos, 567).

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FIG. 858. "MAPA DEL R^L^. MONASTERIO DE RELIGIOSOS CISTERCIENSES, Q.^E^ SITA EN EL PRINCIP.^DO^ DE CATALUÑA," 1798. This manuscript topographical map by the painter Antonio Verdaguer Llunell shows the boundaries of the Catalan Cistercian monastery of Poblet and the surrounding territory.
Image courtesy España, Ministerio de Cultura, Archivo Histórico Nacional, Madrid (Clero, MPD 189).

***Topographical Surveying in Spanish America.*** The consolidation of the Spanish Empire in the New World aroused the Crown's concern to understand the nature of the territory over which it exercised power, an understanding communicated both in writing, through chronicles and descriptions written by soldiers, missionaries, sailors, and officials of the Crown, and in cartography. Territorial expansion in the Americas in the sixteenth and seventeenth centuries served as an impetus for colonial mapmaking, characterized by maritime explorations of the coasts along both seas and including voyages to the Pacific Isles. Terrestrial expeditions to Spanish-claimed territory served two clear objectives: first, to discover mineral deposits of gold and silver, which resulted in the establishment of numerous mining camps that developed into important population centers; and second, to focus on the spiritual conquest of the indigenous population by various religious orders, such as the Franciscans, Augustinians, Dominicans, and Jesuits, all of whom formed missions that became locations of interest on numerous maps and plans.

During the colonial period, mapmaking was not in any sense the exclusive work of a single group. Many learned persons developed maps, such as the mathematician Carlos de Sigüenza y Góngora, creator of the first general map of the Viceroyalty of New Spain (1691) (Buisseret 2007, 1159, fig. 41.16); the Jesuit Eusebio Kino; the naturalist José Antonio de Alzate y Ramírez; mariners such as Bruno Ezeta, Cayetano Valdés y Flores, and Alejandro Malaspina; and distinguished military personnel like Félix de Azara and Miguel Constanzó (Moncada Maya 1994). The most important contributions came from the Jesuits and the military. Until their expulsion (1767) the Jesuits played an important role in colonizing and understanding the claimed territories through their written descriptions and maps, as exemplified by Kino, who traveled to the Baja Peninsula of California in 1683 and in 1687 to Sonora and Pimería, where he would remain until his death. His maps defined the peninsular shape of Old California forty years before other Europeans understood this geography (Burrus 1965).

The military engineers best represent a transition to mapping based on observation and measurement. A technical-scientific corps that relied on an academic organization and training for its members was especially capable of undertaking large-scale mapping. As they were required to prepare maps and plans of every project they undertook, it is difficult to separate the cartographic work of military engineers from their other activities. The inventories elaborated by Horacio Capel et al. (1983) and José Omar Moncada Maya (1993) corroborate their prolific output of maps.

A significant number of maps resulted from the engineers' participation in other expeditions that aimed at discovering territory. These plans and maps were accompanied by detailed verbal descriptions about natural and human resources in Spanish America. These descriptions make it clear that the mapmaking was a secondary or supplementary activity for the engineers. For this reason, their cartographic products should be seen both as working tools and as a means of informing the authorities about the quality of their works and projects. Perhaps more importantly, the maps were a way for Spanish authorities to understand their new territories. Thus, for example, María del Carmen León García (2009, 441) identifies 432 maps and plans created by military engineers for New Spain alone in the second half of the eighteenth century.

The capacity of the engineers to map the landscape was a product of the technical-scientific organization created by the Real Academia Militar de Matemáticas de Barcelona (founded 1720), where individuals in this corps were trained. Later academies were founded in Orán (1732) and Ceuta (1739), which were replaced by academies in Cádiz and Zamora in 1789; when the three academies closed in the last year of the century, they were replaced by the Academia de Alcalá de Henares in 1803 (Moncada Maya 1994, 47–48). The courses offered in the Barcelona academy emphasized the use of calculating and measuring instruments; the subjects of geometry, topography, and land measurement; the use of maps and globes; and classes in design and preparation of maps. Such training prepared a technically competent corps for mapping territories of New Spain (León García 2009, 448). While many engineers were trained in Spain, in Spanish America, starting around 1730, an academy of mathematics opened in Cartagena de Indias, and by the second half of the eighteenth century, the University of San Marcos (Peru) was examining students in military architecture, fortification, hydraulics, geography, and physics (Sanz Camañes 2004, 390). This training not only increased the number of engineers serving in the Americas (from 121 in the period 1721–68 to 183 in 1769–1800) (Moncada Maya 2003, 207) but also led to a recognizable cartographic style that distinguished many manuscript topographical maps (fig. 859).

Certain techniques of representation became hallmarks of Spanish Enlightenment mapmaking (Moncada Maya 2009, 175–76). First, orography on these topographical plans evolved from representing all the territory in equal density to showing mountain ranges and rivers with greater precision; relief representation shifted from being an adornment on the map to showing definitively localized elements. Another feature was the use of astronomical and topographical observations to correct erroneous locations on previous maps by fixing coordinates more securely. A regular feature was standardized


FIG. 859. DETAIL FROM AGUSTÍN CRAME, "ISTMO DE TEHUANTEPEC Y CURSO DEL RIO GOAZACOALCOS," 1774. Manuscript. Crame's rendering of the isthmus between the Gulf of Mexico and the Pacific displays several characteristics of topographical mapping in Spanish America: relief is rendered by color wash and pen and ink drawing, a latitude scale is incorporated (along the right edge), and descriptive text is added (on the left and on the back of the map). Roads are shown in addition to more important river networks offering a route across the isthmus.

Size of the entire original: 71 × 37 cm; size of detail: ca. 42.5 × 37.0 cm. Image courtesy of the Nettie Lee Benson Latin American Collection, Perry-Castañeda Library, University of Texas at Austin (M 973 1774).

scales, which had previously varied widely according to the area they were representing and were expressed in miles, leagues, and Castillian leagues for large- and medium-sized areas; cords, feet, and varas castellanas and piés for smaller areas (Aguilar-Robledo 2009, 25). Finally, the topographical plans of military engineers also established a meridian of origin; although this could vary according to the author, the most common ran through Cádiz, the island of Hierro (Ferro), or Santa Cruz de Tenerife.

The maps of military engineers aided in the Spanish administration of frontier and borderlands areas from South to North America by facilitating communication between military officers and local governors in their substantial effort to limit indigenous threats in South America. Further north, military engineers in unexplored or contested regions, especially in the borderlands of northern New Spain, prepared reports and increasingly accurate maps with observations and information used to reinforce Spanish land claims and improve the defense system of forts and missions. On one important inspection led by Cayetano Pignatelli, third marqués de Rubí, in 1766, engineers Nicolás de Lafora and José de Urrutia created extensive maps based on astronomical observations and territorial measurements, which influenced the subsequent policy of establishing settlements and a defense strategy that relied on forts (*presidios*) (Reinhartz 2005, 67–74). The combination of astronomical observations with on-site triangulation and observation of landscape was put to good effect by Joaquín Velázques de León, whose manuscript study of the valley of Mexico (around 1775) drew on cartographic information derived from his triangulation of the region in 1774 (Moreno 1977).

JOSÉ OMAR MONCADA MAYA, WITH ADDITIONAL MATERIAL PROVIDED BY JORDANA DYM

SEE ALSO: California as an Island; Society of Jesus (Rome); Spanish America

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***Topographical Surveying in Sweden-Finland.*** King Gustavus Adolphus led Sweden to military supremacy during the Thirty Years' War (1618–48) and made Sweden a great power. Systematic land surveying started in Sweden 1628, when the king sent instructions to Andreas Bureus for systematic mapping of the whole kingdom. The surveys were undertaken with the plane table (*mensula Praetoriana*).

The surveys were begun in Ingria (1639), Livonia (1643), Estland (1648), and Pomerania (1681) but were dramatically reduced during the Great Northern War (1700–1721). This war ended Sweden's status as a leading European power. It lost Ingria, Livonia, Estland, and the provinces of Kexholm and Viborg. After another war with Russia (1741–43), Sweden had to cede some towns. In 1766–88 and 1792–1802 Russia commenced new surveys and geographical mapping of these areas using land surveyors hired from Sweden. By the end of the seventeenth century most of the parishes were mapped in mainland Sweden, not including forests and unimproved lands around villages (Peterson-Berger 1928; Richter 1959). In terms of large-scale maps produced by land surveyors, Sweden was considered by Ulf Sporrong to have the "best preserved and most systematic series of early cadastral maps in the Western world" (Baigent 1990, 62).

After the war of 1741–43 a proposal was made by the Finska ekonomiekommission (1745) for a thorough mapping of Finland (Gustafsson 1933, 100). The project was assigned in 1748 to Jacob Faggot, who stressed the importance of mapping for improving the economic situation in Finland. The Geografiska mätningskomissionen ended its surveying in 1757, having mapped a total of 90,000 square kilometers on a scale of 1:20,000 (Gustafsson 1933; Richter 1959, 159).

Faggot obtained a chronometer and quadrant from England for improving the geodetic base (Faggot 1747). A chain of triangulations was measured from Åbo (Turku) to Åland and further on to Grisslehamn in 1748–58. It continued eastward following the coastline, reaching Sveaborg (a fortress near Helsinki) in 1774. The total network was 360 kilometers in length and contained 121 triangles (Ehrensvärd 2006, 336). Another survey chain was measured from the Norwegian border along the coast to the Stockholm archipelago in 1758–67 and continued from Åland to Torneå in 1784–86. By the end of the eighteenth century the entire Swedish coastline was covered by a network of triangulation (Richter 1959). These coastal triangulations were used for making maritime charts but not for geographical maps (Lönborg 1903).

In 1796, Samuel Gustaf Hermelin received a privilege to publish geographical maps in Sweden when a lack of funds prevented government publication. Under his leadership Carl Petter Hällström made reconnaissance missions and longitude observations in various part of Sweden-Finland (Hällström 1815; Ekstrand 1896–1903, LXXVIII; Tanner 1936). According to Edward Daniel Clarke, Hällström used "an excellent sextant made by [Jesse] Ramsden and one of the [John] Arnold's chronometers" already in 1799 when he was in the Torneå Valley (quoted in Mead 1968, 256). Because Hällström had access to the military maps of the Rekognoserings staten (Finnish reconnaissance authority, 1776–1805, af Tibell 1798; called Finska Rekognoseringsverket by later sources), the reconnaissance benefited the public as well (Mead 1968, 269).

Some military surveys at topographic scales were carried out in Finland during the Russo-Swedish War (1741–43) along the coast and the southeastern border. During the Pomeranian War (1757–63, part of the Seven Years' War), the Swedish military based its mapping efforts of Pomerania on models from France. Mapping at the even larger scale of 1:40,000 was begun in 1758 and completed in 1764, with separate maps of villages at a scale of 1:4,000 (Ehrensvärd 2006, 331). After King Gustav III seized power in a coup d'état in 1772, his desire to reinforce the defenses of Finland resulted in the establishment of the Rekognoserings staten; Carl Nathanael af Klercker and four other officers formed *rekognoseringsbrigaden* during the war, 1788–90, while other personnel were placed in different units (af Tibell 1798). Mapping was done in the northern area under the leadership of Göran Magnus Sprengtporten (fig. 860) and in the southern area by af Klercker (see fig. 576) who later supervised both regions. In 1791 coastal areas were included as was Ostrobothnia (Österbotten). Final maps from the survey were drawn at scales of 1:20,000, then generalized to 1:40,000, 1:160,000, 1:320,000, and 1:640,000, with some special maps (*passkartor*) drawn at 1:4,000. Maps expressed relief with hachures and hill shading and were accompanied by commentaries (Harju 2012).

Sprengtporten suggested the establishment of Haapaniemi Krigskola (military cadet school), which started in 1780. Russia received some reconnaissance maps when Sprengtporten joined the Russian court. The use of these maps is unclear (Harju and Lappalainen 2010; Harju 2011). One of the teachers, Otto Carl von Fieandt, published a mapping guide for reconnaissance (1804). Carl Gustaf Tavaststjerna, a teacher in the Kungliga Krigsakademien på Karlberg (Karlberg military academy), published the first book on topographic mapping in Sweden 1807, which discusses the work of the Cassinis in France and different ways to present relief. However, he considered the use of contours unsuitable for general topographic maps because of the work involved (Tavaststjerna 1807, 194; Lönborg 1903, 225).

All results of reconnaissance were secret and not accessible to land surveyors. However, some new roads and waterways were planned as a consequence. The reconnaissance maps did not have a good geodetic basis. Because the maps were not printed, the military had to use Hällström's maps when war started in 1808. The reconnaissance maps are especially valuable for their detailed inclusion of Finnish place-names for the first time (Mead 1968, 269–70).

The reconnaissance survey was dissolved in 1805. Some of the personnel from the Rekognoserings staten moved to Sweden and formed the core of the Fältmätnings-Corpsens (Swedish field survey corps; also called Fältmätnings-kåren) (Gustafsson 1933). The corps, established in 1805, was the idea of af Tibell, who had been leading French military mapping in Italy for Napoleon I (Lönborg 1903, 221). Finland was ceded to Russia in 1809 as a result of the war. In 1812, Fieandt proposed the establishment of a field survey corps in Finland. He reinitiated the school as Haapaniemi topografiska kåren until the school was destroyed by fire in 1818, and it was moved in 1819 to Hamina and renamed the Finska kadettkåren (Harju and Lappalainen 2010).

From 1798 to 1804 the Russian army had made reconnaissance mapping of the "Old Finland" (areas ceded to Russia in peace treaties of 1721 and 1743) at a scale of 1:42,000 under the leadership of colonel Fabian Gotthard von Steinheil. When the rest of Finland was ceded in 1809, more Russian officers were put to work using Hällström's maps enlarged to 1:84,000 along with land survey maps (Gustafsson 1933).

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SEE ALSO: Sweden-Finland

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FIG. 860. DETAIL FROM A REKOGNOSERINGS STATEN MAP MADE UNDER THE LEADERSHIP OF GÖRAN MAGNUS SPRENGTPORTEN, 1777–78. Manuscript; 1:20,000. Extract of a reconnaissance map from the northern portion of the survey showing roads, villages, buildings, land classification, and also boat routes in Puumala, Finland.
Size of the entire original: 190 × 190 cm; size of detail: ca. 40 × 50 cm. Image courtesy of Krigsarkivet, Stockholm (SE/KrA/0411/A/03/1/3 e).

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***Topographical Surveying in Switzerland.*** Mountainous Switzerland presented a major challenge in depicting the topography of the earth's surface. Hans Conrad Gyger designed two manuscript maps of the entire Confederation, one in 1634 and one before 1657, at scales of ca. 1:200,000 and 1:350,000, respectively (see fig. 770), which already revealed the extraordinary artistic abilities of this Zurich cartographer in showing the outline of the terrain (Dürst 1978, 8–10). In his large manuscript *Landtafel* of 220 × 220 centimeters of the Zurich region (ca. 1:32,000), Gyger was able, between 1664 and 1667, to achieve a very natural rendering of the relief in outline with hill-shading and color-perspective effects that established high standards unsurpassed until the nineteenth century. Toward the end of the seventeenth century, the Basel government had its territory surveyed by Georg Friedrich Meyer, which gave rise to maps of the individual *Ämter* (administrative districts), as well as a larger map of Basel in ca. 1680 at 1:10,000 (Suter 1933, 141 [Nr. 10]). This manuscript demonstrated considerable precision in the ground plan but only crudely depicted the topography. These precursors of nineteenth- and twentieth-century topographical representations were thus limited to individual cantons and varied in the quality of execution.

In 1712 Johann Jakob Scheuchzer published the map *Nova Helvetiae tabula geographica* in Zurich in four sheets (ca. 1:230,000), which remained *the* standard complete map of Switzerland until the end of the eighteenth century (Dürst 1999) (see fig. 771). It was based on a mixture of principles from the time of Gyger with local additions, which Scheuchzer had either obtained from his correspondence with other scholars or gathered himself on his travels through Switzerland. There was no comprehensive survey to speak of on the Confederation level, and the defective geometry of the Scheuchzer map, which contains the oldest known altitude datum—a single spot height—on a Swiss map, was already acknowledged by his contemporaries.

In the mid-eighteenth century, two treatises were published that dealt with the problem of depicting the mountainous landscape by a new methodology. In 1754 while in prison, the Genevan physicist and geodesist Jacques-Barthélemy Micheli du Crest calculated the altitude of Fort Aarburg based on barometric observations and subsequently determined the altitude of Alpine peaks at a distance of 40 to 100 kilometers, for which he used a large self-constructed level. Micheli du Crest had the results of his altitude measurement engraved in copper in Augsburg in 1755 as his *Prospect geometrique des montagnes neigées*. This first scientific Alpine panorama is one of the earliest examples of a map-like representation of elevation (Rickenbacher 1995).

In the late 1740s, Franz Ludwig Pfyffer of Lucerne began to depict Mount Pilatus near Lucerne as a miniature three-dimensional model, influenced by the French tradition of relief modeling. By 1786 he had elaborated his "Relief der Urschweiz" on a planimetric and altimetric scale of ca. 1:11,500 (Bürgi 2007, 125) (see fig. 360). Pfyffer used two map-like representations for further dissemination of the topographical information it contained. In 1777, Balthasar Anton Dunker published the first bird's-eye map of the relief in the *Plan perspectif d'une grande partie des cantons de Lucerne*. The *Carte en perspective du nord au midi d'après le plan relief et les mesures du General Pfyffer* by Jakob Joseph Clausner followed in 1786, which was richer in its altitude data thanks to the spot heights determined by Pfyffer. In the same year, Christian von Mechel published a second bird's-eye map in the *Vue perspective de la partie la plus élevée du centre de la Suisse* (Bürgi 2007, 79, 112–14, 146, 157). With the three-dimensional relief model, the map, and the bird's-eye maps, around 3,460 square kilometers of Central Switzerland were depicted toward the end of the eighteenth century in all three topographic representation methods of the analog age.

