I

Iconography, Ornamentation, and Cartography. While eighteenth-century maps continued to include many decorative and iconographic elements, reflections about the images on the maps are practically nonexistent in works related to mapmaking of the period. Neither Nicolas Sanson's *Introduction à la géographie,* published by Guillaume Sanson (1681, editions until 1743), nor *The Construction of Maps and Globes* by John Green (Bradock Mead) (1717), nor *L'usage de la sphère, du globe, et des cartes, pour la géographie* by Pierre Viollier (1704) alluded to the existence of an image, an ornament, or even an illustration on maps. As for manuscript plans, neither Nicolas Buchotte (*Les regles du dessein, et du lavis,* 1721) nor Louis-Nicolas de Lespinasse (*Traité du lavis des plans, appliqué principalement aux reconnaissances militaires,* 1801) asked the question. This discussion of the subject is therefore based on reflections from the seventeenth century.

In his great treatise *La science de la géographie* (1652), the Jesuit mathematician Jean François, who may have been René Descartes's professor at the Collège de La Flèche, actually tackled the subject of the production of maps and globes at length: images, which speak to the senses, should allow those who want to know geography to picture the surface of the earth and the various divisions it entails. Among his many practical suggestions and theoretical guidelines, Jean François alluded to the role of iconography in cartography:

> Some additions can be used extensively in the blank spaces to serve as decorations for globes and maps and as instructions for viewers; such as the following things: 1. The horizon with the winds painted as mouths exhaling, and with the name of each wind written inside each puff. 2. The zodiac with the signs depicted as drawings. 3. The climates in their appropriate meridians. 4. The calms of a peaceful sea, and marine tempests, wherever they are common. 5. Different fish that exist in the various seas. 6. Different animals, fruits, flowers, and other properties of the lands. Various costumes of natives, etc. 7. The rhumbs and marine compasses in some places: because even though each place marked has its own, as well as its own horizon; it suffices to provide them only for some specific points. 8. The regular winds (permanent, annual, and biannual, etc.). 9. The currents and other movements of the sea. 10. Magnetic declinations in different areas of the sea and the land. 11. Anomalies in nature, accidents, and mankind's noteworthy acts, and God's miracles, which have occurred in various places. And if these decorations overwhelm the map and cause confusion, then the locations can be numbered and explanations about what each place contains may be added in a separate area. (François 1652, 359–60)

As we have seen, Jean François considered iconography, in its greatest extension, as an accessory and an ornament of cartography. In his *Méthode abrégée et facile pour apprendre la géographie* (1706), abbé Le François distinguished between lines, dashes, and points found on the geographic representation and between characters, numbers, and figures that allowed for the identification of cartographic places and for which he also gave the codes (or instructions) for reading (Le François 1706, 63). The distinction was traditional, derived from a Ptolemaic vocabulary that separated the representation of the *position* of places from that of the *nature* of places. But we see that iconography was not part of the discussion mentioned by Le François. Iconography brought a dimension or additional distinction, which was ornamentation in cartography.

Ornament on a map (or globe) was that element that was not *in* the cartography but was *added to* the cartography. This addition "serves to accompany the main subject" (Jaucourt 1765, 11:657). Ornament included iconology, the "science that concerns the shapes and representations of men and gods, assigning to each its appropriate attributes, which also serve to differentiate them" ("Iconologie" 1765, 8:488). In a cartouche, along the edges of the map, or even floating as little illustrations in the map's empty areas, iconography welcomed and expressed a whole series of extensive cognitive and ideological dimensions that cartography, in the strictest sense of the word—meaning the geometric drawing of positions and geographic forms, on the one hand, and semiotics (from the legend) on the other—did not support.

The practice of ornamentation may be seen in a map produced by Nicolas de Fer that complies, even at a distance, with the methodological instructions of Le François (fig. 384). What immediately strikes the viewer's eye is the excess of iconography that spreads out across the continents and seeps into the blank areas of the oceans. As with his other maps, de Fer arranged small illustrations and iconographic scenes to form a kind of frame around the map itself, placing around eighty illustrations at the bottom, top, and either side of the image, providing the viewer with a panoply of geographic information.

A close inspection of these scenes reveals:

Ships and routes of expeditionary voyages dated on the map.
Portraits of navigators and well-known discoverers affiliated with various nations.
Work scenes: the fishing and processing of cod, hunting scenes, mining activities (gold mines, and precious metal transport), ways of cultivating and transforming plants (grating manioc, sugar cane processing, production of cassava).
Landscape views: Cape of Good Hope, Niagara Falls.
City plans: Mexico, La Concepcion, Veracruz.
Picturesque scenes: a hookah smoker, beavers collecting wood (a well-known scene later reproduced by Herman Moll).
Many marine and land animals: penguins, manatees, crocodiles, eagles, tortoises, muskrats, and armadillos.
Exotic plants: potatoes, bananas, cocoa, red currants, annatto, spiny palms, manioc, watermelons.
Ethnographic scenes, primarily relating to Canada and Mexico: religious customs, sacrifices, funeral ceremonies, rites of war and peace.
Portraits of indigenous peoples: "Peruvian natives," "Porters of Mexico," "Mexicans" (Aztecs).
Historical events related to discoveries and conquests: the arrival of Hernán Cortés at Veracruz in 1519.

However, no monstrous peoples are found here, as they no longer seem to have a place on maps. The review of the *Traité des Acéphales, ou des hommes sans tête* linked such usage to the past: "one still sees [such] figures today represented on old geographical maps" (*Nouveau Mercure Galant*, September 1714, 98–117, quote on 105–6).

Numerous historical and descriptive texts were added to these images as they spread out over the surface of the map. The texts comment on the represented scenes, add historical explanations to the site of places (known or unknown) and to cities, or identify specific sites placed on the maps (e.g., the Great Wall of China).

While Jean-Baptiste Bourguignon d'Anville (1753, 134) attested to the importance of white space on the map as a signifier of the absence of data, his view did not mean the end of cartographic ornamentation. In fact, one of the hallmarks of the "new" cartography, whether printed or manuscript, was that it had not completely lost older decorative traditions (as shown by the maps produced for the *concours* [competitions] of the École des Ponts et Chaussées; see fig. 631 and Picon and Yvon 1989). Indeed, while the Cassini maps were successful overall in demonstrating a new "scientific" cartography devoid of iconography in which only the description of the lines, points, and surface areas had meaning, at least one sheet of the *Carte de France* nevertheless contained an image of a small cutter sailboat typical of the region and typical of earlier cartographic design, in which ships played an important role (Unger 2010) (fig. 385).

In the extensive collections of eighteenth-century maps in which the stature of iconography had seemingly been diminished in favor of blank or white space, many maps stand out as continuing the iconographic tradition. This was particularly true of planispheres, which remained over the course of the century a place of encyclopedic synthesis, either organized around cosmographic knowledge or aimed to include, through allegorical representations or other figurations, the whole of a written language of the earth in a grammar often likened to that of a cartouche (fig. 386; see also fig. 275).

But one also finds iconographic elements on other types of maps including marine charts, city plans, and regional maps, to name a few. Nor should the title pages of atlases or the frontispieces of map collections be ignored. Iconography was principally deployed around the title cartouches and the legends as well as around the borders, but it sometimes invaded the visual space of the map itself, as in the case of many of the maps published by the Homann firm (fig. 387; see also fig. 377).