Johann Rudolf Meyer, a textile manufacturer from Aarau, opted for a similar methodology when he prepared the *Atlas Suisse*. In 1786 he employed the Strasbourg engineer Johann Heinrich Weiss and in the following year the carpenter Joachim Eugen Müller from Engelberg. The latter made a large relief of the Swiss Alps on a scale of 1:60,000 based on numerous angle measurements drawn with a *Zollmannsche Scheibe* (see fig. 833), elevation sketches, and small peak reliefs modeled directly in the landscape; it comprised an area of over 23,200 square kilometers and therefore more than half of present-day Switzerland. Weiss constructed a triangulation from graphically observed angles (ca. 1:435,000) and then designed the map details on the basis of the relief. Between 1796 and 1802 the *Atlas Suisse* appeared as a copper engraving in sixteen sheets on a scale of ca. 1:120,000 and a general map of ca. 1:510,000. This complete work entailed a major advance over Scheuchzer's map, although it did not avoid criticism (fig. 861). Müller's relief model of the Alps was acquired by the French Dépôt de la


FIG. 861. JOHANN HEINRICH WEISS, *PARTIE DU CANTON DE BERNE, DU VALLAIS ET CANTON DE FRIBOURG*, 1797. This map of the area between Thun and Sion from Johann Rudolf Meyer's *Atlas Suisse*, printed in two colors (blue representing glaciers and the highest elevations), is notable for being based on angle measurements, elevation sketches, and a graphic triangulation, ca. 1:120,000, executed by Joachim Eugen Müller.
Size of the original: 55.5 × 75.5 cm. Image courtesy of the Universität Bern, Zentralbibliothek (MUE Kart 500:10).

Guerre in 1803 and transported to Napoleon's château at St. Cloud (Rickenbacher 2011, 154–60). As early as 1790, the section of the Bernese Oberland-Valais was directly reproduced in several copies at half the scale, 1:120,000.

The *Carte des environs de Genève* (1776, ca. 1:50,000) and the *Carte de la Suisse romande* (1781, 1:86,400), both by Henri Mallet, were surveyed and published as the first regional Swiss maps based on the example of the *Carte de France*. The *Specialcharte des Rheinthals* (1796, ca. 1:41,000) by Johannes Feer, which was based on astronomical and trigonometric observations, showed that sophisticated recording procedures were also implemented in eastern Switzerland. Yet the first geometrically correct representation of the entire country was not realized until the mid-nineteenth century by the *Topographische Karte der Schweiz 1:100.000* (the so-called Dufour map).

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SEE ALSO: Heights and Depths, Mapping of; Height Measurement: Altimetry; Switzerland

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***Topographical Surveys.*** See Engineers and Topographical Surveys; Military and Topographical Surveys

***Trade and Plantations, Board of (Great Britain).*** The Board of Trade and Plantations had its origins in several Privy Council committees created in the early days of the British colonial empire to deal with questions concerning particular trades and colonies. In 1655, Lord Protector Oliver Cromwell established a Committee and Council for Trade and Navigation. When the monarchy was restored in 1660, two separate councils were set up—one for Trade in 1668 and one for Foreign Plantations in 1670—that in 1672 were united as the Standing Council of Trade and Plantations. This was dissolved in 1674, but a Committee of Council maintained its functions until 1696, when William III appointed new commissioners, "the Lords Commissioners for promoting the Trade of our Kingdom, and for inspecting and improving our Plantations in America and elsewhere" and generally known as the Board of Trade (Thurston 1995, 3). After the office of Secretary of State for the Colonies was created in 1768, its holder was ex officio president of the Board, and colonial affairs were the responsibility of the secretary of state and the Board of Trade acting in partnership.

When Britain lost its original American colonies as a result of the American Revolutionary War (1775–83), the need to cut government spending led to the abolition of the Lords Commissioners of Trade and Plantations and of the Secretary of State for the Colonies in 1782. Their responsibilities passed to the Privy Council and the Secretary of State for the Home Department. In 1784, William Pitt established a new Committee of Council on Trade and Plantations. In 1801, colonial business was transferred to the newly created Secretary of State for War and the Colonies.

While the administrative and political histories of the various boards and committees set up is well established in the literature, the same cannot be said of the associated map history. Whereas particular maps and mapmakers have been researched, the history of the mapping context as evinced by the board's own activities and collecting policies still awaits more detailed research.

It is clear, however, that the principal focus of all these authorities was on developing British commercial gains from overseas colonies. It was natural, therefore, that they should from the beginning have interested themselves in geographical information, maps, and surveys, in order to discover the extent and topography of the areas under British administration. As the size of the colonies increased—both in territorial extent and in numbers of colonists—the need for such information increased in order to route roads, site defenses and harbors, resolve boundary disputes, and create administrative units. In 1671, the Council for Plantations asked captains of British naval vessels to obtain information about harbors, islands, and other coastal features of Newfoundland. In 1676, colonial governors were instructed to procure and send home maps of the territories for which they were responsible. Inevitably, compliance was patchy, and eventually the Board directly commissioned surveys: it created surveyor general posts, such as that held by William Gerard De Brahm, and made use of military expertise, as in the case of Samuel Holland. Such surveys, usually of particular areas for specific administrative purposes, normally resulted in manuscript maps and plans. The Board also purchased commercially printed maps, often of larger areas, for general reference. Maps were sometimes gathered into bound volumes for ease of reference and storage. Of such volumes, the so-called Blathwayt Atlas is perhaps the earliest and best known. William Blathwayt, who became secretary to the Lords of Trade in 1679 and was surveyor and auditor general of plantation revenues in America from 1680 until his death, followed the common practice of taking official documents into his personal possession. The atlas that bears his name is an assemblage of printed and manuscript items, most of British origin but some from French and Dutch sources. The State Paper Office records include what seem to be two similar volumes, together containing eighty-six maps, likewise a mixture of printed and manuscript material, dating from 1626 to 1777 (Kew, The National Archives of the U.K. [TNA], SP 112/116).

In due course, the records of the Commissioners of Trade and Plantations were transferred to the State Paper Office as records of the secretary of state; they are now among the Colonial Office records at TNA (original correspondence is in CO 388; entry books in CO 389; miscellanea [e.g., trade statistics, Custom House accounts] in CO 390; journals of the Board, including minutes of proceedings, in CO 391). The proceedings of the Commissioners for Trade and Plantations to the end of March 1704 are described summarily in the *Calendar of State Papers, Colonial: North America and the West Indies* (the whole series, covering 1574–1739, 45 vols., 1858–1994; reissued on CD ROM, 2000). From April 1704 to May 1782, the entries in the journals are printed in full as *Journal of the Commissioners for Trade and Plantations* (14 vols., 1920–38). The proceedings of the Privy Council committees are printed in *Acts of the Privy Council of England: Colonial Series* (6 vols., 1908–12).

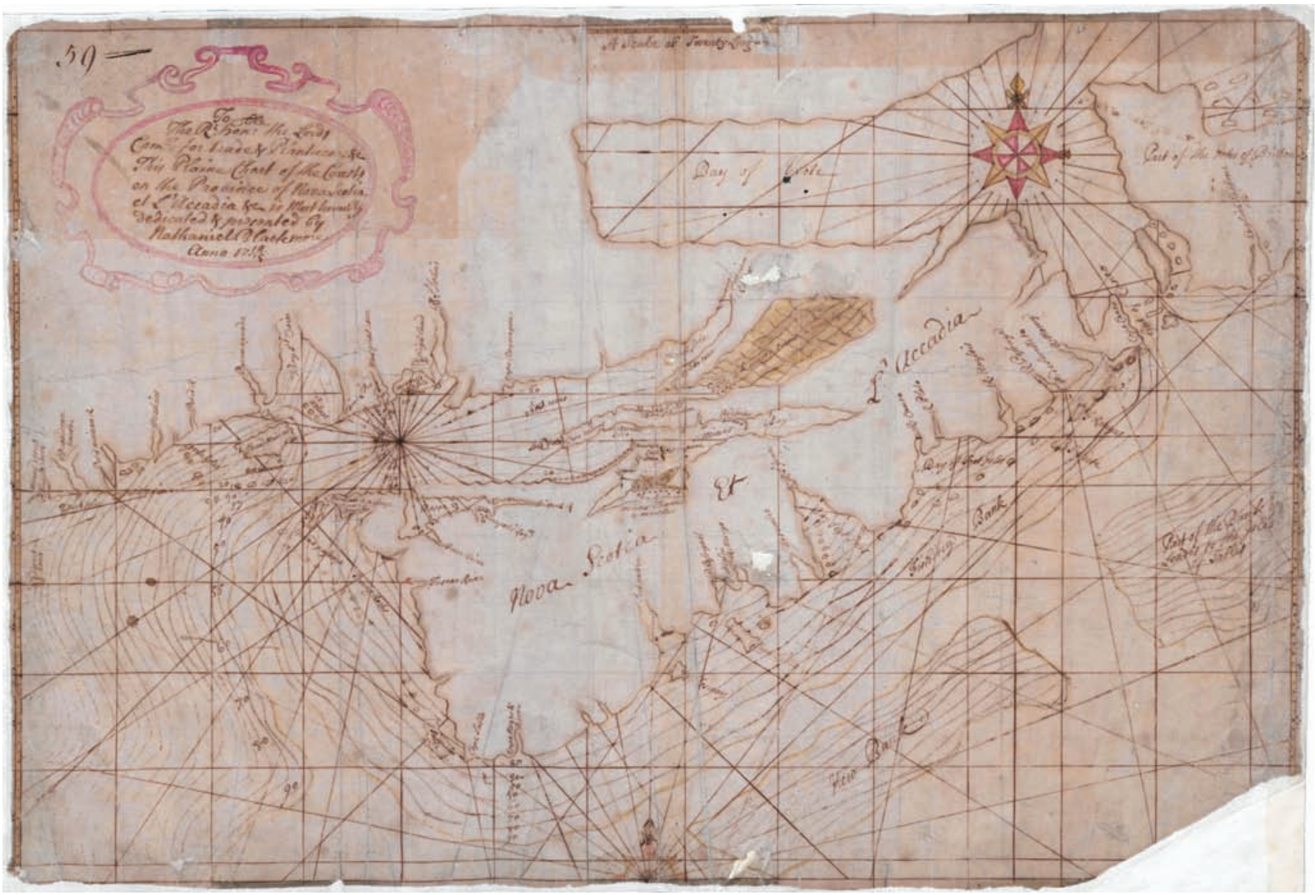


FIG. 862. MANUSCRIPT CHART OF THE COAST OF NOVA SCOTIA. Nathaniel Blackmore, "Plaine Chart of the Coasts on the Province of Nova Scotia et l'Accadia &c.," dedicated and presented to the Board of Trade and Plantations in 1714/5. The lines indicating shallow waters may have been an early attempt at drawing isobaths in open water.
Size of the original: ca. 47.0 × 70.5 cm. Image courtesy of The National Archives of the U.K. (TNA), Kew (CO 700/Nova Scotia4).

Many maps formerly in the office of the Board of Trade are in TNA (record series CO 700, MPG 1, MPGG 1 and SP 112). Board of Trade correspondence is also found in record series relating to individual colonies (CO 5 [America and West Indies], CO 23 [Bahamas], CO 37 [Bermuda], etc.).

The indexes to the printed *Journals of the Commissioners for Trade and Plantations* and the *Calendars of State Papers, Colonial* contain numerous references to surveys, mainly of North America, but also of the West Indies, the East Indies, and West Africa. The few maps that have been identified among the records of the Commissioners of Trade and Plantations show how, by the mid-eighteenth century, the Board had acquired maps and plans relevant to British interests in North and South America, Africa, and India.

A register of maps now in TNA (CO 326/15) indicates that by 1780, more than 350 maps ranging in date from 1692 to 1777 were in the custody of Francis Ægidius Assiotti, draftsman to the Board. Most of these relate to places in North America. A Plantations Office account in the British Library (Add. Ms. 9767) shows that the Board paid for maps to be purchased or copied from many sources. Many maps, plans, and charts that were almost certainly originally in the office of the Board of Trade are now in TNA. They include items sent or presented to the Board (such as fig. 862, Nathaniel Blackmore's chart of Nova Scotia, 1714/15); dedicated to the Lords of Trade and Plantations (such as De Brahm's map of the coast of South Carolina and Georgia, 1757); or published by command of the Board (such as Thomas Jefferys's plan of Halifax Harbour, Nova Scotia, 1759). Other maps include cartographic information reproduced "by permission of the Board of Trade" or "from actual surveys now lying at the Board Trade." The Board was probably the first department of state to authorize the publication of maps to influence public opinion when John Mitchell's 1755 map of North America was published with its implicit sanction (Edney 2008). There is evidence that some mapmakers, such as Henry Popple and John Mitchell, had privileged access to the Board's map collection, which was clearly a valuable cartographic resource far beyond its own official confines.

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SEE ALSO: British America

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***Transit.*** See Instruments, Astronomical

## *Transportation and Cartography.*

TRANSPORTATION MAP
CANAL MAP
CANAL SURVEY
POST-ROUTE MAP
ROAD MAP
ROUTE MAP

***Transportation Map.*** The term *transportation map* refers to a thematic map representing either a whole communication network or a specific itinerary or route. During the Enlightenment, transportation maps comprised a large segment of printed and manuscript cartographic production in Europe. These maps most frequently related to land communication routes, such as royal roads, imperial roads, or post roads, but they also depicted navigable rivers or canals.

Transportation maps could be either printed or manuscript and were produced by several types of individuals. In manuscript, the authors might be civil or military engineers as well as private surveyors, while printed maps were produced by civil servants, geographers, and commercial map publishers. Transportation maps constituted a growing sector of publication, reflecting an increased demand from governments, administrative entities (public works, post services, fiscal administration), landowners, and individuals who traveled for work or pleasure. For governments, both local and territorial, a precise transportation map could serve many purposes as an aid for decision making, planning improvements, road building design and supervision of construction, military and commercial control, and the adjudication of disputes (Watelet 1995, 38–39).

Transportation maps fell into two major groups: small-scale general maps and larger-scale itinerary maps. General maps represented transportation systems at the scale of a nation, province, or region and were often printed. An exception is the manuscript map of communication networks made in Russia during the late seventeenth century (Bagrow 1952). The first maps of the entire European road system appeared during the eighteenth century, exemplified by the *Map of the Post-Roads of Europe* (1758) by John Rocque.

Larger-scale itinerary maps focused on one or more specific routes. They were often inserted in road guides and might emphasize historical and picturesque itineraries. A typical example was *L'indicateur fidèle ou guide des voyageurs* (1765), published by the French engineers Claude-Sidoine Michel and Louis-Charles Desnos. It opened with a *Carte générale de France*, which represented the network of roads described in the work; each itinerary was given a detailed description along with a table indicating to travelers the schedule of public carriages and different stages of the journey. The itinerary was also depicted on a separate strip map that facilitated finding specific places.

STÉPHANE BLOND

SEE ALSO: Administrative Cartography; Geographical Mapping; Ponts et Chaussées, Engineers and École des (School of Bridges and Roads; France); Thematic Mapping

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Watelet, Marcel, ed. 1995. *Le terrain des ingénieurs: La cartographie routière en Wallonie au XVIII^e^ siècle.* Namur: Met; Brussels: Éditions Racine.

***Canal Map.*** Canal maps constitute a particular cartographic genre that underwent great development from 1650 to 1800, ranking with maps of roads and rivers as one of the three principal representations of communication routes. While different sorts of canals might be represented, such as those for interior navigation, drainage of swamps, irrigation, or defense, junction canals account for the majority of the maps conserved. In Western Europe, the growth of navigational canals began in the first half of the seventeenth century, with construction projects multiplying along with the maps representing them. The most common cartographic layout resembled that of route maps, drawn in one large-scale map or as fascicules in sheets, centering the canal lengthwise on adjoining sheets, which allowed the canal to be seen at its full length. In-depth research on canal maps in various national contexts awaits further study to determine if such layout and design was used in all European countries and to what if any extent independent traditions emerged.

These cartographic initiatives were supported by various sponsors (central governments, local authorities, private contractors, or joint-stock companies) and executed by different professionals (architects, civil engineers, military engineers, and/or private surveyors, usually in connection with an institutional framework or an official authority). It is important to note that the use of cartography to propose a new canal was not systematically employed, and many maps were produced after the canals were built as objects of propaganda. Yet many canal maps represented the project stage, resembling sketches in their presentation with their principal goal being to provide an overall view of the project and the scope of the work. These maps should not be regarded as isolated productions, for they accompanied dossiers that included plans of structures, cost estimates, and explanatory memoirs.