This brief inventory of examples of iconography in cartography at the beginning of the eighteenth century offers the following tentative conclusions and directions for further research, especially concerning the three main functions of ornament: to instruct, order, and inform. The primary function of iconography was educational. It would have been thought of as part of a learning and memorization model for geography and history that linked place and image. Nicolas Lenglet du Fresnoy, whose works were published frequently in

FIG. 384. NICOLAS DE FER, *CARTE DE LA MER DU SUD ET DES COSTES D'AMERQUE* [*SIC*] *ET D'ASIE, SITUÉES SUR CETTE MER*; *CARTE DE LA MER DU NORD ET DES COSTES D'AMERIQUE, D'EUROPE ET D'AFRIQUE, SITUÉES SUR CETTE MER* (PARIS: J. F. BENARD, 1713). Engraved by P. Starckman, ca. 1:1,949,000. Printed map with added color in ten sheets.

Size of the original (assembled): 108 × 207 cm; size of each sheet: ca. 54 × 45 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge C 24281 [RÉS]).

FIG. 385. DETAIL FROM CÉSAR-FRANÇOIS CASSINI (III) DE THURY'S MAP OF THE L'ÎLE DE RÉ. From the *Carte de France,* 1:86,400 (1768–72), no. 133. The map shows a little *cotre,* a boat typical of the region.
Size of the entire original: 60.5 × 47.5 cm; size of detail: ca. 40.5 × 34.0 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge FF 18595 [133]).

many languages (including German, Italian, and English as well as the original French), wrote:

> The principal order that must be followed requires a little reading, but with some attention placed on the geographical maps and on the recall of the places included in the introduction being used. Thus, the eyes react much more than the mind; yet in order to focus the imagination, each place that is noted in the book and on the map should be characterized either by some point of natural history, or of ecclesiastical or civil history, or by some type of commerce and by the nature of the soil or the customs of the inhabitants, or by a siege, a battle, or the background of some important family. (Lenglet du Fresnoy 1716, 1:xvii–xviii)

Iconography was also about *showing* the geographical, ethnographical, and natural realities found in the places represented through the map's drawing and toponymy. Using the vocabulary of mathematicians (*géomètres*) of the period, such as Alexis-Claude Clairaut, it involved *enlightening* the spectators by inviting them to read what was in front of their eyes on the map and by allowing them to imagine the places drawn on the map. Similar thoughts were expressed by Lenglet du Fresnoy, who believed that the geography of the map was "more of a science of the eyes than of the mind" (Lenglet du Fresnoy 1713, 1:9), marking an introduction to the idea of the map's readability.

Iconography also had a cognitive function. According to Joan Blaeu, the purpose of iconography was to represent "the graces of each region, the fruits which it bears, the metals it produces, the animals it begets or nourishes . . . [and] . . . the arms or insignia, with the names, whether of dukes or counts or barons or other notable men" (quoted in Andrews 2009, 442). Thus, the illustrated scenes were not randomly selected but chosen in relation to an intellectual program emanating from the descriptive geography of the sixteenth century (both at the cosmographic small scale as well as the chorographic large scale), which appeared in the form of complex compositions, as in the work of Homann. Moreover, one of geography's objectives was specifically to provide information on the natural qualities of soils, cultural customs, forms of governments, animals, plants, significant historical events, and other wonders. Emanuel Bowen's map of Italy (1747) contained these elements, playing on a fascination with volcanoes as well as other natural phenomena (fig. 388). A third dimension, whether of time or space (during this period the two dimensions were not as clearly separated as they are today) (Verdier 2009), could also be illustrated, as in Philippe Buache's map of the English Channel (1752), which included a cross-section of the sea floor between France and Great Britain (see fig. 133).

A historical or descriptive decorative inventory was, in principle, indefinite because it related to the abundant earthly reality that Europeans discovered, but it was not without order. In other words, through the iconographic illustrations, the viewer discovered the cognitive rubric of the map, which could equally be found by reading a book or a travel log.

Decoration was clearly a means of preserving narrative and descriptive dimensions within the geometry of a map. The narrative and descriptive functions of decoration transform the map into a *discourse*: a discourse about the different worlds portrayed by the map. The discourse of de Fer's *Carte de la Mer du Sud* was relatively explicit in its representation of the exploitation of natural resources (the mines), the political and moral (religious) conquest, and the description of American territories (among others) that this map established. The viewpoint was European, and the spectator was observing from Europe, looking toward the rest of the world. Through this lens the viewer was invited to discover places of immense natural riches and opulence, illustrated by iconographic scenes—places that the spectator