France and Britain were clearly preeminent in the printed production of this cartographic material, though manuscript canal maps also flourished in the German states and the Netherlands, where provincial and state authorities embargoed the dissemination of large-scale maps. From the seventeenth century, the growing number of French canal maps corresponded directly to government efforts supporting this means of communication. Jean-Baptiste Colbert, *contrôleur général des Finances* of King Louis XIV, favored waterways and encouraged the construction of canals designed to compensate for problematic roads. The many improvements made in surveying techniques, thanks notably to Italian, Dutch, and Flemish engineers, supported these efforts. The Canal du Midi (or Canal des Deux Mers) was without question the largest canal construction of the Ancien Régime and the most extensively mapped navigable infrastructure. In 1662, Pierre-Paul Riquet, an engineer and entrepreneur from Languedoc, presented the initial project to Louis XIV, who authorized the work in 1666 to join the Atlantic Ocean to the Mediterranean Sea via the Garonne River and a canal 250 kilometers long. The construction was accomplished in record time, with work completed in 1681. This remarkable enterprise provoked a cartographic fad until the end of the eighteenth century, as many private publishers took an interest in this subject, the most distinctive being Jean-Baptiste Nolin, who produced *Le canal royal de Languedoc* (fig. 863), a longitudinal map in three sheets dedicated to the deputies of the province of Languedoc. Many other printed maps publicized this vast enterprise, favored by royal power (Konvitz 1987, 106), and the cartographic theme became an instrument of propaganda in itself (Mukerji 2002). The date of the canal's authorization (1666) coincided with the foundation of the Académie des sciences and the Paris Observatory by Louis XIV, who manifested the growing interest of the state in geographic questions. The painter Henri Testelin pictured the monarch with a large map of the Canal des Deux Mers (ca. 1680), emphasizing the central role of the map in allowing royal power to recoup the patronage of an enterprise from its local origins. During the eighteenth century, many canal projects were elaborated and represented on maps or plans. Few projects were completed, however, except when the Canal du Centre and Canal de Bourgogne were opened at the end of the century. Waterways henceforth competed with roads, which were also absorbing the financial investments of the government.

In England, most canal projects took place in the second half of the eighteenth century (Hadfield 1984), responding to needs of the early Industrial Revolution, as with the Sankey Canal (in northern England, connecting St Helens to the River Mersey) or the Grand Junction Canal (connecting a number of waterways to the River Thames). The high density of canals in England resulted from government policies about water that encouraged the production of numerous maps. By the end of the century, the most mapped was the Bridgewater Canal linking Worsley's coal mines to Manchester, the first section of which opened in 1761.

The use of canals was long established and frequent in the Netherlands, the Southern Netherlands, and northern Italy. Due to this strategic infrastructure, canal maps in these countries are numerous in the archives. They describe large canal networks; for example, the Dutch canal network consisted of about 415 kilometers in 1700. Nonetheless, a policy of canal construction occurred only later in most other European countries, which explains the limited number of canal maps before the nineteenth century.

STÉPHANE BLOND

SEE ALSO: Administrative Cartography: Netherlands; Topographical Surveying

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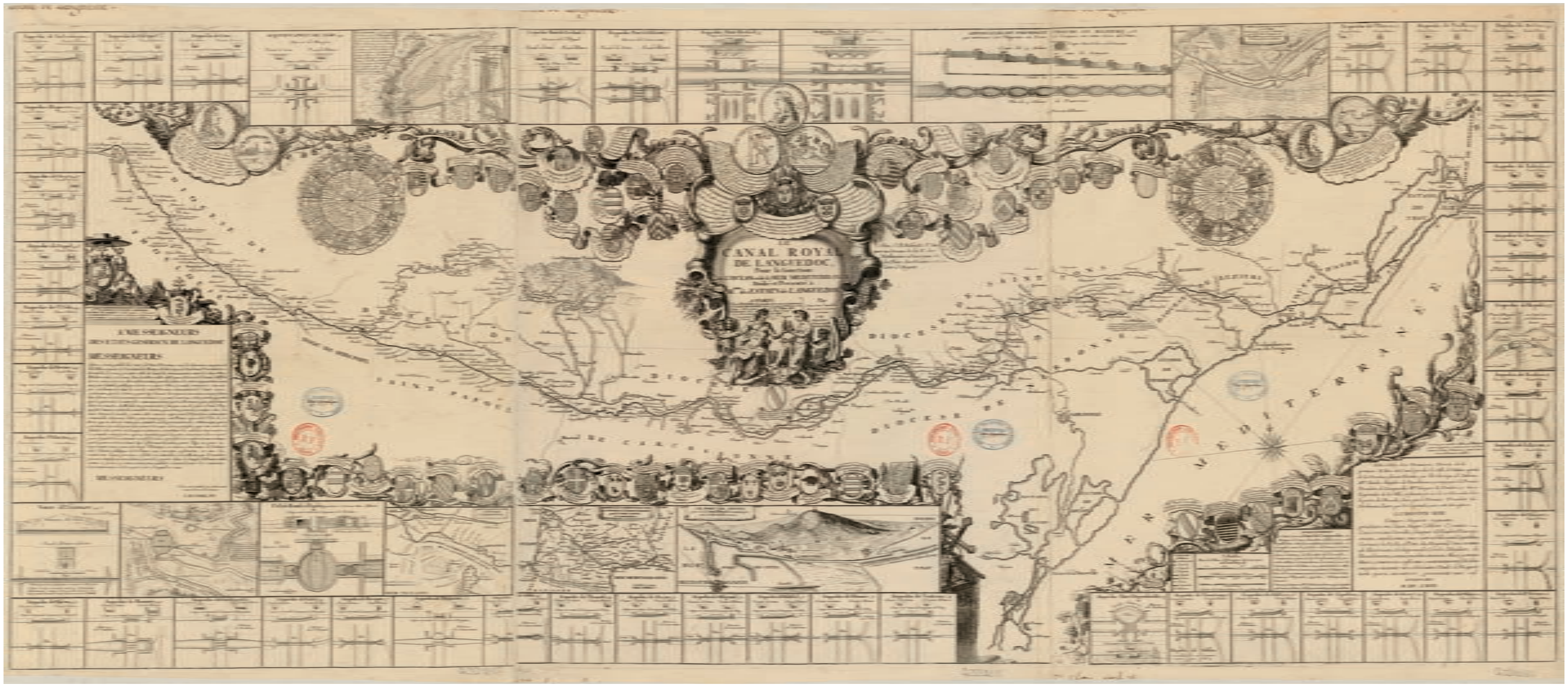

FIG. 863. *LE CANAL ROYAL DE LANGUEDOC, POUR LA IONCTION DE L'OCEAN ET DE LA MER MEDITERRANÉE*, BY JEAN-BAPTISTE NOLIN, 1697. With this vast map composed of three sheets assembled, Nolin represented all the elements relating to the construction of the Canal du Midi: the cartography of the route, small cartouches with plans of various architectural structures (locks, basins, bridges, and aqueducts), and richly decorated medallions containing the coats of arms of the deputies of the États du Languedoc who supervised the construction of the works. It expressed the power of the built world over the natural environment and the power of local authorities.
Size of the original: 59.0 × 143.5 cms. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge DD 2987 [1473 B]).

*Modern Europe,* ed. Pamela H. Smith and Paula Findlen, 248–76. New York: Routledge.

Pinon, Pierre. 1995. *Canaux: Rivières des hommes.* Paris: R.E.M.P.A.R.T., Desclée de Brouwer.

***Canal Survey.*** The construction and development of canals responded to the demands of public authorities attempting both to reinforce their territorial control and to improve internal communications. First military needs and then economic factors led to canal building, as the development of manufacturing and industrial operations took advantage of water transport over roads for the conveying of heavy and bulky merchandise. Architects, civil engineers, military engineers, and private contractors all played a role in canal construction and its cartography. As the production of canal maps shows, canals were significant in different types of space: urban canals, such as those developed in the Netherlands for water supply and public sewers and those tributary to the Grand Canal of Venice as communication routes; countryside canals connecting rivers or creating communication networks; and in the environs of military fortifications, where they provided defense without specific navigation activity. The rhythm of navigational canal construction varied from country to country. The Italian and Flemish hydraulic engineers were the precursors whose procedures were reproduced in many countries in Western Europe: Germany, France, the British Isles, Spain, and Switzerland. Dutch engineers, proficient in canal construction, were strictly limited to the propagation of their specialized knowledge. France and England clearly stood out for the large number of completed projects. The methods of the canal survey were similar to those of the itinerary traverse, with the added function of often serving as a planning and construction document designed for the approval and building of the canal.

In France, several canals were constructed during the second half of the seventeenth century, while the following century was marked by a number of incomplete projects, due notably to competition from roadways (Pinon 1995). Military concerns played an important role in the development of canals. During the second half of the seventeenth century, several canals were built in northern and eastern France with the goal of facilitating troop movement and provisioning fortified locations, as

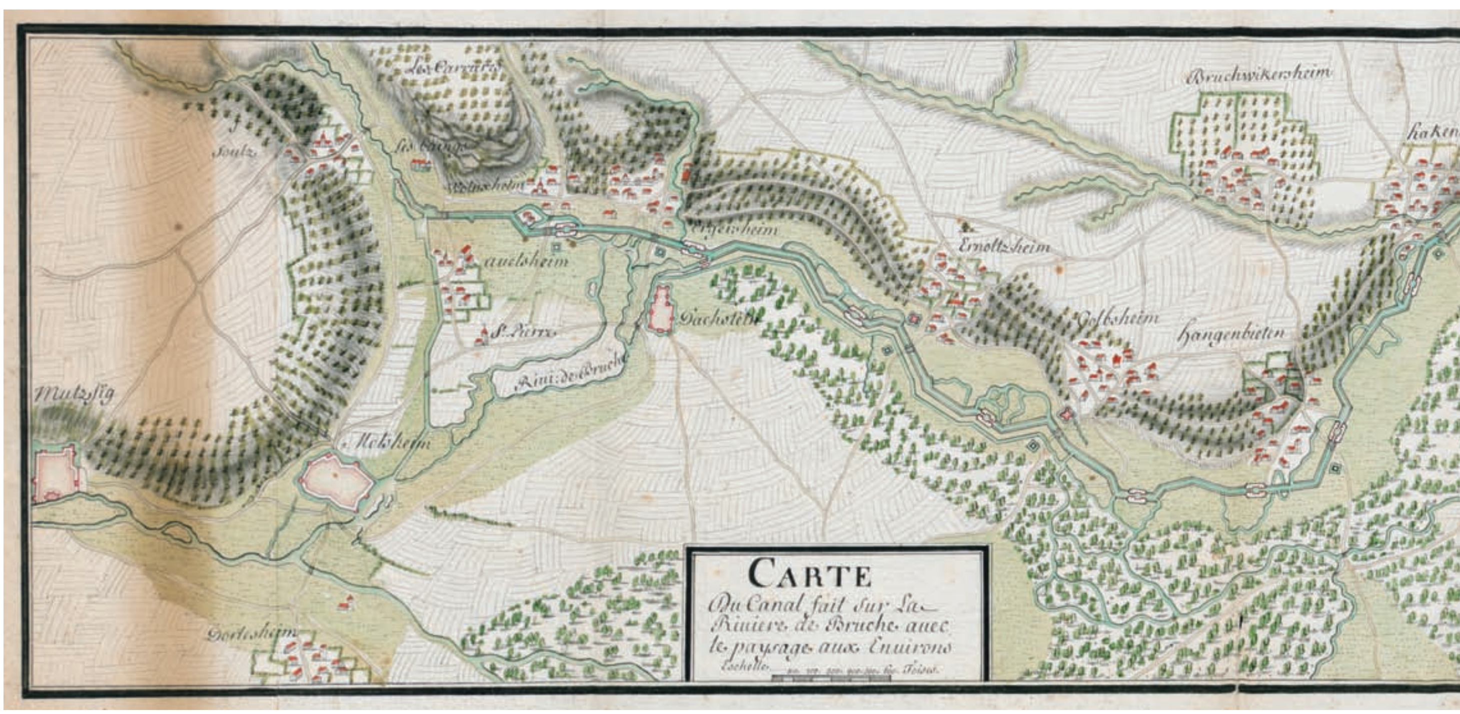


FIG. 864. "CARTE DU CANAL FAIT SUR LA RIVIERE DE BRUCHE AVEC LE PAYSAGE AUX ENVIRONS," 1688. On this anonymous manuscript map, produced in ink and watercolors, the rendering of the canal is laid out at the center of the drawing. The construction envisioned allowed the doubling of the Bruche River in order to facilitate the transportation of materials from Molsheim (left) to Strasbourg (right). The construction constitutes, on its own, a line of defense and a frontier, with numerous structures and redoubts that ensure its protection. The techniques of representation and the figures adopted in the drawing are similar to the majority of military maps drawn up during this period.

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exemplified by the canal on the Bruche River (fig. 864), a defensive structure between the cities of Strasbourg and Molsheim. In the eighteenth century, canal design increasingly fell to the engineers of the Ponts et Chaussées, who henceforth served as specialists on questions related to the development of territory (Desportes and Picon 1997, 38–45). The majority of projects were worked out and mapped by experts in public works such as Émiland Gauthey, the engineer of the États de Bourgogne who designed the Canal du Centre (also known as the Canal du Charolais). Jean-Rodolphe Perronet, *premier ingénieur* of the Ponts et Chaussées, also developed canal projects such as the one linking the Yvette River to the Bièvre, which he presented in the form of an itinerary map. On the eve of the French Revolution, the French network included about a thousand kilometers of canals (Goger 1997, 184), for which the cartographic evidence is mostly in manuscript form, except for those canals that needed an important administrative investment, thus requiring printing.

In contrast to France, English projects were concentrated in the eighteenth century and were not centrally controlled. There, waterways provided the means of transport essential for growing commercial demands linked to the Industrial Revolution (Hadfield 1981). The initiative for construction often came from landowners or joint-stock companies. Parliament was responsible for deciding which projects would receive authorization, perhaps with a royal concession to collect tolls for navigation. The majority of manuscript English canal maps were produced by engineers with technical knowledge and mastery of the skills needed to produce precise maps, but these experts did not belong to a centralized administration on the French model, which explains an absence of overall coherence in their work.

By 1790, the English waterway system of canals stretched across more than 3,500 kilometers. In many other countries, such as Belgium, Sweden, Russia, and Germany, the development of canals began only at the beginning of the nineteenth century, in order to serve mining and industrial centers. Before this period, projects that were both mapped and completed were rare.

STÉPHANE BLOND

SEE ALSO: Ponts et Chaussées, Engineers and École des (School of Bridges and Roads; France); Topographical Surveying; Traverse: Itinerary Traverse

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***Post-Route Map.*** Printed maps of post routes developed alongside road maps, frequently outstripping and driving production of the latter. Post routes were among the most frequented road networks in Europe, which explains the great interest in mapping them. The two principal producers of post-route maps were civil engineers and private map publishers (editors and engravers). In certain cases, the post administration commissioned maps. Maps produced by civil engineers were rare and often from later periods, usually taking the form of itinerary or route maps—that is, focusing on the course of one post route in particular. Commercial publishers produced smaller-scale general maps representing the network of post routes of a realm or a province. Their diffusion from the second half of the seventeenth century was a cartographic phenomenon, reflecting a response to the continuous development of post services and allowing users to verify whether or not the destination of their correspondence lay near a post relay. These maps provided a view of the entire network, of its different branches, and of the routes of couriers and public coaches. From about 1650 to 1800, several Western European countries produced post-route maps, but the main centers of production remained France and England, with the German states and the Austrian monarchy following their lead, especially after the 1748 *Postordnung,* which established regular passenger coach service throughout the Habsburg Empire.

In France, many royal roads were also post routes, giving them an important place in the hierarchy of communication routes. The government placed a high priority on its control of this strategic infrastructure, which was important for the transmission of dispatches, orders, and administrative documents. Hardly surprisingly, this desire to control communications manifested itself cartographically. The first map of the French post-route network was Nicolas Sanson's *Carte geographicque des postes qui traversent la France* (1632; see fig. 739). Cartographic representation did not decline in the succeeding decades, as both demand and production increased. Taking into account both original and reeditions, Guy Arbellot (1992, app. 2) tallied close to ninety general maps of post routes between 1650 and 1800. The Jaillot family of engraver-printers dominated the market by producing numerous general maps. In 1689, Alexis-Hubert Jaillot published the *Carte particulière des postes de France* (fig. 865), which served until the end of the eighteenth century as the basis for many revised and augmented editions, each incorporating new post relays. These maps were also produced in a reduced and convenient format for placement inside post almanacs as a valuable tool for orientation. French publishers did not restrict their interests to France; Jaillot, Guillaume Delisle, and Gilles Robert Vaugondy regularly produced maps depicting the post network of several European countries, some of which were copied and published abroad, notably in Amsterdam. For example, in their *Atlas universel* (1757), Robert Vaugondy and Didier Robert de Vaugondy produced post routes from the German Empire, Spain, Portugal, Italy, and the British Isles.

England rivaled France as a center of post-route map production, with the first maps to depict the English network dating from the late 1660s. These maps were complemented, augmented, and constantly republished until the end of the eighteenth century, either within assembled works or on separate sheets (Delano-Smith and Kain 1999, 166–72). The most emblematic work of the period is that of John Ogilby. In *Britannia* (1675), Ogilby published a map of the main English routes that were represented individually on maps in the form of bands or strips. The work included a preface entitled "Of the Post-Roads of England," which enumerated the major itineraries. In the mid-eighteenth century, John Rocque, a surveyor and engraver of Huguenot ancestry, published his *Map of the Post-Roads of Europe* (1758), which probably represents the first map of post routes on a European scale and bears witness to the extension of knowledge with regard to the geography of roads. Franz Johann Joseph von Reilly drew upon this extended knowledge base for his *Allgemeiner Post Atlas von der Ganzen Welt* (also titled *Atlas universae rei veredariae bilinguis*, 1799), a collection of forty maps covering the whole of Europe, including Russia (see fig. 785).

STÉPHANE BLOND

SEE ALSO: Administrative Cartography; Thematic Mapping: (1) Austrian Monarchy, (2) German States

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FIG. 865. *CARTE PARTICULIÈRE DES POSTES DE FRANCE,* ALEXIS-HUBERT JAILLOT, 1690. This map produced by Jaillot was based on Sanson's 1632 model (see fig. 739). Jaillot's map depicts and enumerates the different post relays that were connected to one another by small segments. These maps presented a geometric rendering that rarely corresponded to the reality of the terrain.