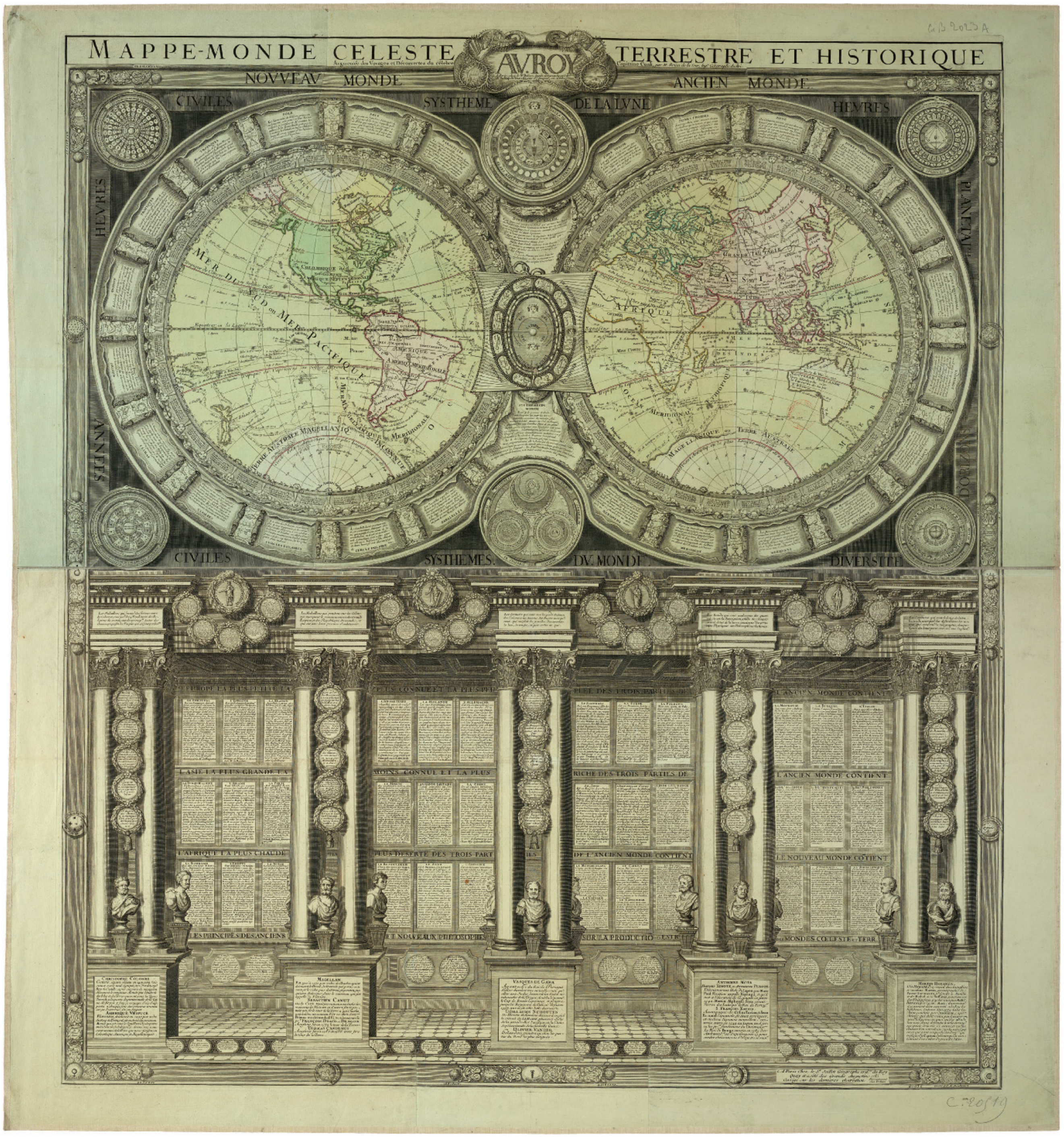

FIG. 386. LOUIS BRION DE LA TOUR AND LOUIS-CHARLES DESNOS, *MAPPE-MONDE CÉLESTE TERRESTRE ET HISTORIQUE* (PARIS, 1786). One printed map, two hemispheres, ca. 1:35,000,000. Size of the original: 105 × 105 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge B 2023 [A]).

FIG. 387. JOHANN BAPTIST HOMANN, *PROSPECT UND GRUNDRIS DER KEISERL. FREYEN REICHS UND ANSEE STADT HAMBURG, SAMT IHRER GEGEND,* CA. 1715. Printed map, hand colored, ca. 1:40,000. Size of the original: 49.5 × 58.5 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge D 13665).

was also invited to dominate. While the discourse of de Fer's map is one of power, that of Bowen's map of Italy is curiosity.

The iconographic richness in de Fer's *Carte de la Mer du Sud* allows one to apply art historical methodology to cartography in the same manner as Daniel Arasse (1996) applies it to the details in painting. Arasse spreads out and breaks apart the whole of the representation. Similarly, the iconographic saturation of de Fer's map produces a fragmentation and dispersion of the meanings on paper: the image that lies before the viewer might be considered a synthetic view, but it is instead a juxtaposition of details calling for the viewer's gaze to wander over the paper and gradually discover the wealth of information. The iconography clutters the view and strips the map of its unity as a whole, its basis of internal connection. De Fer's map eludes the instructions of Roger de Piles regarding the unity of the composition and the fixity of the eye. De Piles (1708) specifically emphasized the necessity of the whole and renounced the idea that parts of the image could be dealt with independently. In this sense, the iconographic ornament could be considered a risk for cartography, the risk of getting lost in the details, and certainly, the risk of only pleasing the eyes. Criticism of ornamentation came from both eighteenth-century cartographers and certain art theorists of the

The visible difference between the outlines of this & those of most English & Foreign Maps, makes it necessary for us to inform y^e Curious that for y^e sea Coast we have principally follow'd y^e C. de Maurepas's Correct Chart: And with respect to y^e inland parts we have had recourse to Riccioli & Delisle The whole being adjusted by the most approv'd Astronomical Observations.

The Eruptions of M^t. Vesuvius have been numerous. In that of 1631 by the violence of y^e Shock the Sea retired several times, left Ships on dry ground, many Villages were consum'd & 30000 people perished. In 1694 the Mountain raged a great while & threw out burning matter with such force, that it reached Benevento about 30 Miles off. On y^e 23^d. of July 1707 it began to throw out Stones accompanied by vast streams of Flame & smoak & on the 3^d. of Aug. it raged with great violence throwing out such quantities of Cinder & Ashes that it was dark at Naples at Noon Day. In the beginning of June 1717 after a horrid Noise & hideous bellowing which caused even the houses at Naples to shake, it threw out vast quantities of melted matter w^ch. stream'd down y^e Mountain like a Pot boiling over.

Mount Ætna or Mongebello in Sicily throws out sometimes pure Flame and at other times a thick smoke with Ashes. Streams of liquid Fire run down with great quantities of burning stones. It has made several great Eruptions particularly those of 1669 and 1693 by the former of which Catania suffer'd extremely; and by the latter it was almost totally destroy'd so that most of it now lies in Ruin.

The 10^th. it grew very outrageous again, Roaring & Groaning most dreadfully. The largest streams of liquid Fire seem'd half a mile broad & 5 miles long. Sometimes two or 3 distinct Columns of flame and sometimes one vast Column that seem'd to fill the whole Crater, which is about 400 Yards diam^r. would burst out, throwing up burning Stones upwards of 1000 foot perpendicular above the Summit of the Vulcano; w^ch. falling down again, resembled y^e Stars in our Rockets. The Noise resembled a mixed sound made up of the Raging of a Tempest, the murmour of a troubled Sea & the Roaring of Thunder & Artilley confused all together.

FIG. 388. EMANUEL BOWEN, *A NEW AND ACCURATE MAP OF ITALY DRAWN FROM THE LATEST AND BEST AUTHORITIES, AND REGULATED BY THE MOST APPROVED ASTRON: OBSERVATIONS*, 1747, 1:6,050,000. This map uses the images of volcanoes in Italy to play on the eighteenth-century fascination with marvels of nature.

Size of the original: 24.1 × 33.0 cm. Image courtesy of Geographicus Rare Antique Maps, Brooklyn.

same period, showing that this issue was not separating art from science, but rather blending the two—conceiving how the pleasure of looking, of contemplating the whole ensemble, is legitimized in science as well as art.

Iconography's place and function in European cartography of the seventeenth and eighteenth centuries require broader thinking about the role of cartography itself within the educated and artistic (scholarly) cultures where it developed. Furthermore, iconographic analysis involves an examination of the training and development of a geographical culture in the European general public at that time and of the procedures and directions taken by that culture. That which was called "cartography"—an anachronistic term even for that time—actually constituted a system of complex images that lay side by side and overlapped or interacted graphically. In addition, the images were politically and intellectually diversified and at times even contradicted one another. Iconography fulfills that part of the program of geography that geometric drawing and semiotics alone cannot. Iconography may therefore be summarized as follows: it allows the viewer to see the terrestrial and maritime world and all it contains, meaning (in Jean François's vocabulary) to be able to imagine it, and while looking at a map or a globe, to grasp the worlds inside it that are represented there. This view assumes that the purpose of the map is not only to represent the terrestrial or maritime world and the particular territories included, but also to depict ideas about this world as well as the intentions or interests that one anticipates developing there. By accepting that the map conveys a complex visual discourse, one understands the essential and significant place iconography holds in the elaboration of this discourse.

JEAN-MARC BESSE AND NICOLAS VERDIER

SEE ALSO: Art and Design of Maps; Cartouche; Color and Cartography; Decoration, Maps as; Landscape, Maps, and Aesthetics; Signs, Cartographic; World Map

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Imaginary Geographies and Apocryphal Voyages.

Herman Moll's world map, drawn to accompany William Dampier's *A New Voyage Round the World* (1697), demonstrates the transformation of knowledge brought by the seaborne ventures of the previous three centuries (see fig. 871). Outside Europe, the main continents—Asia, Africa, the Americas—are immediately recognizable even if their outlines are misshapen; but closer inspection reveals significant errors and gaps. The interiors of Africa and Asia have little detail; only the western half of Australia and the eastern side of North America are shown (its west coast extending no further north than California, drawn as an island); the Arctic is marked by some tentative coastlines, but the Antarctic is a void. Some of the lack of detail stems from the small scale of the map, but in general Moll's construction gives a fair impression of the extent and limitations of geographical knowledge in the period. To fill the gaps would be a priority for governments, explorers, and adventurers in the eighteenth century, but meanwhile the empty spaces on the maps provided ample room for imaginary lands and peoples, reached by apocryphal voyages and travels. Spurious voyages and travels came in many guises. Sometimes both voyage and voyager were fictitious; at other times an imaginary exploration was credited to a historical personage. Accounts of some apocryphal travels and their discovery of marvelous lands were simply hoaxes; others had a satirical or political intent. At the far edges of fantasy, writers described space flights, journeys to the center of the earth, and time travel (Adams 1962).

For earthbound writers, the uncharted expanses of the Pacific, covering one third of the globe's surface, offered tempting possibilities (Fausett 1993). In 1668 Henry Neville published *The Isle of Pines, Or, A Late Discov-*

ery of a Fourth Island near Terra Australis, Incognita. The island's name was not a reference to trees but to the fictitious shipwrecked narrator, George Pine; the result of his stranding on the island with four women was that he fathered forty-seven children and by the time of his death boasted 1,789 descendants. Neville's little book was quickly translated into Dutch, French, German, and Italian and was followed by longer accounts. *History of the Sevarites or Sevarambi* by Denis Vairasse, written by a Frenchman but first published in 1675 in English, again used the voyage-shipwreck-castaway as a way of reaching his utopia, set in "the third Continent, commonly called Terræ Australes Incognitæ" (in the book's subtitle). The next year Gabriel de Foigny's *La Terre Avstrale connve* appeared, the tale of another unfortunate shipwrecked mariner. His South Land had a population of 144 million, "much Biger and Taller than the Europeans; and . . . lived much longer than they" (Foigny 1693, preface [4]). Logically and prophetically, these splendid physical specimens, so superior to Europeans, were called "Australians." Daniel Defoe's *The Life and Strange Surprizing Adventures of Robinson Crusoe* (1719) was set somewhere off the Orinoco, but it was based in part on the real-life adventures of Alexander Selkirk, marooned on Juan Fernández during one of William Dampier's several expeditions to the South Seas. Much of Jonathan Swift's book on Gulliver's travels (1726) was set in the Pacific, and there are hints of real voyages and real people throughout. In 1722 Swift wrote that he was reading "I know not how many diverting Books of History and Travells"—and it showed (Williams 1963, 430). Houyhnhnms Land was a large island off the south coast of New Holland; the island of Lilliput was placed (oddly) northwest of Van Diemen's Land, which would place it firmly in the interior of Australia; Brobdingnag, "Discovered, AD 1703," was north of California (fig. 389) (Williams 1997, 72–75, 208–9).

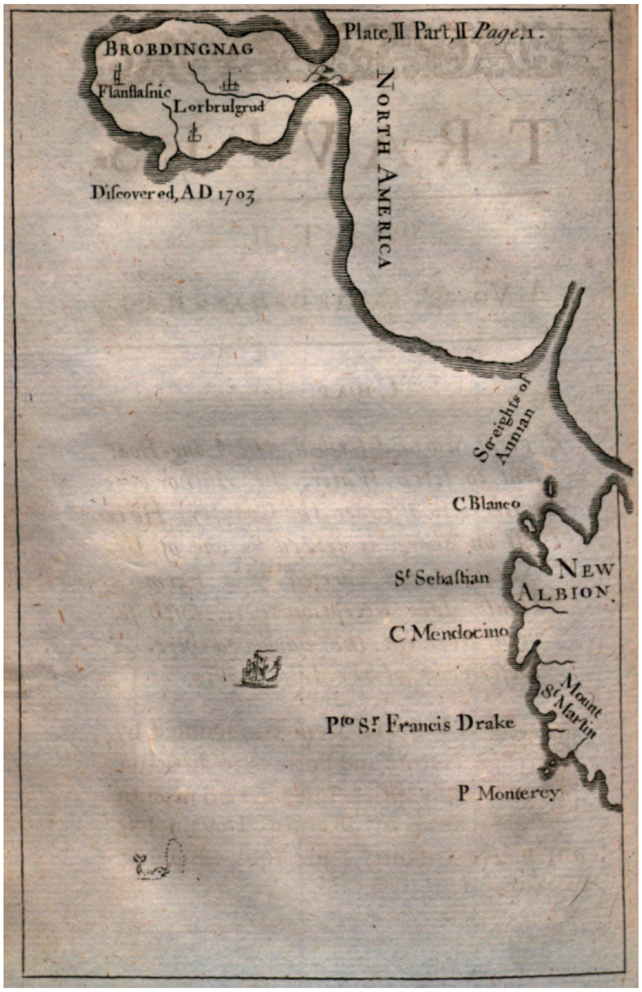

FIG. 389. BROBDINGNAG, IN JONATHAN SWIFT'S ACCOUNT OF GULLIVER'S TRAVELS, 1726. From Swift's *Travels into Several Remote Nations of the World*, 2 vols. (London: Printed for Benj. Motte, 1726), vol. 1, pt. 2, pl. II (before 149). The curious shape of Brobdingnag, "a great Island or Continent (for we knew not whether)" (1:153) was shown in the unexplored seas north of Drake's New Albion and the "Streights of Annian," which some geographers erroneously but hopefully thought might be the entrance of the Northwest Passage.

Size of the original: 15.5 × 10.2 cm. Image courtesy of the Department of Special Collections, Memorial Library, University of Wisconsin–Madison.

The utopian and satirical travels set in the Pacific tended to confirm common assumptions of the existence of unknown lands in far southern latitudes, but they were too outlandish to have much influence on the geographers of the day. Very different was the impact of apocryphal travels in North America, where at the beginning of the eighteenth century the rival empires of Spain, France, and Britain jostled for supremacy. Much of the excitement of those years was caught in *Nouveaux voyages* (1703) of Louis Armand de Lom d'Arce, baron de Lahontan. The book was a bestseller in several European languages, despite or perhaps because of its imaginary geography. Among Lahontan's creations was the Rivière Longue (Lewis 1998, 126–28, fig. 4.60), flowing into the Mississippi from a distant ridge of mountains to the west, while on the far side of those mountains another river whose banks were dotted with towns and cities ran into a salt lake a thousand miles in circumference (Adams 1962, 55–63; and see fig. 611). A close relative of these waterways was the Mer de l'Ouest of the eminent French geographer Guillaume Delisle, shown on the maps as a great inland sea stretching from California into the heart of the American continent (Lagarde 1989; and see fig. 202). The concept of the western inland sea obsessed French explorers in the first half of the eighteenth century (Mapp 2011, 147–65, 194-257; Belyea 1994). Related to it was a series of other reports: of a strait sighted by Juan de Fuca in 1592 on the Pacific coast in latitude between 47° and 48°N through which he passed into a great inland sea whose shores were "rich of gold, Silver, Pearle, and other things" (Purchas 1905–7, 14:417); of Cree reports of a light-skinned bearded people of advanced civilization who lived on the banks of the Rivière de l'Ouest; of vaguer Native American reports of salt water and white men over the horizon, where great ships sailed (La Vérendrye 1927) (see fig. 393). Such constructs distorted all attempts to represent the geography of the western half of the American continent, for they could not coexist with the unsuspected reality of a massive mountain range running parallel to the Pacific.