Size of the original: 67 × 62 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge DD 2987 [704B]).

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***Road Map.*** Between 1650 and 1800 the number of small-scale general maps depicting road networks increased dramatically and constituted one of the most productive sectors of printed European cartography. Information on roads was of interest to several groups, including governmental authorities; administrative bodies whose functions were linked to roads, such as the postal service; and individuals, especially travelers. The majority of printed maps of road networks were produced by publishers and engravers with the commercial goal of maximum diffusion. Their maps were regularly augmented, corrected, republished, and copied—evidence of the ever-increasing demand to which publishers and engravers responded. Most European countries produced road maps, but, as in other domains, Britain and France had the largest sheer volume of road map production.

In Britain, the most emblematic and innovative printed oeuvre was the work of Scotsman John Ogilby, king’s cosmographer and geographic printer, who published *Britannia* (1675), which contained a general map of the roads of England and Wales and a series of itinerary maps. Their originality lay in their uniform presentation, with each map displaying the road and its immediate surroundings on a strip of paper (fig. 866). Each map was accompanied by a table of distances as well as texts that briefly described the locales en route (cities, villages, castles, monuments, and natural elements). *Britannia* was the first atlas to represent the roads of an entire nation. Although he was not the inventor of such roll or strip maps, Ogilby greatly contributed to the diffusion of this cartographic genre, and *Britannia* served as a model for numerous European publications during the eighteenth century (Harley 1970, XXIX; Delano-Smith and Kain 1999, 168–78; Mayhew 2000, 66–85; Delano-Smith 2006, 50–54).

Sir Herbert George Fordham emphasized the preeminence of the British and French contribution to road maps, guides, and illustrated itineraries (Fordham 1920, 1926). Their numbers increased throughout the eighteenth century. After the publication of *Carte geographicque des postes qui traversent la France* by Nicolas Sanson (1632; see fig. 739), France witnessed an intense production of general roadmaps, not always on the national scale but more and more frequently representing provincial or regional networks, for example, the *Carte itineraire du duché de Bourgogne* (1771) by Joseph-Dominique Seguin, *ingénieur géographe du roi.*

The first French road guides that included maps appeared at the end of the seventeenth century. Geographer Pierre Duval led the way in 1677 with the *Cartes pour les itineraires et voïages modernes,* which included itinerary maps displayed on strips larger than those of Ogilby but employing similar representational techniques. In the eighteenth century, the diffusion of road guides containing maps developed enormously, responding largely to the growing popularity of travel. Multiple road guides were published in ever smaller and more practical formats for portability during a trip or in the field. These works, which mixed text and image, often included a general map as well as maps of specific itineraries. Certain titles were republished multiple times, including *L’indicateur fidèle, ou Guide des voyageurs* (1762), *Etrennes utiles et nécessaires* (1771), and *Le conducteur français* (1776). In 1766, the *ingénieur geographe* Louis-Charles Desnos published his *Nouvel itinéraire général*, which presented a general map of France as well as a series of road maps organized by the administrative divisions of *généralités*. These regional French maps were followed by other maps that represented the road network of most other European countries, including the British Isles, Spain, Portugal, Italy, Switzerland, the Netherlands, Germany, Hungary, Poland, Prussia, and Denmark. This cartographic display in one volume demonstrated the strategic importance of roads on a European scale.

STÉPHANE BLOND

SEE ALSO: Geographical Mapping; Ogilby, John; Thematic Mapping

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***Route Map.*** In contrast to *road maps*, which are smaller-scale maps depicting the road network of a province or a country, *route maps* at a larger scale focus on one particular road itinerary or on several interconnected routes. Because of the preoccupation with roads by central governments and public authorities, this type of map spread widely during the period between 1650 and 1800 and were usually ordered by administrators or landowners

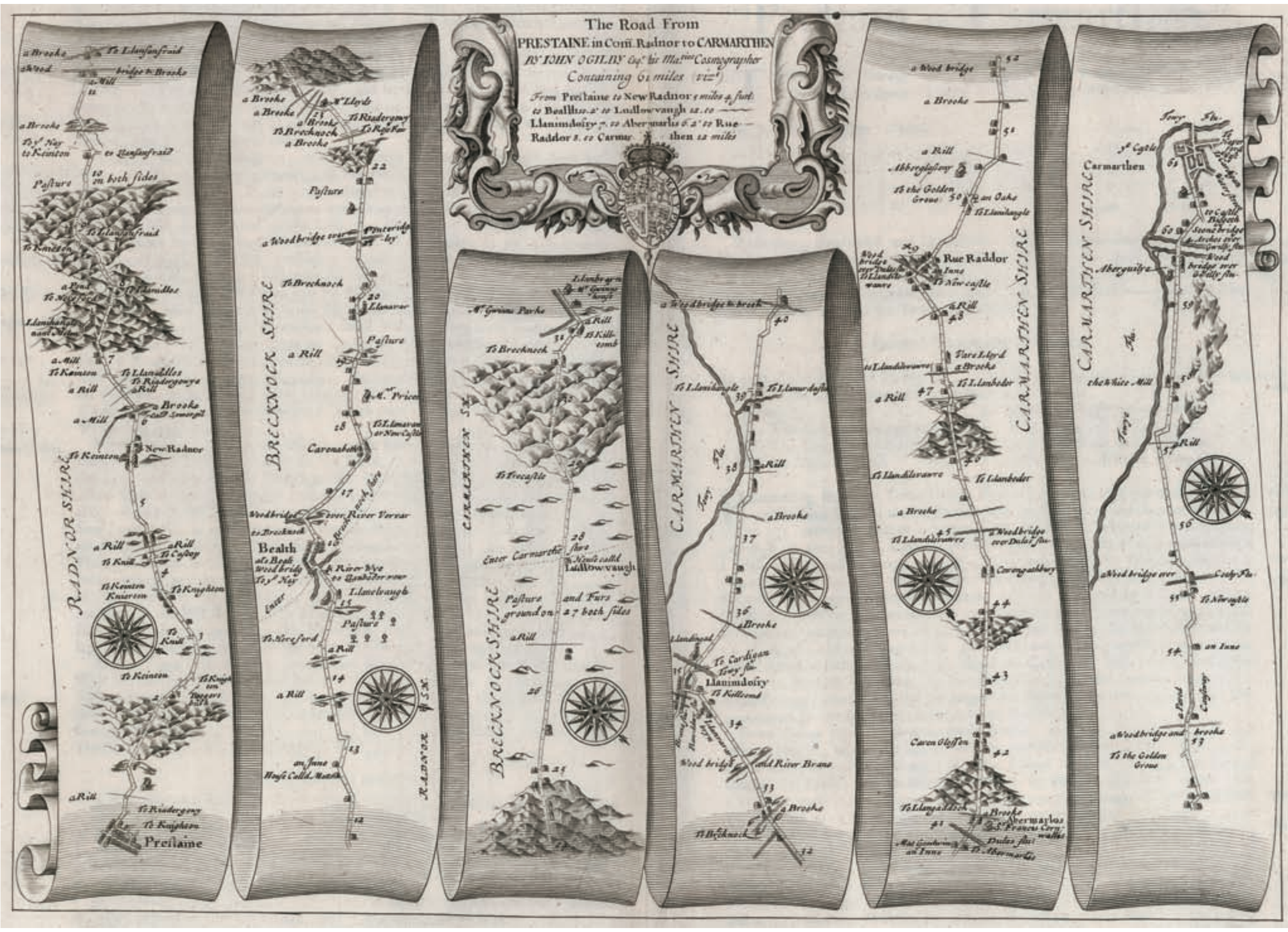


FIG. 866. JOHN OGILBY, *THE ROAD FROM PRESTAINE IN COM. RADNOR TO CARMARTHEN*, 1675. This road itinerary presented in six bands is representative of Ogilby's strip maps. The compass roses indicate how the orientation of the strips varied, so that the road always ran along the center of the band. Ogilby's maps used a consistent set of symbols, set out in the introduction to *Britannia,* with elements of the countryside rendered in a summary and schematic manner. Hills were arranged to show ascent (hills right side up) and descent (upside down). From John Ogilby, *Britannia, Volume the First: Or, An Illustration of the Kingdom of England and Dominion of Wales* (London: Printed by the author, 1675), pl. 84 (between 166 and 167).
Size of the original: 32 × 46 cm. Image courtesy of the David Rumsey Map Collection, David Rumsey Map Center, Stanford Libraries.

who were directly affected by what they deemed as important land communications.

Route maps may be classified in two main ways: first, by the administrative structure that required the map, and second, by their use. Administratively, route maps were ordered by royal, provincial, seignorial, commercial, and military prerogatives. As for their employment, Marcel Watelet, based on his work with route maps in Wallonia, suggests the following six uses: for resolving technical problems in the construction of roads, including the expropriation of land; for decision making regarding road projects using network maps; for the control of public works; for the planning and design of bridges, gateways, and other works of architecture; for the adjudication of local, regional, and international conflicts; and for specific users such as customs agents, who gathered information on entry points to urban centers (Watelet 1995, 38–39).

In contrast to road maps, which were commonly engraved and printed, route maps often remained in manuscript. These maps were not used for way-finding or to provide an overall view of a road network; rather, they were produced with the more practical goal of supporting the development of particular roads at given times and in specific places. Civil or military engineers, geographers, architects, private surveyors, and even lawyers, as in the principality of Liège (Watelet 1995, 95, 102), participated in field operations, carefully measuring distances and applying mathematical principles, which generally took into account the latest advances in the science of cartography.

Route maps regularly adopted the layout of itinerary road maps, with the cartographic information placed lengthwise across the page. Graphically, the maps represented a route along a central band in the middle of the sheet, with representations of the road's immediate surroundings in varying dimensions shown above or below the road. The maps thus presented a fairly precise idea of topography and obstacles to establishing a route, including mountains, rivers, and swamps. The earliest of these maps, dating from the second half of the seventeenth century, were the work of military engineers. They closely studied the terrain in order to produce maps of itineraries for moving troops to scenes of conflict or to fortified areas. Such maps qualified as military secrets, thus explaining their manuscript format and limited accessibility.

During the course of the eighteenth century, work dedicated to public routes and roads across private or noble lands multiplied, and from then maps served as support plans for road building projects. In France, Philibert Orry, the *contrôleur général des Finances*, launched a vast cartographic investigation focused on royal routes. His goal was to make available precise maps of different road itineraries in order to centralize decision making in Paris and to determine what development projects were necessary (Blond 2014, 35–37). This work, produced between 1740 and 1780, is better known as the "Atlas de Trudaine," named after the father and son administrators who directed the stages of this inventory. Engineers who belonged to the administrative corps des Ponts et Chaussées conducted the fieldwork, producing in all more than 2,400 maps of road sections and more than 750 plans of built structures along these routes (including aqueducts and bridges) (Blond 2014, 277). Each route itinerary was mapped on a large oblong sheet at a scale of ca. 1:8,640. Each sheet or fascicule represented a portion of an itinerary (fig. 867); several sheets together provided the overall view of the route and its immediate surroundings, allowing the observer to judge where modifications to the projected route were necessary. Route maps similar to this model existed elsewhere in Europe, for example in the Low Countries of the Austrian monarchy, where many frontier roads had military importance (Watelet 1995, 38–44). In Sardinia, at the end of the eighteenth century, King Vittoreo Amedeo III ordered itinerary maps to depict the *reale strada*, the future royal route from Nice to Turin (Biblioteca reale di Torino, Atlas Saluzzo, 1752).

Some maps were published in collectors' editions for specific purposes as, for example, routes with symbolic status. The *ingénieur géographe du roi* Louis-Pierre Daudet produced maps referring to major royal events, such as the travel of the sovereign to Reims for the coronation. His "Route de Paris à Reims" (ca. 1722) was produced in manuscript for King Louis XV but was also


FIG. 867. DETAIL FROM THE "GRANDE ROUTE DE PARIS EN ANGLETERRE" NEAR THE CITY OF AMIENS (PICARDY), CA. 1740–80. Map from the manuscript "Atlas de Trudaine," Généralité d'Amiens, drawn with China ink and watercolor, it gives a fairly precise idea of the topography by using the graphic techniques standardized by the École des Ponts et Chaussées—specific coloring and shading to represent landforms and land use. This allowed engineers to modify or correct the path of the route. The lengthwise layout is typical of route maps.

Size of the entire original: ca. 67.5 × 104.5 cm; size of detail: ca. 25.5 × 54.5 cm. © Archives nationales (France) (F/14/8453, fol. 1).

engraved for public consumption. Different maps from the "Atlas de Trudaine" were produced in small-format, bound manuscripts, with very rich elaboration and especially careful drawing, directed to the king or his ministers. They represented routes strategic for the realm, such as the "route de Paris à Lyon," the "route de Paris en Espagne," and the "route de Paris à Strasbourg."

STÉPHANE BLOND

SEE ALSO: Geographical Mapping; Ponts et Chaussées, Engineers and École des (School of Bridges and Roads; France)

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***Travel and Cartography.*** Maps and travel go hand in glove, and the period from 1650 to 1750 was perhaps the golden age of travelers' cartography. On the one hand, explorers had circumnavigated the globe, and European empires had settlements and entrepôts from the African coasts to the Pacific Islands to the American river valleys. Maps, albeit with different levels of detail and accuracy, described the world. Yet eyewitness information still had value, and the traveler who collected and shared geographical knowledge derived from personal experience or local interlocutors was welcomed as wise and useful by cosmographers and geographers compiling ever more "useful," "exact," "correct," and "accurate" maps. By the late eighteenth century, however, as on-site surveys displaced compilations for producing the most highly valued and accurate maps, travelers' cartographic contributions became less trustworthy, unless noted scientists such as Charles-Marie de La Condamine and Alexander von Humboldt produced the data. This period thus saw both the rise and the decline of the European traveler as mapmaker or purveyor of valuable "new" information, as well as the proliferation of cartography in travel accounts both factual and fictional. Map production and use by travelers can be considered in two main categories: one related to the European Grand Tour, already well established in the seventeenth century, and the other to Europeans going farther afield, notably to the other three "corners" of the earth: Asia, Africa, and America.

MOTIVES, METHODS, AND PREPARATION European travelers (*voyageurs*)—defined in Antoine Furetière's *Dictionaire Universel* (1690, 3:852) as "those who travel for pure curiosity and then write their accounts"—fall into two main groups. The first were elites who traveled for education or leisure in Europe largely for self-improvement and who emphasized finding novelty and marvel in well-traveled destinations. The second were those who, from wealthy noble to common sailor, sought out more distant and unfamiliar destinations from the Levant and Far East to South America and Africa for curiosity as well as for commerce, diplomacy, religion, science, self-improvement, or social conscience. Both groups described their journeys prolifically and in increasing number as travel infrastructure improved and many political/religious conflicts subsided, if temporarily, during the long eighteenth century. As numerous travel journals, logs, epistles, and narratives attest, Grand Tour participants, who made up most of the former group, had little interest in geography or cartography until they added mountains, lakes, and other destinations to what had been largely urban-centric trips; they tended to follow specific itineraries through Great Britain, France, the Netherlands, Germany, and Italy and to produce relatively formulaic content, emphasizing architecture and antiquities over customs and manners. For travelers to most other destinations, on the other hand, collecting and crafting "accurate" geographic information and maps was part of travel; their accounts took an *omnium gatherum* approach to content, covering natural, cultural, religious and political history, commerce, and other topics.

Both sorts of travelers emphasized their own eyewitness authority and novelty, either by the diversity of subjects (such as Maximilien Misson, *Nouveau voyage d'Italie,* 1691) or more thorough observation (such as John Fryer, *A New Account of East India and Persia,* 1698), which, by the mid-eighteenth century, was increasingly tied to expertise and precision, as Humboldt explained his long preparations and acquisition of instruments in order to observe the torrid zone (Humboldt and Bonpland 1814–29, 1:33–39). How voyagers observed and collected changed over time. Yet from Francis Bacon, who criticized a propensity to make travel diaries not on land but on the ocean "where there is nothing to be seen but sky and sea" (Bacon 1625, 100–101), to Horace-Bénédict de Saussure, who in 1796 warned the "geologist traveller" against errors caused by trusting the "reliability of his memory or to the accuracy of his first impressions" (quoted in Bourguet 2010, 381), instructions agreed: notes, not memory, produced credible results.

A curious traveler's kit, too, expanded. In 1686, lawyer and chevalier Charles César Baudelot de Dairval issued a two-volume instruction for traveling *sçavans* interested in antiquities, prescribing that they use an *arbalète* (cross staff), thermometer, and compass on shipboard (Baudelot de Dairval 1686, 2:695–98, 707). A decade later, John Woodward's pamphlet directed travelers interested in natural history to record observations of earth, air, and water using a weatherglass, thermometer, and quadrant (Woodward 1696, 10–16). By 1799, Humboldt's instrument list, comprising items collected over two years, included a pocket chronometer, two telescopes, two sextants (first produced commercially only in 1757), a theodolite, quadrant, compass, graphomètre, and magnetized needles (Humboldt and Bonpland 1814–29, 1:33–39). Not all travelers brought all available devices, of course, but the toolkit was extensive.