The most alluring of the reports of earlier voyages were those that promised a short sea route from Europe to Asia through or round North America. For the English in particular, shut off from more southerly routes, the Northwest Passage became a sort of holy grail, "the maritime Philosopher's Stone" as one enthusiast for its discovery explained (quoted in Williams 2002, 151). No episode in oceanic exploration offers a greater contrast between imagination and reality, between expectation and disillusionment; and in the repeated searches for a passage, the accounts of apocryphal voyages played a crucial role. The most influential of these was also the most improbable. In 1708 an account appeared in an English periodical of a voyage said to have been made in 1640 by a Spanish admiral, Bartholomew de Fonte, from Lima to the northwest coast of America. There, in latitude 53°N, he entered a series of waterways and at his easternmost point met a merchant vessel from Boston that had sailed west from Hudson Bay. There was no Spanish admiral named Fonte, and the whole concoction can be explained only by the fashion for imaginary voyages in the Britain of Swift and Defoe. Nevertheless, when the account was reprinted in the mid-eighteenth century, it was used to support British efforts to find a Northwest Passage, while in France it led to an outburst of speculative cartography. In 1747 Joseph-Nicolas Delisle, younger brother of the celebrated geographer Guillaume Delisle, returned home after more than twenty years in Russia, where he had helped to plan Vitus Bering's expeditions. In France he collaborated with Philippe Buache, *premier géographe du roi*, in presenting to the prestigious Académie royale des sciences a memoir and map that showed northwest America divided by the straits described in the Fonte account, while farther south Fuca's account was used to support the thesis of a gigantic Mer de l'ouest (fig. 390). The publication of the map and memoir in June 1752 launched a radically new interpretation of the geography of North America in a hubbub of publicity and controversy (Lagarde 1989; Williams 1997, 267–70). The new system split the world of French cartographic scholarship. Some cartographers of repute such as Jean Janvier, Louis Denis, and Roch-Joseph Julien were attracted by its plausibility; but Didier Robert de Vaugondy and Jacques-Nicolas Bellin, two of the best-known geographers outside the Delisle family circle, remained unconvinced.

On his voyage to the northwest coast of America to search for the Pacific entrance of the Northwest Passage, James Cook was brusquely dismissive of the Fonte and Fuca accounts, but in 1778 he was misled by a map as bizarre as any produced by the French cartographers whose work he scorned. *A Map of the New Northern Archipelago* (1774) was the work of Jacob von Stählin, secretary of the Saint Petersburg Akademiya nauk, and claimed to depict Russia's post-Bering voyages to the Alaskan coast. It showed Alaska not as a peninsula but as a large island (fig. 391). A wide strait between it and the American mainland well to the east of Bering Strait led into the Arctic Ocean, which, according to some contemporary scientists, would be ice free away from the coast. Cook hoped to sail through the strait, out into the Atlantic, and home. After months of frustrating exploration along the Alaskan coast, Cook found that Bering Strait provided the only way north, and once through that his ships were confronted by a great wall of ice. Of Stählin's strait there was no sign. Belief, based on the apocryphal accounts, in the existence of a navigable Northwest Passage persisted for almost another twenty years. In 1786 Jean-François de Lapérouse spent a month exploring the inlets and channels of a single Alaskan bay (Lituya Bay) before declaring that the Fonte account was a "ridiculous tale" (1994–95, 1:148). For the ambitious Spanish expedition under the command of Alejandro Malaspina, exploration of the Alaskan coast in search of a strait allegedly sailed through by Lorenzo Ferrer Maldonado in 1588 was an exercise in futility. A reader in the twenty-first century, Malaspina concluded, would be amazed to see how seriously the yarns of Fuca, Fonte, and Ferrer Maldonado had been taken in an age that called itself scientific and enlightened (Malaspina 2003, 477). Finally, George Vancouver in three seasons of strenuous, difficult survey work (1792–94) found no waterway navigable for shipping leading eastward from the Pacific coast. He noted wryly the appropriateness of the date on which his two ships sailed from England in 1791 "for the purpose of discovering a north-west passage, by following up the discoveries of De Fuca, De Fonte, and a numerous train of hypothetical navigators"—1 April, or All Fools' Day (Vancouver 1984, 4:1382).

There were apocryphal travels in other parts of the world. In 1720 Defoe's Captain Singleton marched westward from Madagascar across Africa in anticipation of European explorations of the nineteenth century. A little earlier George Psalmanazar passed himself off as

FIG. 390. PHILIPPE BUACHE, *CARTE DES NOUVELLES DÉCOUVERTES AU NORD DE LA MER DU SUD* (PARIS, 1752). Published in June 1752, Buache's was the first printed map to comprehensively show the alleged discoveries of Bartholomew de Fonte in 1640 and to link them to recent Russian explorations, as presented to the Académie des sciences by Joseph-Nicolas Delisle in 1750. The huge Mer ou Baye de l'Ouest was based on the work of Buache's father-in-law, Guillaume Delisle, and is shown here with the entrances thought to have been discovered by Juan de Fuca in 1592 and Martín d'Aguilar in 1603.

Size of the original: 45 × 64 cm. Image courtesy of the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland (OS-1752-10).

a Formosan and wrote the far-fetched *An Historical and Geographical Description of Formosa* in 1704, which included a totally imaginary Formosan language. The boundary between fact and fiction was often blurred. In 1767 the Royal Society accepted and printed a letter from a young midshipman describing the monstrous "giants" of Patagonia he claimed to have seen on John Byron's discovery voyage of 1766–68 (Adams 1962, 34). There was even a final ripple of interest in the Welsh prince Madoc and the descendants of his supposed voyage to America in 1170, and not until explorations along the upper Missouri in 1795–96 could the young Welshman John Thomas Evans report sadly to his sponsors in Wales that "there is no such People as the Welsh Indians" (quoted in Williams 1979, 183). By the end of the eighteenth century, explorers were moved by an insistent determination to show things as they were, to dispel myth and illusion. At sea the chronometer revolutionized navigation, while on land the travels of Alexander von Humboldt provided a model of empirical, scientific observation. There was more precision and less imagination about the maps now. The role of speculative cartographers in stimulating interest in remote regions was buried beneath complaints about their uncritical methods and lack of practical experience. As Louis-Antoine de Bougainville insisted, geography was now a science of facts (1771, 183).

GLYNDWR WILLIAMS

SEE ALSO: California as an Island; Defoe, Daniel; Geographical Mapping; Geography and Cartography; Northwest Passage; Sea of the West; Southern Continent

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FIG. 391. JACOB VON STÄHLIN, *A MAP OF THE NEW NORTHERN ARCHIPELAGO*, 1774. From Stählin's *An Account of the New Northern Archipelago, Lately Discovered by the Russians in the Seas of Kamtschatka and Anadir* (London: Printed for C. Heydinger, 1774). The tracks of Semën Ivanovich Dezhnëv (1648), Vitus Bering (1728), and Ivan Sindt (1764–68) are marked. None approaches the wide strait shown lying between Alaschka Island (Alaska) and North America.
Size of the original: 20.2 × 26.9 cm. Image courtesy of the John Carter Brown Library at Brown University, Providence.

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Indigenous Peoples and European Cartography.

The role of cartography and the process of mapping and mapmaking in traditional societies is the focus of volumes in *The History of Cartography* series, especially volume 2.3, *Cartography in the Traditional African, American, Arctic, Australian, and Pacific Societies* (1998). The present essay concerns the cartographic interaction between indigenous peoples and Europeans during the long eighteenth century, a period in which Europeans moved further into the interior of territories that had for the most part been explored during earlier periods, primarily in the Americas, Africa, and Asia, and also in the islands encountered throughout the Pacific Ocean. Europeans were in contact with diverse native peoples, many of whom were unknown to those arriving for the first time. As colonization moved inland, contact increased between Europeans and autochthonous populations, who in turn provided considerable information about local geography that would become indispensable for Europeans as they moved deeper into these territories. But natives did not serve merely as informants. In the spirit of the Enlightenment, European savants engaging in nascent ethnographies also transformed these peoples into objects of study, and cartography came to be one of the frameworks in which information about them was registered and codified. Such ethnographic information appeared not only in the maps themselves, but also in the legends, keys, and marginal illustrations on maps. As Jeremy Black has written, “The mapping that was carried out by Europeans was, in part, dependent on native contributions. This took a variety of forms, including not only the provision of information, but also that of personnel. The willingness of European mapmakers to draw on multiple sources for maps was important to this process, but so was their desperate need for information” (Black 2003, 66–67). When considering the relationship between cartography and native populations of the new worlds, three different interpretive approaches emerge. The first consists of compiling an inventory of the maps produced by indigenous peoples themselves. The second investigates the way in which indigenous maps or indigenous informants served as sources of information for European cartographic knowledge. The third examines how European cartography represented these populations.

AN INVENTORY OF INDIGENOUS MAPPING Although it is known that Europeans appropriated maps produced by native peoples, tracing these sources is very difficult (Mapp 2011; Dawson 2000). Despite the fact that this process occurred and that indigenous peoples delivered information on local geography and their *habitats*, few of these documents have survived, largely because of their ephemeral materiality—they were frequently drawn in the sand, on cloth, or on the skin of animals. Christian Jacob calls these documents ephemeral maps (*cartes éphémères*), since aside from the nature of the materials used to construct them—like sand, dirt, or even ash—they reveal the essence of a cartography “whose rudimentary trace, without the resources of mimesis and without ornaments, is reduced to its instrumental expression.” The ephemeral map, according to Jacob, is the result of the dialog possible between the native who knows the territory and the “foreigner, ignorant of the path to follow,” who does not share the same linguistic code (Jacob 1992, 57; Safier 2009, 171–72).

Nonetheless, some examples of cartographic exchange can be traced. Francis Nicholson, the governor of South Carolina in the early eighteenth century, copied two indigenous maps of the lower Mississippi region made on animal skins, in color, one by the Catawba around 1721 and the other by the Chickasaw (Lewis 1998a, 22; Galloway 1998, 225–26). The map of the Hudson Bay region of 1760 compiled by Moses Norton includes a note indicating that the shape of the northern part of the bay was based on information provided by natives (Lewis 1998b, 137, figs. 47.1, 47.2). James Cook depended on the Māori to gather information about New Zealand on his 1769 visit with the *Endeavour*. After the native chief Tupaia had drawn a map of the northern coast of the island on the ship’s deck, Cook took a piece of paper and copied the drawing (Withers 2007, 106; Barton 1998, 500–501). On his 1787 expedition to the inhospitable and savage extreme eastern frontier of Russia, Jean-François de Lapérouse sought information from the Ainu population about Sakhalin, which he supposed to be a peninsula. According to Lapérouse’s diary, one of the Ainu drew a map in the sandy soil indicating an island, which determined the subsequent cartographic representation of the region (Latour 1987, 215–19; Okladnikova 1998, 338; Withers 2007, 98).

Samuel Hearne of the Hudson’s Bay Company likewise explored the arctic and subarctic regions of Canada in 1770, inspired by a map of the region made two years earlier by the Chippewa (Lewis 1998a, 23; and see fig. 380). In Brazil, indigenous peoples played an essential role in the conquest of the interior by helping the Portuguese understand the intricate network of rivers and tributaries that cut through these regions, especially in Amazonia and the regions of Mato Grosso and Goiás in the center-west of the continent (Holanda 1990, 1994). At the end of the seventeenth century, this

FIG. 392. DETAIL FROM THE "CARTE GENERALE DE LA CHINE," BY JEAN-BAPTISTE BOURGUIGNON D'ANVILLE, 1730. Manuscript. The "Explications" describe the sounds and meaning of Chinese place-names on the map. Longitudes are indicated from both Ferro and Beijing.

Size of the entire original: 40 × 50 cm; size of detail: ca. 17 × 30 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et Plans Ge D 10588).

knowledge encouraged the Portuguese to abandon the representation of Brazil as an island, separated from Spanish lands by a series of rivers that met to form a golden lake, Xaraies (Xarayes) (Holanda 1986, 92–93). Instead, they began to identify the hydrography of the region as a *pantanal*, or swamp, a term that referred to the cyclical phenomenon of flooding caused by the Paraguay River (Costa 1999).

EUROPEAN USE OF INDIGENOUS MAPS While finding original maps produced by native peoples can be difficult, tracing native contributions to the formation of European geography proves much easier. Natives were important informants and guides for Europeans in a variety of contexts—exploration, administration, and religious proselytization—as numerous examples demonstrate. Native assistance in the cartographic production of the Jesuits provides one global example. The Jesuits established missions in various places throughout the world under the aegis of the Catholic monarchies. From China to the Americas, their relations with native peoples were fundamental in constructing a cartographic view of the world and its indigenous inhabitants. The *Lettres édifiantes et curieuses* (34 vols., 1702–76), which gathered accounts of Jesuit missionaries from the four corners of the globe, were accompanied by maps that incorporated indigenous information. Jesuits sponsored the *Nouvel atlas de la Chine* (1737), compiled by Jean-Baptiste Bourguignon d'Anville from the survey of China ordered by the emperor in 1708, which in turn was realized by local authorities under the supervision of Jesuit priests (Cams 2014) (fig. 392).

In Africa, Europeans rapidly discovered that "in order to survive there, it was necessary to interact with, and often appropriate knowledge from, African people," especially geographic knowledge indispensable for the penetration of the interior (Santos 2010, 543). In his map of Africa (1727), d'Anville included small notes referring to information acquired by Europeans in contact with the natives for regions not yet explored by colonizing nations. D'Anville granted authoritative status to these indigenous reports and attributed an advanced understanding of geography to some of the peoples. The merchants of Zambézia, for example, "did not tire of carrying their astrolabes to measure the sun and charts to mark altitudes" (quoted in Santos 1988, 121). Many of the indigenous sources of d'Anville's information came via the Portuguese ambassador to France, Luís da Cunha, representing the long-standing Portuguese presence on the continent and mapping of the coastlines. D'Anville also drew on published Jesuit documents, travel books, manuscript memoirs, and additional Portuguese maps, all of which may have made use of indigenous information (Furtado 2012, 147–210). Numa Broc describes the case of French and British explorers relying on native information concerning distances in the area of Guinea and the locations of the Senegal and Niger Rivers in the later eighteenth century (Broc 1975, 76, 341, 343). Greater use of indigenous information was made in the nineteenth century, when Europeans penetrated more deeply into the continent (Bassett 1998).