MAPS FOR TRAVELERS By the seventeenth century, before their departure European travelers had access to maps of many places on their itineraries, as well as instructions on how to consult them (Bourguet et al. 2002; Collini and Vannoni 2005). As in later periods, map gazing could inspire the would-be traveler. Amsterdam-based traveler Jean-Baptiste Tavernier credited "Maps, from which I never could keep off my Eyes" as inspiration for voyages (Tavernier 1678, [preface]). More practically, maps helped travelers plan and execute trips, becoming more numerous, accurate, and thematically diverse by the height of the Enlightenment. Seventeenth-century travelers could consult atlases and sheet maps of countries and regions, such as the nine-map atlas, *L'Asie en plvsievrs cartes novvelles* (1658) by Nicolas Sanson, offering purportedly accurate information about the cities and topography they would encounter on their journeys to land-based and island empires. Grand Tourists heading to European political, commercial, and cultural capitals could acquire specialized maps for travel, including post and road maps and city plans designed for "countrymen" and "strangers" including street names and commercial, religious, and other landmarks (e.g., John Norden, *A Guide for Cuntrey Men in the Famous Cittey of London,* 1653). Thus, in 1782, Prussian clergyman Karl Philipp Moritz could prepare to depart London on a walking tour with "an accurate map of England in my pocket" and a book lent by an English merchant titled "A New and accurate description of all the direct, and principal cross Roads in Great-Britain" (Moritz 1797, 106).

Road maps such as the one Moritz used improved considerably in this period, particularly in France and England, shifting from a royal cartography to a public one. By the mid-eighteenth century, maps of routes and distances followed by official postal couriers and diligences in continental Europe grew more detailed, including road lines broken by circles to indicate post roads and stops, distances between post changes, and often distance measurements in several European systems (e.g., German, English, and French miles, leagues, furlongs, and even stadia to make the map intelligible to an international readership). Since large flat maps were not easy to consult in carriages and on horseback, some publishers cut them into book-sized pieces, pasted to a linen backing, folded, and sold as pocket maps; others divided the map into sections and sold the collection, often boxed. The one hundred strip maps of routes in England and Wales published in the atlas *Britannia* (1675) by "His Majesty's Cosmographer and Geographick Printer" John Ogilby were intended to simplify travel and improve trade (see fig. 866). As individuals began tearing out the strip maps, a smaller portable-format *Itinerarium Angliæ* appeared within the year and the volume remained in print into the eighteenth century. French and Italian strip maps soon followed (fig. 868).

Those headed beyond continental Europe also carried plenty of reading material, but rather than guidebooks for travelers, they turned to their predecessors and more weighty "histories" such as Leo Africanus's treaty on Africa; Spanish and Portuguese navigators' and missionaries' accounts of the Americas and Asia; Dutch, British, Italian, and other merchants' and diplomats' reports home; and atlases or other cartography based on these works. Many accounts were translated and made accessible within great compilations of travel narratives published by Giovanni Battista Ramusio (*Delle navigationi et viaggi,* 1550) in Italy, Richard Hakluyt (*Principall Navigations,* 1589) and Samuel Purchas (*Pvrchas His Pilgrimage,* 1613) in England, Melchisédech Thévenot (*Relations de divers voyages cvrievx*, 1663–96) in France, Arnoldus Montanus (*Ambassades mémorables,* 1680) in the Netherlands, and others including Theodor de Bry and Pieter van der Aa. Still, as Tavernier noted, "A Man cannot travel in *Asia,* as they do in *Europe*; nor at the same Hours, nor with the same ease. There are no weekly Coaches or Wagons from Town to Town. . . . no certain Stages, or Inns to entertain Travellers" (Tavernier 1678, 1). As a result, earlier travel accounts served a double function as both history and guide to subsequent voyagers, and voyagers such as Tavernier expected that his account would continue this tradition, starting his "exact Description" with "several Roads which may be taken from *Paris* into *Persia*" (Tavernier 1678, [preface]).

While maps for travelers such as Tavernier lacked roads, failed to indicate distances between places, and (as many travelers commented) inaccurately placed many cities or towns, they offered orientation and approximate itineraries to be complemented from travel accounts' discussion of distances or times necessary to travel between cities, recommendation of routes, and identification of locales with caravanserais, or inns, or accommodating consuls or merchants. Specialized navigational materials existed for sailors and pilots, but travelers might not have access or expertise to use the manu-


FIG. 868. ROAD MAP FOR TRAVELER. *Viaggio da Bologna a Ancona* from the anonymous *Guida per il viaggio d'Italia in posta = Guide pour le voyage d'Italie en poste,* new ed. (Turin: Gratelli Reycends, 1776). By the eighteenth century, travelers in Europe could find road maps for most of Western Europe, showing post routes and, when in book form, providing information on exchange rates, the cost of changing horses, and vehicle taxes. This strip route map from a bilingual French and Italian pocket guide to traveling by post in Italy made it easy for the reader to find the post stops by picking them out on a line linking city names to points on the road. Rivers en route are also noted.
Image courtesy of the Bibliothèque nationale de France, Paris.

script or printed rutters (or pilots) used by professional navigators, nor carry or consult navigators' tables.

The voyager's use of maps during travels and in presenting an account varied. Most referred to maps as important resources: the reader was supposed to refer to them to better understand the progress of the narrative, as Thomas Herbert recommended (1638, 342). On the other hand, map elements were also likely inaccurate or misleading, and the author sought to contribute geographic knowledge so subsequent cartographers could improve them. The Westphalian physician Engelbert Kaempfer arrived at "the Country of Kui" in June 1690, commenting that there is "not the least hint" of the steep rocky coasts that he saw "in our Maps" and expressing surprise that more disasters didn't result from inaccurate sea charts (Kaempfer 1727, 1:13). Such distrust of prior cartography spread, even as maps improved. Henry Swinburne, touring "the two Sicilies" from 1777–79, echoed the skeptical approach of earlier scientific travelers. When situating the mountain ranges of Naples (and other points), Swinburne found "errors in the best maps" and questioned the foundations of his cartographic sources and geographers' methods, especially the "four-sheet map" of Naples by astronomer Giovanni Antonio Rizzi Zannoni assembled in Paris "from memory, combination of different observations, and old maps" (Swinburne 1783–85, 1:151–52).

MAPS PRODUCED BY TRAVELERS Even though published cartography was plentiful, increasing, and improving, travelers in this period were as much map producers as map consumers. In an age of increasing scientific knowledge and experiment, eyewitness authority mattered, and travelers brought firsthand information not only about the places they visited, but the routes there and back which either they or "cabinet" or "armchair" geographers in the metropolis quickly transferred to maps. Evidence that travelers created maps for their accounts tends to come from the authors themselves rather than from the maps, which rarely credited the authors; their discussion indicates whether their eyewitness status or scientific training made the maps useful. The "Ad Orig. Eng.: Kempfer delin," which denoted Kaempfer as the author of sketches of the Meinam River and provider of details in the volumes' other maps (Kaempfer 1727, vol. 1, pl. VII), was the exception, not the rule. Alexandre-Olivier Exquemelin, author of a best-selling history of Caribbean buccaneers that (like most popular travelogs) was swiftly translated into a half-dozen European languages, made sure the first edition showed a map of the isthmus of Panama, site of the South American silver transit, which he claimed was "exactly drawn on site" by himself (Exquemelin 1678, title page). Inaugurated in the 1678 Amsterdam first edition, this map, unsigned by author or engraver, was routinely copied in later editions. The truth of Exquemelin's claim to have based his maps on observation is clear from map details: not only rivers, mountains, and cities, but also routes, locations of Indian villages, and labels and views of the harbor and offshore islands that might serve pilots (fig. 869).


FIG. 869. MAP BY TRAVELER. *Carte de l'Isthme de Panama* from Alexandre-Olivier Exquemelin, *Histoire des avanturiers qui se sont signalez dans les Indes,* 2 vols. (Paris: Jacques le Febure, 1686), vol. 2, between 184 and 185. When travelers made their own maps—or publishers could plausibly claim they did—information highlighting how maps were exactly drawn on site was a selling point often appearing in the cartouche. The 1686 French edition of Exquemelin's work attributed the map of Panama, a copy of the map in the original 1678 Dutch edition, to the author, even though no such claim appeared on the original.
Size of the original: 20 × 30 cm. Image courtesy of the Newberry Library, Chicago (Ayer 127.E9 1686).

In contrast to Exquemelin, French engineer François Froger started his personal account of travel in 1695–97 along the coasts of Africa and South America on an official naval expedition by emphasizing that he could serve his homeland by indulging a lifelong passion to see foreign lands because he had studied mathematics and "relations" (travel accounts) of the worlds' peoples, differentiating himself (and the maps he drew) from travelers who traversed the world for the pleasure of "seeing different objects." Froger bolstered his assertations of seriousness of purpose by claiming "frequent conversations" with pilots and "exact" observations permitted by stays in ports, as well as "great number of figures drawn on the spot" (Froger 1698, preface, title page). Froger also focused his cartography; instead of making general maps, he particularly addressed himself to charting entries to ports and rivers, either drawing from scratch (in Rio de Janeiro, Gambia, and Bay of All Saints) or reworking maps or memoirs (for the Straits of Magellan and Cayenne, where he showed new limits). The volume's port and river delta maps, implied to be his work (although again without attribution), indeed seem to promote French trade or conquest.

For areas such as Japan and Africa, with limited European trade and without imminent imperial projects, knowledgeable amateurs' cartographic contributions were welcome into the eighteenth century, as travelers adapted new tools and applied surveying techniques. Kaempfer sketched his own maps as he traveled using a large mariner's compass to measure the directions of roads, mountains, and coasts. Because Japanese authorities sought to keep this information on the island, Kaempfer dissembled, keeping the compass privately in a Javanese box that openly exposed an inkhorn filled with plants and clothing. Similarly, in 1729, Thomas Shaw, chaplain to the English factory at Algiers, sent Sir Hans Sloane, physician and president of the Royal Society, his traveler's map of the Kingdom of Tunis. Shaw explained his method—repeat journeys, use of a mariner's compass, comparison with ancient texts, and previous cartography—and emphasized that his work was "very faithfully laid down" based on recent observations there. Sloane published map and commentary, suggesting respect for this amateur but knowledgeable cartographer (Shaw 1729–30, 177).

ACQUIRING LOCAL KNOWLEDGE: OBSERVATION AND COLLECTION Observing firsthand, making their own measurements, and drawing their own maps was not the only way travelers contributed to cartographic knowledge, for they had more than their eyes and, later, instruments, to gather information. Many followed Baudelot's advice to "study the geographic map of the country, which one must bring, and confer about it with those who are on site . . . to remark that which is missing in one and the other" and drew from experts encountered on land and sea (Baudelot de Dairval 1686, 2:697). At sea, travelers attuned to geography, such as Thomas Herbert and Pietro Della Valle and ship captains such as William Dampier, were exposed constantly collecting knowledge for navigation, and their journal entries often became itineraries of sea journeys and included daily reports of navigational data, including wind directions, compass bearings, drawings of coastlines likely copied from navigational charts or pilots' rutters, and tables of navigational data (fig. 870). Herbert began a typical diary entry presumably copying from the ship's log, as follows: "The last of *[J]une* we raised the *Antarticke* Pole, thirty five degrees of longitude, and twenty sixe degrees, the variation of the Compasse three degrees, our course South South-east, the Sunnes declination twenty two degrees, twenty six minutes, and twenty two seconds, in the seventeenth degree of *Gemini*" (Herbert 1634, 12). While Herbert did not identify the source of his detailed knowledge of the ship's progress through the Atlantic, Della Valle was so impressed as he sailed toward India that, in addition to reporting similar data, he explained to the reader how navigational charts were made and who had a role in collecting the necessary information (Della Valle 1665, 6–9).

On land, travelers also collected local knowledge for a metropolitan audience by discussing geographical questions with non-European interlocutors. François Bernier, for example, discussed the source of the Nile with two Ethiopian ambassadors to Delhi (one Muslim, one Christian) (Bernier 1670). While Bernier did not suggest that the three of them pored over a map, he did know European cartography, expressing surprise that the Muslim ambassador claimed the source should be more "deça" (on one side) of the line on European maps that follow Ptolemy rather than "dela" (on the other). Not all thought such consultations were worthwhile. Jonathan Swift's fictional ship's surgeon and captain Lemuel Gulliver described the length of Brobdingnag's city of Lorbrulgrud as "three *Glonglungs* (which make about fifty four English Miles)" and 2.5 in width, which he verified by pacing the "Diameter and Circumference" barefoot on the hundred-foot long map, and so "measured it pretty exactly." Meant to "satisfy my curious Reader" and draw a chuckle, this parody consultation and survey mocked the lengths travelers would go to learn from contacts whose methods and knowledge might be suspect (Swift 1726, 1:70).

On the road, travelers were also avid map collectors

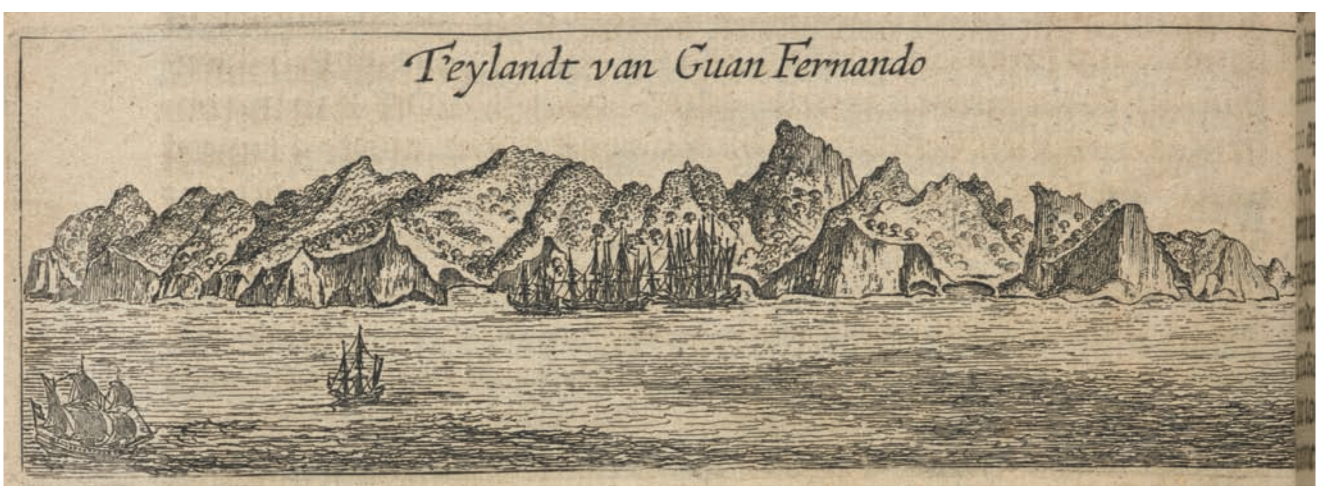


FIG. 870. COASTAL VIEW BY TRAVELER. *T'eylandt van Guan Fernando,* from Jacques l'Heremite, "Beschryvingh vande voyagie om den gantschen aerdt-kloot, gedaen met elf schepen, onder't beleyd van den Admirael Iaques l'Heremite, ende Vice-Admirael Gheen Huygen Schapenham, in de iaren 1623, 1624 ende 1625," in *Iournalen van die voyagien* (Amsterdam: Iacob Pietersz Wachter, 1643), 50. Travelers on ocean journeys, from sea captains to their passengers, frequently copied views from navigation manuals or rutters into their published accounts, with or without the soundings and bearings that made the originals useful. This coastal view of the Island of Juan Fernandez, off the coast of Chile, included in the journal of the Nassau Fleet under the command of Dutch merchant and admiral Jacques l'Heremite, offers a clear view and is placed usefully for readers within a longer description of the fleet's anchorage off the island. However, it lacks the information that would help sailors to orient a ship.

and brought locally produced maps home for consultation. Grand Tourists not only purchased guidebooks such as Louis Coulon's *Le fidele condvctevr povr les voyages de France, d'Angleterre, d'Allemagne, et d'Espagne: Montrant, exactement les raretez & choses remarquables qui se trouuent en chaques villes, & les distances d'icelles* (1654) that celebrated the ancient and modern curiosities, marvels, and delights of capitals such as Paris and Rome, university towns such as Heidelberg, or volcanoes and bays of Naples and Pozzuoli, but also the post and route maps and plans of the cities mentioned. Once brought home, such maps might be used for private study, or find their way into library collections. John Bargrave, later canon of Canterbury, made four trips to Italy between 1646 and 1660, and on the first, commissioned a portrait of himself and his traveling companions pointing at the map of their destination, signaling their location through the map to complement a background landscape of Siena. He bequeathed his collection of Sanson's maps, "which cost me five pounds to the author himself, at Paris," and 133 sheets of "cutts" of Trajan's Pillar in Rome to the library at St. Peter's (Peterhouse) College, Cambridge, as well as his "larger and lesser mapps of Italy, oulde Roome and new . . . together with all the cutts in my trunks of all the antient ruines, the pallaces, statutes, fountaines, the Cardinalls, souldiers, philosophers, &c. of Italy, France, High Germany" (Bargrave 1867, xix).

If maps acquired on Grand Tour travels were published for a European audience and destined for armchair travelers and students, those from Asia, the Americas, or even Russia were often destined for patrons, publishers, and colleagues in academic societies, such as Britain's Royal Society and France's Académie royale des sciences. The works Kaempfer brought from Japan in 1692 included several roadbooks for the use of travelers, giving an account of the distances of places, the price of victuals, carriage, and the like, with many figures of the buildings, and other remarkable things to be seen on the road. Kaempfer also brought back ten maps: four of Japan; city maps of Osaka, Kyoto, Nagasaki, and Edo; and a pictorial map of land and sea routes between Edo and Nagasaki (Kaempfer 1727, passim). After Kaempfer's death, Sloane, later president of the Royal Society (1727–41), purchased his manuscripts and supervised translation and publication of the travel account. John Gaspar Scheuchzer, Sloane's secretary and Kaempfer's translator and editor, commented that while Japanese cartography was less accurate than European efforts, and based on lesser knowledge of mathematics and physics, the maps were extensive and detailed, so he "followed" one of "several" for the *History* (Scheuchzer in Kaempfer 1727, 1:xxi). French astronomer and abbé Jean Chappe d'Auteroche collected maps on his missions to observe the transit of Venus in Siberia (1761) and New Spain (Mexico) (1769). A Russian scholar's essay and map of Kamchatka accompanied the first trip's account, and a map of Mexico City the second. The abbé acquired his Mexico maps from Creole priest and leading cartographer José Antonio de Alzate y Ramírez, and particularly praised two: one based on Hernán Cortés demonstrating conquistadors' knowledge of California as a peninsula, and another that was "very exact" and based on the "most faithful memoirs of voyagers that he studied in the country itself" (Chappe d'Auteroche 1772, 68 note i).