But as Barbara Belyea has made clear in the Amerindian context, indigenous geographical knowledge was not easily translated into the vocabulary of European mapmakers, who did not always understand the character of the description or the graphic signs or the purpose of traditional mappings (Belyea 1998, 135; Mapp 2011, 194–232). She points out that "native maps have surprisingly constant characteristics. . . . highly stylized, highly standardized geographical indicators. . . . their network of lines is unframed, hence independent of a spatial grid or ground" (Belyea 1998, 141–42). Thus, notions of direction, distance, scale, and time were expressed in ways completely alien to European thinking; topographical features such as hills, mountains, valleys, plains, rivers, and lakes were described with vocabulary that did not have counterparts in European languages (Mapp 2011, 223–28). In North America, Louis De Vorsey viewed the lack of distinction between rivers and roads on maps produced by Europeans in the eighteenth century to be unequivocal evidence of the influence of indigenous cartography (De Vorsey, cited in Cumming 1998, 109). The "Cours des rivieres" (after 1730) illustrates information from Ochagac and his fellow Cree of the river connection between Lake Superior and Lake Winnipeg that French geographers would convert into a river extending across the North America continent (Lewis 1998b, 71n77, 144–45) (fig. 393). The expedition of Meriwether Lewis and William Clark in the early nineteenth century, essential to the western colonization of North America, created a map on which the representation of distance distinguished between the spatial vision of natives and that of Europeans and the difficulties of this dialog. In their diaries, the explorers noted the information provided by natives, especially Sacagawea, the Minnetare woman who accompanied the expedition: 22 July 1805, "the Indian woman recognizes the country and assures us that this is the river [Missouri] on which her relations live, and that the three forks are at no great distance," and 8 August, "the Indian woman recognized the point of a high plain . . . which she informed us was not very distant from the summer retreat of her nation on a river beyond the mountains which runs to the west" (Lewis and Clark 1989, 199–200, 218). The translation of indigenous distance and scale into European cartography was more problematic, however. As d'Anville wrote in the justification for his *Amérique méridionale* (1748), despite the fact that a South American Creole named Pedro Vicente Maldonado informed him that "Indians apply proper diligence to their routes," d'Anville himself found that in some calculations they appear "to go beyond verisimilitude," demonstrating that European geographic logic often trumped first-person reported experience on the part of native peoples (d'Anville 1750, 215). Likewise, when traveling in South America, Alexander von Humboldt's confidence in native geographical knowledge was limited, and he was often far more ready to accept European testimony for questionable geographic information than he was certain indigenous informants (Safier 2009, 183).

Even as Europeans incorporated the geographic information provided by indigenous peoples and consolidated it into a European framework, at the same time indigenes adopted an increasingly Western approach to mapping and describing their own territory. The difficulties of translating native understanding into European knowledge during the long process of colonization of these continents in the eighteenth century resulted, in various locations, in the formation of a generation of mixed-race natives who became mediators between the indigenes and Europeans, allowing for a common idiom, indispensable for the production of geographic knowledge that could be appropriated by Europeans. Such was the case in Brazil, where mixed-race people of Portuguese and indigenous heritage carried out the great exploratory expeditions in the west that sought both to imprison natives for slave labor and also to search for precious metals. As heirs of a hybrid Indian-European tradition, these mixed-race people, known as *paulistas*, learned indigenous techniques for penetrating the wilderness, incorporating the geographic knowledge that natives had at their disposal, and taking advantage of the trails natives had established leading to the interior. And yet, they eventually produced documents that would be used by more traditional European cartographic practitioners. Another example of this consolidation of knowledge incorporating indigenous sources took place in the second half of the eighteenth century under the auspices of Sebastião José de Carvalho e Melo, marquês de Pombal, the first minister of Portugal. A generation of "young Luso-Africans, whites and mulattoes, born in Angola," was trained in the Aula de Geometria de Luanda, which taught the most up to date European methods of mapmaking. This group, known as the Geração de 60, or the sixties generation, was fundamental to the modernization of the administration of the region, uniting traditions of native geography and European practices (Santos 2010, 547–48).

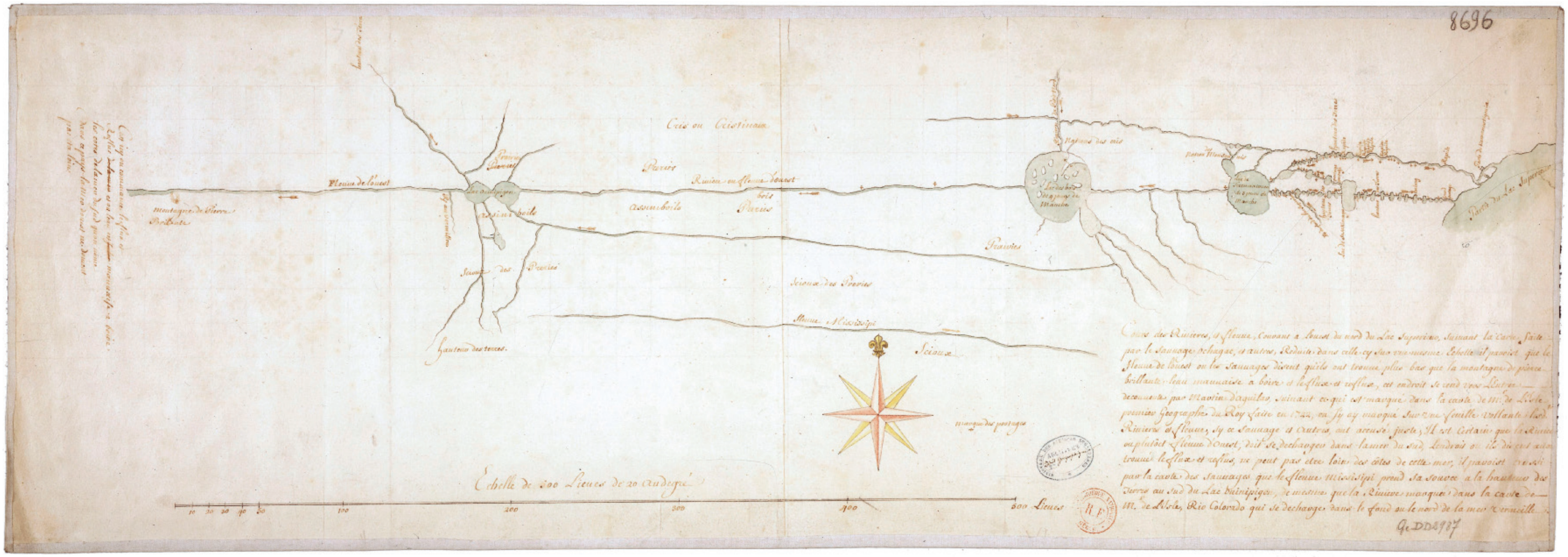

FIG. 393. "COURS DES RIVIERES, ET FLEUUE, COURANT A L'OUEST DU NORD DU LAC SUPERIEUR, SUIUANT LA CARTE FAITE PAR LE SAUUAGE OCHAGAC ET AUTRES," AFTER 1730. This map from d'Anville's collection bears a note explaining that the original work came from Cree Indian reports. These had been transmitted to French authorities by the fur trader Pierre Gaultier de Varennes de La Vérendrye. Manuscript, ca. 1:5,000,000 (500 lieues de 20 au degré [= 54.7 cm]).
Size of the original: 33.5 × 100.0 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans Ge DD-2987 [8696 B]).