PUBLISHING TRAVELERS' MAPS Not only did travelers make maps as they traveled or collect maps and geographic information and data, but, as described above, they or their editors also considered maps an integral element in the published account and useful for readers. With the exception of Grand Tour narratives, whose readers as participants were expected to have access to atlases or specialized city maps, most accounts published in Great Britain, France, and the Netherlands included maps specially prepared for each publication; German and Italian editions tended to have fewer graphic elements. Travel accounts and maps were so intertwined that even fictional travelogs, such as *Gulliver's Travels* (Swift 1726) and *Robinson Crusoe* (Defoe 1719) required maps to seem complete. Many—both fact and fiction—deployed maps, as publisher Jean-Frédéric Bernard wrote in 1727, "to make known the situation and bearing of the country a voyager describes" (Bernard 1715–27, 8:2). Presumably to increase the details, the maps were often large foldouts. To facilitate consultation during reading, such general maps tended to be located opposite the first page or at the end of a published account, although there were some exceptions. Edward Terry's preface to the reader of his travels to India discusses the importance of a map of the monarchy and, reflecting custom and reader convenience, the map itself appears as a foldout between the table of contents and first page of text. However, for a 1777 reprint of the text (with redrawn map) the foldout map migrated to the middle of the book, in a discussion of the provinces "in this most exact affixed map" (Terry 1655, A4; 1777, 85). Often, these maps included dotted ("pricked") or colored lines to show the traveler's itinerary, and for longer trips, world rather than regional maps might serve. A planisphere map showing the route taken by Daniel Defoe's fictional Robinson Crusoe (see fig. 200)—modeled on real maps by Herman Moll and privateers William Dampier (1697) (fig. 871), Woodes Rogers (1712), and Edward Cooke (1712) (and perhaps by the same cartographer)—was placed not at the front of the first book, where it might initiate the real journeys, but on the page facing the first date the shipwrecked Crusoe

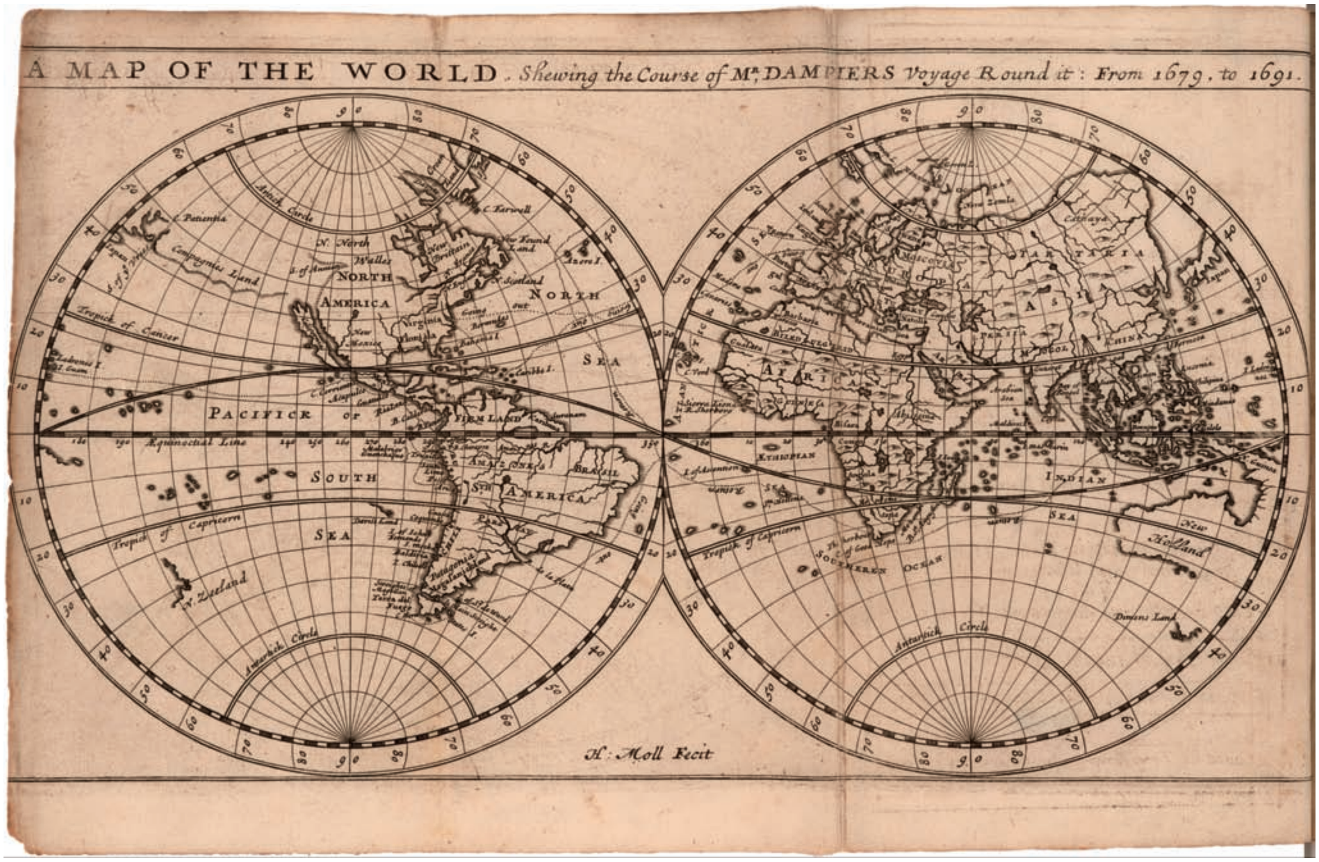


FIG. 871. WORLD MAP SHOWING TRAVEL ROUTES. *A Map of the World. Shewing the Course of Mr. Dampiers Voyage Round It: From 1679 to 1691,* from William Dampier, *A New Voyage Round the World* (London: Printed for James Knapton, 1697), facing title page. London-based mapmaker Herman Moll plotted William Dampier's voyage round the world by using a dotted line to mark the "going out" and "return" journeys. A similar map adorned the second volume of Robinson Crusoe's fictional voyages to help convince readers that they had indeed taken place (see fig. 200).
Size of the original: 16.2 × 29.2 cm. Image courtesy of the John Carter Brown Library at Brown University, Providence.

began to keep a journal, that is, the start of his documented journey found in the second book (Defoe 1719, 79–80).

In addition to itinerary maps, many accounts of sea journeys offered coastal or harbor views, and land travelers often included a "platform" or view of cities visited or specific geographic features, as well as illustrations of inscriptions, processions, gemstones, and flora and fauna, or plans of buildings or ancient ruins, according to the travelers' interests. Such maps were generally placed into the volume near discussion of its subject, whether printed on a page of letterpress or tipped in as a separate page or foldout. Sometimes views were labeled, with lists of identified sites appearing in the text opposite. Travelers who mapped extensively, such as Martino Martini (Japan) or Alexander von Humboldt (South America), might also place maps created during or based on their travels into a separate geographical atlas.

If an account was popular enough to merit multiple or international editions, additional maps might be added, indicating that maps contributed to strong sales and increased the book's value—a suggestion supported by eighteenth-century book catalogs for sales of private collections from France, Italy, Belgium, and Great Britain, which advertised missing maps in travel accounts that might have been printed fifty or a hundred years earlier. In the first French edition of Bernier's travel to India (1670), no map accompanied the discussion of the Nile's source, but the French publisher copied a 1683 French map into the 1709 edition, presumably more interested in drawing attention to this question than providing the most updated information. Thomas Herbert included three maps (Madagascar, Caspian Sea, and the Bay of Mauritius) and sketches of bays where the ship docked (perhaps taken from the ship's rutter) in the first edition of his relation (1634). The second edition (1638) added two maps of India and a bigger map of the Caspian Sea and surrounding territories specifically

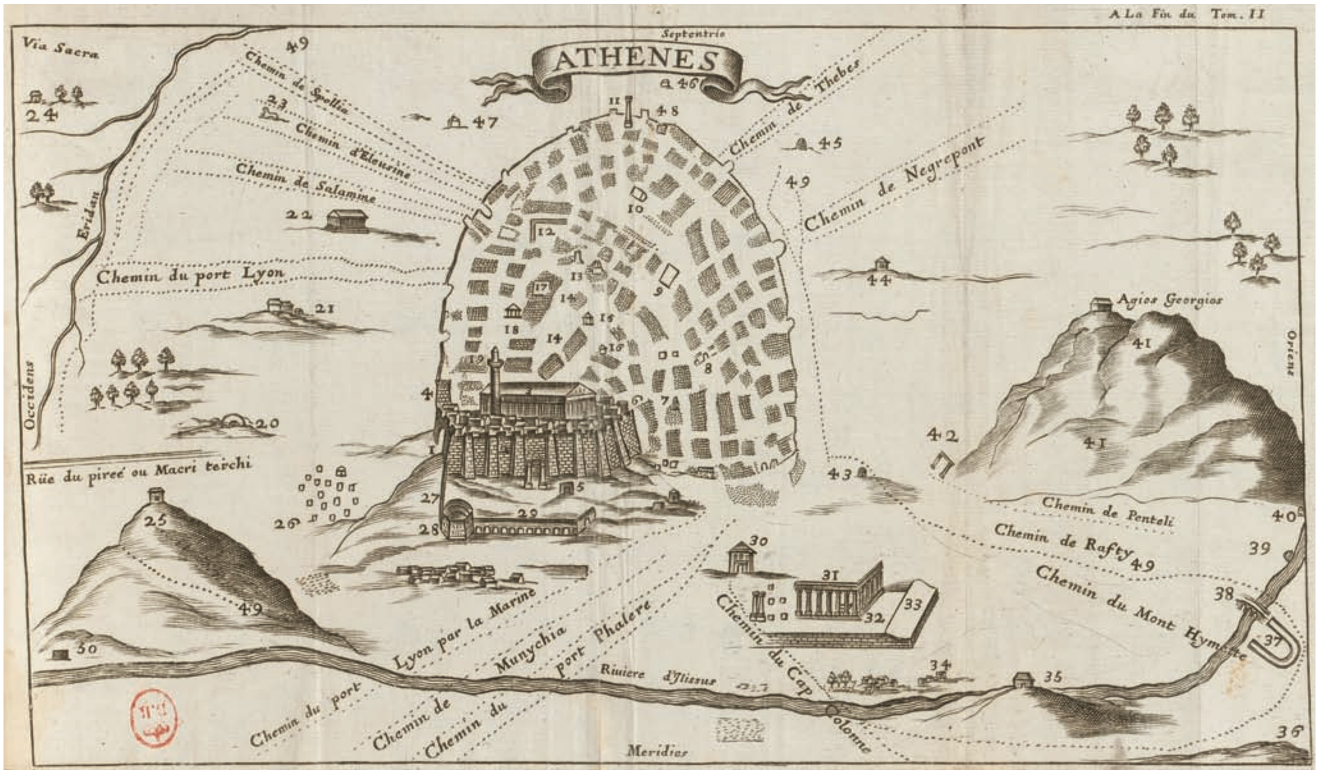


FIG. 872. PLAN BY TRAVELER (CITY PLAN, RUINS). Jacob Spon, *Athenes*, from Jacob Spon and George Wheler, *Voyage d'Italie, de Dalmatie, de Grece, et dv Levant, fait aux années 1675 & 1676*, 3 vols. (Lyon: Antoine Cellier, 1676), tipped into the back of vol. 2. French physician and antiquarian Jacob Spon visited Athens following Georges Guillet de Saint-George's *Athenes ancienne et novvelle* (1675), which contained a foldout plan of the city and its environs that Spon simplified and corrected showing fifty key sites and putting a few important buildings on the map. Numbers on the map correspond with a list of sites on the preceding pages.
Size of the original: ca. 14.5 × 24.0 cm. Image courtesy of the Bibliothèque nationale de France, Paris.

so "that you [the reader] may the better go along with us" and, for Persia, guaranteeing that "neither the position of Places are false, nor names of Townes fictitious or borrowed" (Herbert 1638, 149). French physician Jacob Spon traveled to Greece, Dalmatia, and the Levant. Early editions of his account included several maps and plans, including foldout maps of Attica and the island of Delos. The second volume added a foldout plan of Athens with numbers indicating almost fifty key sites in the city and its environs, and half a dozen named routes to attractions, signaling direction with dotted lines. A numbered list of the main attractions, keyed to the sites on the map, followed at the end of the volume (fig. 872).

By the eighteenth century, maps based on surveys or thematic maps and plans became the preference of travelers and publishers. By this time, Europe was hungry for maps by travelers not only to independent empires, such as Japan, with their own cartographic traditions, but also to colonies whose metropolises jealously guarded official maps, and where local experts were members of elite circles who, thanks to their connections with travelers, might be invited as corresponding members of academic societies. Those societies, in turn, valued not only observation but measurement and surveying, increasingly demanding training and technical expertise. In many cases, cartographic travelers were official agents and/or members of royal societies. With Bourbon monarchs on both French and Spanish thrones in the eighteenth century, the Franco-Spanish expedition (1735–45) to South America to measure an arc of the meridian at the equator led by French academician Charles-Marie de La Condamine and Spanish navy lieutenants Jorge Juan and Antonio de Ulloa is one of the best known; another was that of abbé Chappe d'Auteroche to observe the 1769 transit of Venus in California, an event that paved the way for his Mexican colleague Alzate y Ramírez to become a corresponding member of France's Académie des sciences. Maps from both missions were delivered to imperial powers, but La Condamine's map of the Amazon River's course quickly appeared in his 1745 *Relation abrégée d'un voyage* (1745), with copies reengraved by

Jacques-Nicolas Bellin for the Paris (1757) and Amsterdam (1773) editions of Antoine François Prévost's *Histoire générale des voïages*. Ulloa and Juan published a travel account filled with city maps, plans of forts and bays, and landscapes in South America that were new to the reading public. Even Chappe d'Auteroche's 1769 notes were useful: although he and most of his colleagues died returning to Mexico City, the editor of his notes considered that his diaries "furnish at least an itinerary of the route from Veracruz to Mexico City, and from Mexico City to the west coast of Mexico," making them the basis of the publication (Chappe d'Auteroche 1772, 106–7).

Thematic maps took root even in accounts of exploration of the European countryside of French vineyards and Mediterranean islands in ways analogous to adventures in Amazonian jungles or Afghan mountain passes, and achieved similar international attention and republication. Travelers to these territories, such as Arthur Young, an agriculturalist visiting revolutionary France, and Henry Swinburne, a Grand Tourist and artist in Sicily, generally included maps in published accounts and described the lands they visited. If the maps of Naples and Italy in Swinburne's lavish two-volume *Travels in the Two Sicilies* (1783–85) were not his own, the many coastlines and mountain passes, labeled as views, were his work, and showed Sicilian and Neapolitan landscapes much as earlier travelers revealed the contours of Asia and America. Maps in some early editions of Young's account, *Travels during the Years 1787, 1788 and 1789* (1792), were based on a hydrographic map described as French in origin and largely excised topographic, geographical, and jurisdictional information. On the same rather empty outline base map, Young created three thematic maps: his itinerary; soil qualities in different regions; and France's climate and routes, which used angled lines to indicate crops (olives, corn, vines) grown in different zones. The map of Young's itinerary established his credentials as a traveler and the book's as a travelog; the two maps of his scientific analysis situated the text as one of exploration of a novel topic, if not a novel land, and as purveyor of new information, though their accuracy might seem questionable. France's geography and topography were sufficiently familiar for Young to leave them out and the topic sufficiently novel for the maps to appear in many editions. The three-volume French edition, *Voyages en France, pendant les années 1787–88 et 90,* which combined the route and climate maps, even promised to include additional data from a French scientist.

The most celebrated early nineteenth-century cartographic traveler was Prussian baron Humboldt, whose expeditions in the Americas (1799–1804) and eastern Russia (1829) made him a household name and whose innovative mapping was based on what he learned while traveling. Combining his interest in the natural world with precise readings of barometric pressures, temperatures, and mountain heights, Humboldt produced new themes for cartography in his isothermal maps and distribution maps showing the geography of plants.

CREDIBILITY OF TRAVELERS' CARTOGRAPHY If the travelers cited above seem to substantiate geographers' trust in travelers as sources of ever fresher, more accurate, more quantitative data for their maps, not all travelers' observations were considered improvements. Despite Tavernier's efforts at accuracy, the limitations of an interested but untrained observer were clear. No cartographer could base an accurate geographic representation of the author's trip on his text or sketch maps. While Tavernier occasionally reported distance in leagues ("*Merdin* is not above two Leagues from *Cousasar*"), he more often employed less precision ("About twice Musquet-Shot from thence" or "a Journey of six hours") (Tavernier 1678, 67–69). Because of such vague description, subsequent travel accounts dismissed Tavernier as too superficial, too trusting of others' information, and too reliant on memory. So Tavernier's potential contribution to European geographical knowledge—that his ship sailed around Japan and proved it an island, rather than a peninsula, as geographers such as Guillaume Delisle still postulated—was considered suspect (see Scheuchzer in Kaempfer 1727, 1:xix–xx). Over time, such skepticism would only grow, emulated by Swift's Gulliver. Put into a canoe after several weeks confined to his cabin and not knowing "in what Part of the World we were," he worked his way in two days over what he claimed were eighteen leagues to what he decided was New-Holland, and failed to convince "my worthy Friend Mr. *Herman Moll*" that "the *Maps* and *Charts* place this Country at least three Degrees more to the *East* than it really is" (Swift 1726, 1:166–67). The reader, evaluating fictional Gulliver's trail of suppositions, would clearly side with the renowned and very real Dutch-born geographer in rejecting a conclusion based on no initial data and without instruments or other means of on-site measurement.

Still, some travelers' information, if gathered "scientifically," retained value for mapmakers in metropolitan workshops regardless of the traveler's place of origin. Jean-Baptiste Bourguignon d'Anville, in a letter published in 1750, described his collection, analysis, and application of dozens of manuscript and printed maps from an international who's who of travelers, diplomats, and military men for his compilation map of South America (d'Anville 1750). After comparing the observations and theories of French and other academicians with on-site work of navigators for the coasts, for the interior of the continent he drew upon sources as early as 1708 and as late as the previous decade's scientific travelers including La Condamine, Juan, and Ulloa, in addition to British admiral George Anson, Portuguese brigadier José da Silva Pais, French military engineer Amédée-François Frézier, French marine officer Joseph-Bernard, marquis de Chabert, and Jesuit missionary Samuel Fritz. Even Rennell admired the geographical matter collected by Europeans until the late seventeenth century, and found d'Anville's maps of Asia and India of 1751 and 1752 surprisingly good, especially considering "that this excellent Geographer had scarcely any materials to work on for the inland parts of India, but some vague itineraries, and books of travels" (Rennell 1788, 6)—a remark that highlights a singular difficulty for mapmakers: even knowing that some of the data travelers produced or collected was of limited credibility, it was potentially better than no information at all.

USE OF TRAVELERS' MAPS BY GEOGRAPHERS AND OTHER PUBLISHERS Travelers' information and the maps they collected did not just appear in their own accounts. Seventeenth-century geographers compiled data from many sources, including travelers and their accounts, to create maps for atlases that travelers later used and criticized. For his 1691 *Mercvrio geografico*, Giovanni Giacomo de Rossi identified some of those travelers by name. The cartouche of plate 107, *Il regno della China* (1682), noted his use of the "most recent accounts of the most illustrious voyagers of our century," particularly three Jesuit missionaries (the Austrian astronomer Johann Grueber, Portuguese Bento de Góis, and Italian Martino Martini), Tavernier, and unnamed "others." The maps reflected a century of travel information evaluated and combined. By the late eighteenth century, such compilations were considered less reliable than on-site evaluation.

Agents of empire, particularly Jesuit missionaries, were among the most prolific and respected global cartographic travelers, deploying their training in mathematics and astronomy particularly in China and the Americas. Trent-born mathematician and Jesuit Martini, who confirmed that the Cathay of early travel reports and the China of Jesuit missions were one and the same, returned to Rome after a decade in China and submitted historical and cartographic information for publication. His works included the *Novvs atlas Sinensis,* with maps of the Chinese empire and fifteen individual Chinese provinces measured in "Stadia Sinensia" and German miles, and a map of Japan with its administrative divisions, which formed part of volume 10 of Joan Blaeu's *Atlas maior* (1655), a work then valued for its up-to-date accuracy. Also from Trent, the Jesuit Eusebio Kino not only established twenty-four missions in Baja California, but also used his skills as astronomer, mathematician, and mapmaker to map Sonora and Sinaloa, the Gulf of California, and Baja California, showing the last of these definitively as a peninsula and not an island. Kino's astronomical skill was celebrated by Mexican poet Sor Juana de la Cruz, and his maps made their way not only into Spanish archives, but into print in France, where Nicolas de Fer published *La Californie ou Nouvelle Caroline* (1720) based on a 1696 Kino manuscript map and a German missionary periodical showing Kino's travels from 1698–1701.

In the eighteenth century, the popularity of travel narratives remained high, and at least some remained important sources of information, as evidenced in new compilations assembled and disseminated by John Harris of London (*Navigantium atque itinerantium bibliotheca: Or, A Compleat Collection of Voyages and Travels*, 2 vols., 1705), Jean-Frédéric Bernard of Amsterdam (*Recueil de voiages au Nord*, 8 vols., 1715–27), and Johann R. Forster and Matthias C. Sprengel of Leipzig (*Beyträge zur Völker- und Länderkunde*, 14 vols., 1781–90), among others. The original maps, however, did not always retain their value. Bernard's *Recueil* mixed old with new maps, including a map separating the Northern and Southern Hemispheres by Delisle and a "new map" of Georgia made for the collection along with copies of maps from the original accounts, while Forster and Sprengel's *Beyträge* offered "original maps" (*mit Original Charten*). Travel narratives excerpted from the Earl of Oxford's collection came with new maps by Moll introducing each region (*A Collection of Voyages and Travels . . . with Great Variety of Cuts, Prospects, Ruins, Maps, and Charts*, 2 vols., 1745). Prévost's *Histoire générale des voïages* included numerous plates of engravings and maps by Bellin, offering cartographic unity rather than travelers' mapmaking.

Between 1650 and 1800, the basic cartography available to travelers improved continuously with on-site observations, criticism, and revised editions. Geographic maps, road maps, city plans, and coastal and other views improved and were increasingly available. Travel practices changed little, then as now: the consultation of maps prior to departure, the acquisition of maps on location, the filling in of maps as one goes. The practices, cartographies, and timetables of an early modern European traveler in the age of sail and horse-drawn diligences created the tools adapted for their steam-, gas-, and electric-age counterparts.

In terms of mapmaking, by the close of the eighteenth century, specialists began to take over the work of improving geography while travelers' accounts lost much of their appeal as sources of new and accurate information. For the description of land, distance, and travel times, the testimony of travelers who were trained, with expertise in surveying and measurement, was valued more than that of educated amateurs on-site. Travelers still mapped and travel accounts included an increasing number of maps, but, unless travelers were in the service of the state or were respected naturalists with political and academic connections, the focus of their studies had to be innovative, such as Arthur Young's agricultural studies, if they were to see their cartographic contributions published.

JORDANA DYM

SEE ALSO: Antiquarianism and Cartography; Defoe, Daniel; Geographical Mapping; Imaginary Geographies and Apocryphal Voyages; Ogilby, John; Public Sphere, Cartography and the; Thematic Mapping; Urban Mapping: Enlightenment

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## *Traverse.*

SURVEYING TRAVERSE
ITINERARY TRAVERSE
MARINE TRAVERSE

***Surveying Traverse.*** In traverse surveys, linear and angular measurements were combined and the principal points were connected by a single journey. Traverse surveying suited a wide variety of situations, scales, and levels of precision. The route formed a series of straight stretches, the length and bearing of each of which were measured. The results were usually entered as numbers in a field book, although in some cases bearings were plotted on a plane table. In a compass traverse, the magnetic bearing of any line at the start could be checked by a back bearing from the finish back to the start,

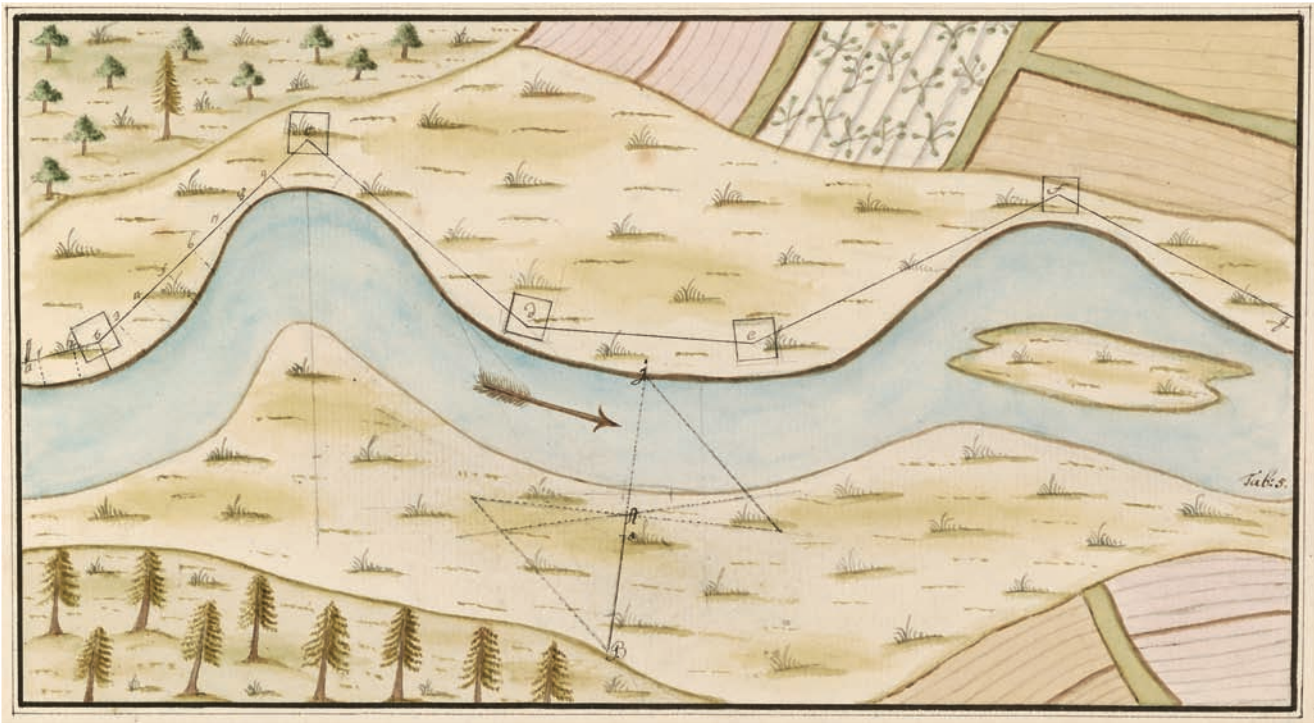


FIG. 873. SURVEY TRAVERSE WITH PLANE TABLE. This diagram from a German surveying manual illustrates the process of using a small plane table—represented at each successive station by a small square—in a traverse to map a river. From each straight leg of the traverse, the surveyor could measure offsets to the river bank. From Johann Christoph Schlönbach, "Practische Anleitung zum Feld-Messen," 1759, fol. 65. Size of the original: 19 × 31 cm. Image courtesy of the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland (OML-1759-9).

which would have to differ from the forward bearing by 180 degrees. A closed traverse ended back at the starting point, which meant that the survey could be checked. Almost always there was a discrepancy between the first and last positions of the initial point, and so the errors were distributed around the polygon. An open traverse was less reliable, though it could end on a point that had been surveyed by a more accurate method. Short perpendicular measurements were taken from known points on the polygonal lines to fix the positions of features or places. From the eighteenth century, there was discussion in surveying literature about the balance that should be struck between having fewer survey stations and thus having long distances between them and having shorter distances between the stations to reduce the length of offsets.

Distances could be measured by a chain or a surveyor's wheel, also known as a perambulator or waywiser. The latter, though faster, was less appropriate for boundary traversing, where much of the route did not lie along a good road. Bearings and angles might be measured by instruments with a magnetic needle: taking true angle measurements rather than compass bearings was preferable and was the technique used by Joel Gascoyne in late seventeenth-century England (Ravenhill 1991, 10). In eighteenth-century Ireland, the perpendicular angles between the side lines and main lines were normally determined by eye, which meant that the longer the offset, the more likely it was that the feature was misplaced (Andrews 1985, 313). Alternately, a plane table might be used to determine angles graphically (fig. 873). Traversing was particularly useful in areas where visibility was restricted and especially where only one survey line could be seen at a time. For instance, in thick woodland or deeply incised valleys traversing was the most practical method. In early seventeenth-century England, John Speed used traversing, probably with a plane table, for surveying towns (Bendall 2009, 12).

Traverse surveys were used throughout the Enlightenment. They were common in seventeenth-century Ireland, both in plantation surveys and in work by private surveyors. Gascoyne used traversing along linear landscape features for his map of Cornwall published in 1699 (Ravenhill 1991, 10). In the mid-eighteenth century, William Roy used traversing in his survey of Scotland between 1747 and 1755. Each surveyor had six soldiers and a noncommissioned officer assisting him. One of the soldiers carried a theodolite, two measured with a chain, the two survey points for each leg of the traverse were each marked by a soldier, and the last soldier acted as a batman. Measured traverses were taken along the important features; the other points were fixed by the intersections of bearings taken from traverse stations and minor details were sketched in by eye (Gardiner 1977, 441). Joseph Lindley and William Crosley used traversing in their survey of the county of Surrey published in 1793. Although the backbone of the survey was provided by triangulation, based on eighty-five stations, the topographical detail was provided by a plane table traverse along the roads (Harley 1966, 373–74).

Concerns over accuracy and improvement of instruments to measure angles meant that over time traversing became less popular. In Sweden, open traversing was prohibited in land surveys after 1780 although closed traverses were still allowed, and in Great Britain surveyors working for the Ordnance Survey were discouraged from using traverses after the 1820s (Andrews 2009, 144).

SARAH BENDALL

SEE ALSO: Instruments for Angle Measuring; Instruments for Distance Measuring; Measures, Linear: Surveying Measures; Property Mapping

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***Itinerary Traverse.*** The itinerary traverse (or route survey) was the operation of taking measurements in the field prior to the preparation of a final road or route map based on these measurements. During the Enlightenment, important advances resulted from improvements in tools and measuring techniques particularly in France, England, and regions of Italy and Germany (Bousquet-Bressolier 1995, 96–103).

Many types of individuals participated in this type of field measurement. Using the example of a surveyor from Liège, Alexandre Carront, Marcel Watelet (1995, 182) listed the many nouns describing the large-scale surveyor in French: *mathématicien*, *géographe*, *géomètre*, *mesureur*, *mécanicien*, *arpenteur*, *arpenteur-juré*, and *ingénieur*. A similarly varied nomenclature may be found in other European languages and contexts. In France, the term *géographe* could designate a person with the technical knowledge and necessary competence to "draw up" a map, that is to take measurements, make calculations, and represent the data on a map. *Géographes* could be private surveyors, surveyors chartered by local districts, or civil or military engineers employed by the state. In France, from the early eighteenth century, the engineers of Ponts et Chaussées took responsibility for the majority of development projects and the cartography of French roads. Their training emphasized techniques for map production, starting with theoretical training at the École des Ponts et Chaussées in Paris, followed by periods of practical training in the provinces alongside more experienced engineers.

The itinerary traverse required solid knowledge in practical geometry, elementary calculations, and trigonometry, as applied in the field. Instructional treatises multiplied from the end of the seventeenth century, such as *La science des ingenieurs* (Bélidor 1729) or *La sience de l'arpenteur* (Dupain de Montesson 1766). Fieldwork generally began with more favorable weather at the end of winter or early spring. Before moving to the field, surveyors prepared general maps that included a summary sketch of an itinerary that incorporated the topography of the locale and their projected work. In certain cases they used coordinates obtained during operations of general triangulation (chains of geodetic triangles), which added more precision. In France, the works of the Cassini family were used for many itinerary operations. For example, Jean-Rodolphe Perronet recommended that his engineers in the Ponts et Chaussées use the *canevas* of four hundred geodetic triangles of the *Nouvelle carte qui comprend les principaux triangles qui servent de fondement à la description géométrique de la France* (first drafted 1744; see fig. 19), based on the fieldwork of Jacques Cassini (II) and César-François Cassini (III) de Thury (Blond 2014, 139–40).

The surveyor measured the distance along a section of the route, using either chains or perambulator or an estimate of the time traveled at an assumed speed (usually indicated in feet); the direction of the route was obtained by compass readings. Surveyors often kept a journal in which the direction, distance, and other observations were noted. This separate journal obviated too much information on the map. After field operations, the plan was drawn up to show the itinerary, with the different measurements along the way serving as a framework for the map (Edney 1997, 91–96). When the itinerary was new, its course was sometimes represented on the ground in the form of a straight line.

Surveyors used various instruments for measurement that were costly to acquire and difficult to manipulate. The surveyor's chain remained the classic and

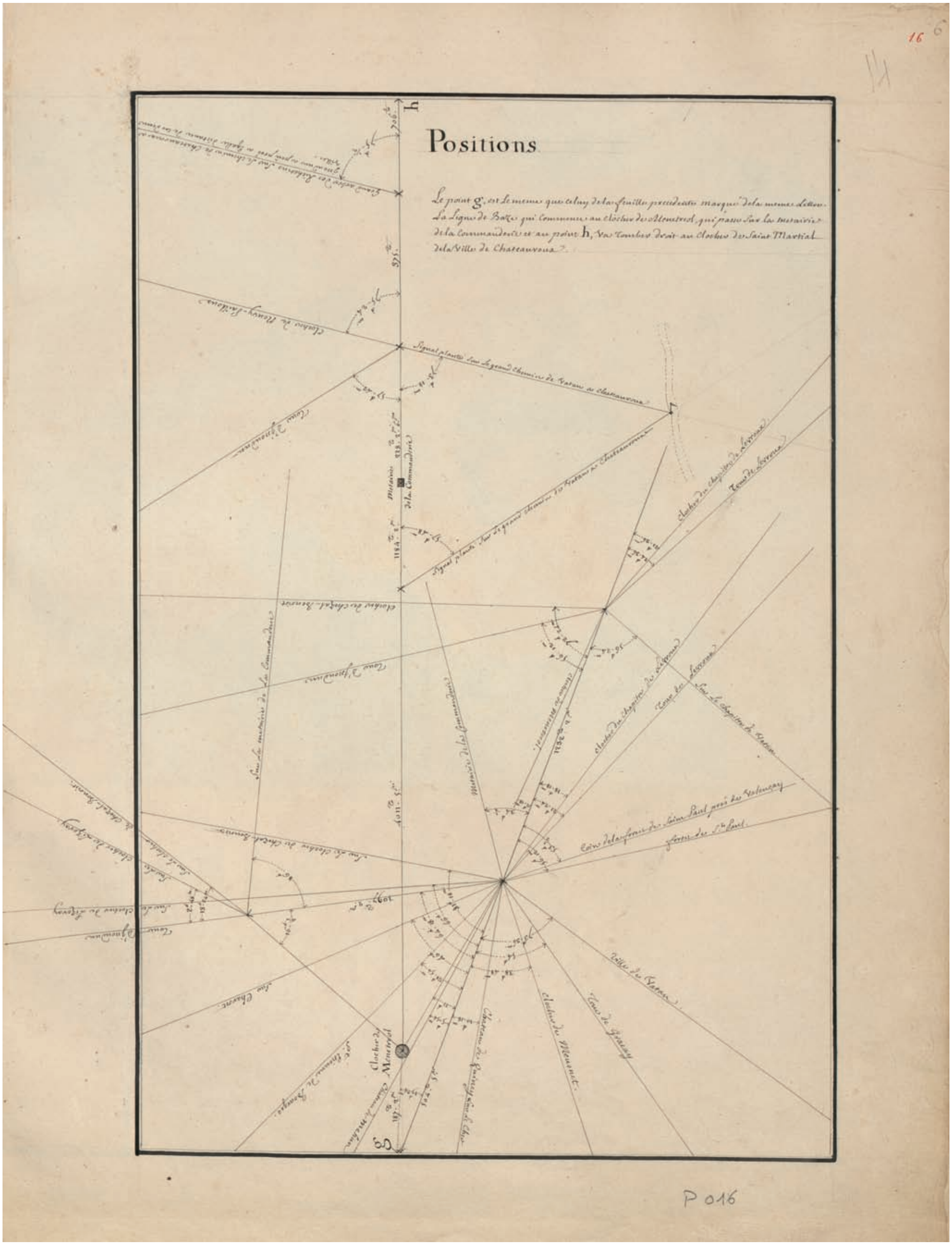


FIG. 874. ONE SHEET FROM THE "GRANDE ROUTE DE PARIS À TOULOUSE." This image, taken from the manuscript "Atlas de Trudaine," Généralité de Bourges, represents the multiple operations undertaken by the engineer, including sightings and the measurement of angles and distances. These indispensable data were used for the precise rendering of the route. Size of the original: ca. 54.0 × 41.5 cm. © Archives nationales (France) (CP/F/14/8459, fol. 16).

indispensable tool for measuring the length of a road itinerary, a canal, or a river. A *planchette*, or plane table, supported by feet, facilitated the recording of measurements. A graphomètre, or half-circle, came into wider use in this period for the measurement of angles; the addition of a telescopic lens allowed ever more precise sightings by limiting the margins of error (Koeman 1988). From the end of the seventeenth century, French military engineers used these tools, and in the eighteenth century, the use of the graphomètre was a fundamental part of the training program of the civil engineers of the Ponts et Chaussées. By that time, greater precision was demanded in the field. The observer sighted reference points in the countryside such as church belfries or castle towers, then calculated the angle they formed with the baseline of the itinerary. By applying trigonometric formulas to the measurements of angles and the length of the baseline, the itinerary could be more precisely rendered (fig. 874).

Surveyors used other tools with specific functions, including the essential magnetic compass for direction, squares, rulers, and levels (Watelet 1995, 68). Assistants helped to transport this equipment and to take measurements. In due course, all these data were recorded on a draft copy that became the basis for a second phase of operation, the fair drawing produced in the office of the cartographer.

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SEE ALSO: Engineers and Topographical Surveys; Instruments for Angle Measuring; Instruments for Distance Measuring; Measures, Linear: Itinerary and Geographical Measures; Transportation and Cartography: (1) Road Map, (2) Route Map


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***Marine Traverse.*** In parallel with the traverse on land, in navigation at sea the "day's work," or dead reckoning, involves estimation of the track followed from the last position known with certainty. Until the problem of longitude was solved after the mid-eighteenth century, such certainty could come only from the bearing of a carefully identified seamark on the coast and, possibly, its association with a value of latitude. An elite group of navigators in the Enlightenment during the second half of the eighteenth century were also capable of determining a position by astronomy in the open sea, including both latitude and longitude. Whatever the source of the point of departure, reckoning had to be accomplished by solving one of "the sailings": parallel, plane, traverse, tangent, rhumb line, or spherical.

The day's work involved combining the different vectors that made up the track of a ship during a given period in order to determine its new position at the end of this period. The reckoning was determined by plotting on the chart the different courses and distances comprising the segments of the track during a specific period of time. Before the invention of the Mercator projection at the end of the sixteenth century, this operation was carried out with a reduction quadrant (sinical quadrant) (see fig. 592) or a Gunter's scale. This instrument was still frequently used in the eighteenth century, notably when the charts in use were too small in scale for effective usage of rhumb lines and parallel rulers.

On the chart, the recording of track and position, whether deduced by observation or by reckoning, made use of rhumb lines. Following the historical division of the horizon and the compass into thirty-two graduations of 11°15′, these points of the compass firstly designated the angle between two lines of bearing, and then the thirty-two lines of bearing themselves. Rhumb lines were present on plane charts until the eighteenth century and also on charts drawn on the Mercator projection, inasmuch as these charts showed a compass rose with its thirty-two points. The resultant network of rhumb lines, or loxodromes, on the plane chart—called, in French, a *marteloire*—greatly facilitated the plotting of bearings when near land or the plotting of the day's work during ocean passage.

Resolving the day's work graphically was accomplished with a protractor and the simple Mercator graduation of meridians and parallels on a large sheet (*grand-aigle* in French, double elephant in English). This process allowed the resolution of courses and estimated distances run into difference of latitude, or northing/southing, and difference of longitude (or departure in the case of plane or traverse sailing). When the planned voyage involved little change in latitude, the record of the number of miles traversed could be readily produced at a constant scale for the day's work, without recourse to calculation of a base track. This would be the case, for example, in a transoceanic voyage along a single parallel.

Whether by graphical or arithmetical procedure, the resolution of a traverse involved the following trigonometry: the distance run formed the hypotenuse of a right triangle the other sides of which were composed of the difference of latitude and the departure. However, if the latitude changed significantly in the course of a voyage, this procedure had to be carried out at shorter and shorter intervals. In such a case it was critical to divide the route into sections and to calculate each triangle at the scale of the midlatitude. Thus, allowance was made for the increase in the length of a minute of latitude as one moved farther away from the equator, as represented on the Mercator projection (Chapuis 1999, 730–31).

The distance run in the French *lieue majeure* involved the conversion of the leagues traversed on the midlatitude of the voyage into leagues at the equator; in French, it was called *réduction des lieues mineures en lieues majeures* (Bouguer 1753, 333). Similarly, since in the mid-eighteenth century the similarity of the geoid to an ellipsoid of revolution was accepted and the sphericity of the earth had been acknowledged much earlier, parallels were recognized to be circles that decreased in radius as one moved from the equator to the poles. The value of the minute of longitude was, therefore, a function of latitude. Consequently, another correction had to be made using meridional parts, the lengths of the arc of the meridian between the equator and a given parallel expressed in leagues at the equator (Chapuis 1999, 726–27).

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SEE ALSO: Instruments for Angle Measuring; Instruments for Distance Measuring; Marine Charting; Measures, Linear: Marine Measures

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***Triangulation, Marine.*** See Sounding of Depths and Marine Triangulation

***Triangulation Surveying.*** The surveying technique of triangulation enacts a basic geometric principle: if the magnitude of one side of a triangle and the two adjacent angles are known, the third angle and the lengths of the other two sides can be determined. The process of triangulation is relatively straightforward. By observing the horizontal angles formed between "stations"—hills and tall buildings that afford good views—a surveyor can define a network of triangles across a region (fig. 875). If the length of one side of one triangle is known, whether by estimation or measurement, then that length can be carried through the network to fix the relative locations of all the landmarks. The history of the technique is complicated, however, both by the different kinds of cartographic work for which it was adopted and by how the lengths of the triangle sides were determined: either by graphically plotting out the triangles on paper or by trigonometric calculation.

The technique was described by several commentators in the early sixteenth century, most completely by Gemma Frisius in 1533 in his *Libellvs de locorvm describendorvm ratione*, published as an appendix to his edition of Peter Apian's *Cosmographicus liber*. Frisius presented it as a means to control and give geometrical structure to regional surveys: with the triangulation complete, the surveyor locates and maps topographical features within the triangles using intersecting sight lines, linear traverses through the landscape, and sketching. This method was used by Jacob van Deventer for provincial surveys in the Netherlands in the 1530s and 1540s and by Philipp Apian for his survey of Bavaria in 1554–61. In 1615–17, Willebrord Snellius, professor of mathematics at the University of Leiden, first used triangulation for geodetic purposes to measure the length of an arc of a meridian and thereby calculate the size of the earth. After 1650, these different applications were increasingly blended together.

Jean Picard established the basic technique of Enlightenment geodetic survey when in 1668–70 he surveyed a chain of triangles along part of the Paris meridian. In addition to carefully measuring angles between hills and church spires with a large, highly precise, and specially made instrument, he also carefully measured two "baselines" along flat roads (AB and XY in fig. 257). He used trigonometric functions to calculate the lengths of the triangle sides and then to convert them to the length of the meridian. Most, but not all, geodetic surveys included a second baseline: by comparing its measured and computed lengths, geodesists could determine

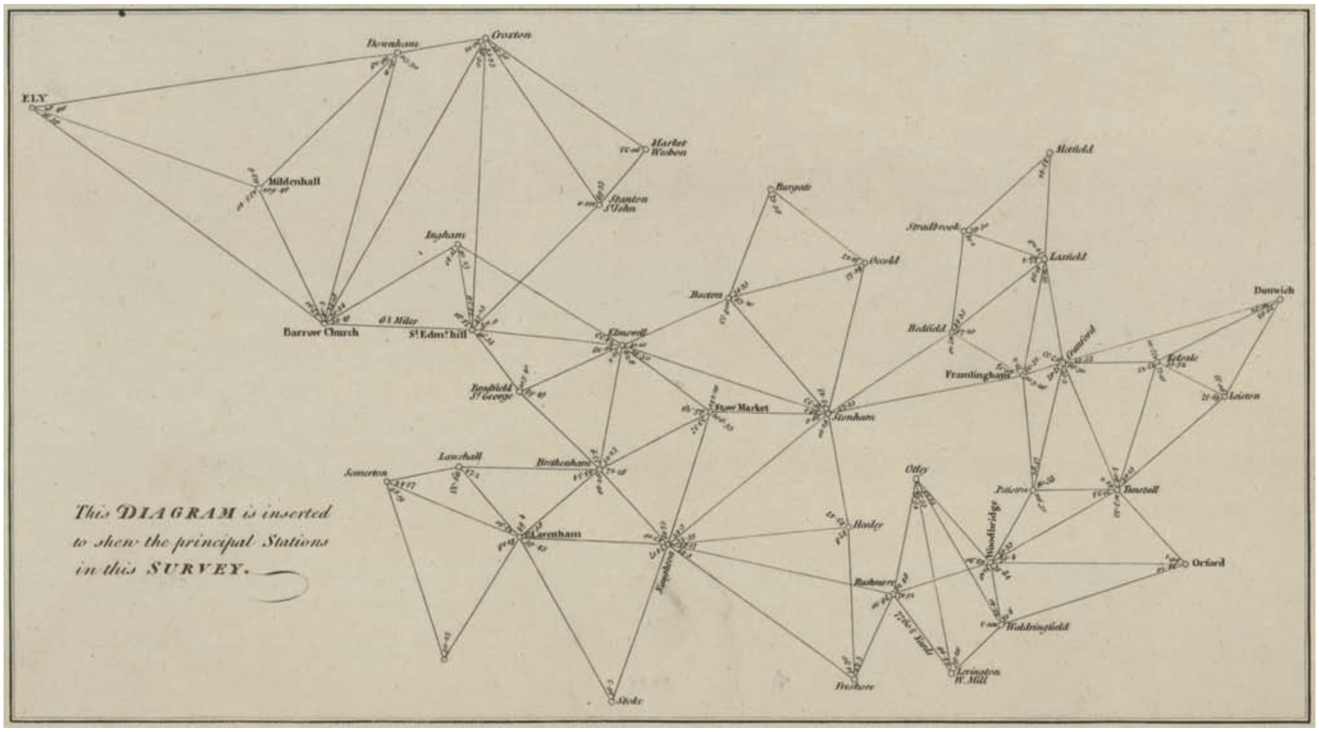


FIG. 875. DETAIL FROM JOSEPH HODSKINSON, *THE COUNTY OF SUFFOLK . . . 1783*. Inset map on sheet 1 showing the forty-one triangulation stations used in the survey. Most of the stations were on high ground and were visible from several directions, with some as far apart as fifteen miles. Size of the entire original: 120 × 162 cm; size of detail: ca. 18 × 33 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C. (G5753.S7 1783 .H6 Vault).

whether or not they had undertaken the triangulation properly. Because of its reliance on the computation of each triangle, such work was generally called a "trigonometrical" survey or operation.

In mapping small regions, triangulation provided a geometrical framework by fixing the relative locations of stations. This use of the technique required much less instrumental precision, less mathematical sophistication, and, in general, less on-site care than did geodetic work. A surveyor could easily place the triangulation stations on paper by simply drawing each triangle in turn. Starting with a known side (measured or estimated), he drew lines forming the correct angles (based on his observations) at each end of the first side to create the two adjacent sides; the intersection of these two lines fixed the location of the third station and provided the lengths of the adjacent sides; he then used one of these adjacent sides to draw the next triangle and repeated the process until the network of triangles was complete. There was no need to make any trigonometrical calculations. This would seem, for example, to have been the process used by Joseph Hodskinson in his 1776–83 survey of Suffolk. In his diagram of his triangles (see fig. 875), Hodskinson did not indicate a specially measured baseline but instead specified the lengths of two sides of his triangles, of 6½ miles and 7760½ yards (ca. 4½ miles) respectively; on the ground, both of these lines run over hills and valleys, so it is not clear how Hodskinson determined their lengths (Dymond 1972, 3–4). Moreover, Hodskinson made no claim to have made a "trigonometrical survey." No special term was used for this simpler form of triangulation, and surveyors referred only to the triangles on which their surveys were based.

The French were the primary advocates of triangulation-based surveys during the Enlightenment and sought to blend the geodetic with the regional. Picard's geodetic survey also fixed the locations of some places in Paris to assist in David Vivier's survey of Paris and its environs (see fig. 4). Jean-Dominique Cassini (I), first director of the Paris Observatory, and his son Jacques Cassini (II) not only extended Picard's chain of geodetic triangles along the Paris meridian but also undertook a regional triangulation, so that by 1739 France was enclosed by four hundred triangles surveyed from eighteen bases. In

1745, the third member of the family to work on the project, César-François Cassini (III) de Thury, presented the Académie des sciences with a map in eighteen sheets comprising eight hundred connecting triangles (see fig. 19). Secondary triangulation and topographical surveys commenced by 1750, and the final *Carte de France* was published in 1783 (Pelletier 2013).

Other countries followed France's lead. In England, John Adams established a very long baseline on low-lying Sedgemoor, Somerset, by December 1681, but his projected national survey did not come to fruition (Hewitt 2010, 69). Joel Gascoyne probably used a local triangulation for his map of Cornwall in 1699, as did many of the surveyors of county maps after 1750, anticipating at a regional level the nationwide trigonometrical survey by the Board of Ordnance (Harley and O'Donoghue 1980). Giovanni Antonio Rizzi Zannoni claimed to have undertaken a survey of Oldenburg that was in part based on *trigonometricis dimensionibus* (trigonometric measurements); a map printed under his name depicted several branching chains of triangles, but there remain questions about the quality and techniques used in this triangulation (Heinz 2015, 119–20). Elsewhere in Europe, the manpower and instrumental costs of triangulation required monarchs, princes, or a wealthy elite to support national or provincial projects. Entries in this volume on geodetic and topographical surveying in various European spatial contexts describe these triangulation endeavors, such as those of Denmark after 1761 or of Saxony starting in 1780.

After 1780, the Greenwich-Paris triangulation and the retriangulation of the Paris meridian to determine the length of the meter together inaugurated modern triangulation practices. These surveys, and their continuation and extension by both the British and French militaries, established extensive triangulation networks as the method of controlling national topographical surveys in the nineteenth century. It seems that in codifying these practices, French engineers coined the term "triangulation," thereby giving this multifaceted practice a conceptual unity. Henceforth, more precise, trigonometrically based geodetic work has been understood as primary triangulation, less-precise regional work as secondary triangulation ("Opérations" 1802–3, 1).

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SEE ALSO: Geodesy and the Size and Shape of the Earth; Geodetic Surveying; Greenwich-Paris Triangulation; Heights and Distances, Geometric Determination of; Instruments for Angle Measuring; Instruments for Distance Measuring; Lapland and Peru, Expeditions to; Meter, Survey for the; Military and Topographical Surveys; Topographical Surveying

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***Typographic Printing.*** See Reproduction of Maps: Typographic Printing