EUROPEAN MAPPING OF INDIGENOUS PEOPLES

Indigenous peoples were not merely informants for European cartography; they were frequently the subject of a cartography that sought to represent their organization and distribution throughout the globe. Although such maps were efficient instruments for providing visibility to ethnographic information gathered by European explorers, they also demonstrated the concrete limits on the reliability of this information. In the first place, this thematic cartography created fixed locations to represent peoples who, in most cases, were nomadic. This difficulty in recording the nomadic character of any group can be observed in several maps. In the *Carte de la Nouvelle France, où se voit le cours des grandes rivières de S. Laurens & de Mississipi aujour d'hui S. Louis* (171–), for example, the compiler records the presence of "nomadic peoples" (*pays des quelamiloueches peuples errans*) west of the Mississippi delta. Jacques-Nicolas Bellin's *Carte du Bresil* (1764), based on a map by d'Anville, leaves the interior of northeastern Brazil blank, with the inscription: "The interior of the country is unknown and the nomadic nations that inhabit it are named Tupayas."

The representation of indigenous groups was transformed by a cartographic method that emphasized fixed position rather than movement, resulting in many examples of indigenous peoples shown as fixed entities in a specific territory. In *Mœurs des sauvages ameriquains, comparées aux mœurs des premiers temps* (1724), Joseph-François Lafitau included a map of the North and South American continents, noting in the map's legend the name and location of the principal native peoples, which in turn helped the reader who may have been unfamiliar with American geography to visualize their locations (Withers 2007, 18). Herman Moll's *A New and Exact Map of the Dominions of the King of Great Britain on ye Continent of North America* (1715), commonly known as the "Beaver map," shows the location of indigenous tribes from Newfoundland to Carolina, like the Iroquois of Virginia, "hearty friends to ye English." This sort of strategic information allowed the map to call the attention of the English Crown to the opportunities available for colonizing the region. Delisle's *L'Amerique meridionale* (1700) also presented several groups of native peoples: tribes included the Tupinambá or Tupí in Brazil; the Omagua in the Amazon; the Paraguaio in Paraguay; and the Chaquese in Bolivia, among others. Nelson-Martin Dawson speculates that Delisle included and excluded indigenous groups on his 1703 printed map of Canada based on their existence or extinction (Dawson 2000, 173–78).

Printed European maps of Africa in the eighteenth century also presented the interior, little explored at this point, as largely blank space, despite the omnipresence of a diverse range of local populations. The majority of cartographic representations of Africa reproduced preexisting models or depended upon information provided by natives along the coast, particularly in the context of the slave trade. Paolo Petrini's large four-sheet wall map of Africa (ca. 1700) based largely on seventeenth-century material, by Nicolas Sanson and Nicolas de Fer in particular, served as a schematic model hardly altered throughout the century in commercial European cartography (fig. 394). Petrini's map divided the continent into kingdoms, with a few ethnographic observations written on the map itself, such as the note referring to the people of Guinea as "bad people." On his 1700 map of Africa, Delisle changed the longitudinal dimensions of the continent, based on more recent astronomical observations, but continued the use of textual ethnographic descriptions in the map's interior (see fig. 289). D'Anville's 1749 map of Africa eliminated much of that text, leaving the interior largely empty (Stone 1995, 23–46). These two models were followed by map publishers until significant exploration by the British, under the aegis of the African Association (founded 1788 by James Rennell and Joseph Banks), promoted systematic exploration as part of the Association's antislavery goals (Broc 1975, 343).

As for the representation of the native inhabitants of Oceania, in 1778 Johann Reinhold Forster drew a map representing various islands of the South Pacific and above the name of each island he inserted the names of indigenous groups (Withers 2007, 100–101). The author affirms in the map's title that this information was received "according to the Notions of the Inhabitants of o-Taheitee and the Neighbouring Isles, chiefly collected from the accounts of Tupaya [i.e., Tupaia]" (Finney 1998, 446–51).

Another type of thematic map, a population map, presents indigenous populations in pictorial form. The population map was a kind of a census that showed the people living in a given space—a city, a county, or a captaincy—and noting whether they were black, white, free, slave, or Indians. Following J. B. Harley and David Woodward's definition of maps as "graphic representations that facilitate a spatial understanding of things, concepts, conditions, processes, or events in the human world" (Harley and Woodward 1987, xvi), population maps functioned as "an instance of cartography as inventory. . . . in an appealing graphic format" (Safier 2009, 159).

During the sixteenth century, the unknown interior of new worlds was often painted over with mythological images of savages; Indians, mostly cannibals; and animals, like parrots, elephants, and other exotic species. For the most part, in eighteenth-century printed maps, iconic images of natives, such as the tribes at war found on the map of South America in Sebastián Fernández

L'AFRICA, DIVISA SECONDO L'ESTENZIONE DELLE SVE PRINCIPALI PARTI
DOVE I REGNI, E GLI STATI, SONO POSTI AL LVOCO LORO, CON TVTTE LE OSSERVAZIONI DE' SIG.RI DELL'ACCADEMIA REALE DELLE SCIENZE DEL RE CR.MO IN PARIGI
Composta da N. DE FER Geografo del SER.MO DELFINO DI FRANCIA.

FIG. 395. DETAIL FROM THE "MAPPA DA COMARCA DO SABARA," BY JOSÉ JOAQUIM DA ROCHA, 1778. A Portuguese military engineer, Rocha learned his mapping techniques at the Aula Régia de Arquitetura Militar before going to Brazil some time between 1763 and 1768.

Size of the entire original: 74.0 × 50.5 cm; size of detail: ca. 18.5 × 21.5 cm. Image courtesy of the Arquivo Público Mineiro, Belo Horizonte (SC-005).

de Medrano's *Breve tratado de geografía* (1700), were disappearing, along with other pictorial images placed within the map itself. Yet in many cases, illuminated drawings in the margins of the map provided more detailed information about the ethnographic nature of a region, as seen in the border illustrations of Petrini's map of Africa, which describe the diverse peoples who inhabited the continent. In other maps, such images contain a more powerful, if elusive message. A Luso-Brazilian manuscript map by José Joaquim da Rocha titled "Mappa da comarca do Sabara" (1778) contains a vignette with a fierce native, partly hidden behind a tree, pointing his bow and arrow at a mapmaker who appears entirely oblivious to his native observer (fig. 395). Identifiable as a military engineer by his garb, the cartographer is totally absorbed in his task, a com-

(*facing page*)
FIG. 394. PAOLO PETRINI, *L'AFRICA, DIVISA SECONDO L'ESTENZIONE DELLE SVE PRINCIPALI PARTI* (NAPLES, CA. 1700).

Size of the original: 91 × 116 cm. Image courtesy of the Barry MacLean Collection, Green Oaks.

pass his sole instrument. Instead of fear pervading the scene of confrontation between the unarmed cartographer and the armed native whose land is being mapped and thus appropriated, the eighteenth-century beholder might have seen the victory of a higher civilization over a primitive and uncivilized one or even the domination of an enlightened scientific culture over the indigenous Brazilian. A more recent interpretation suggests reading this representation as a standoff between the two cultures over the all-important issue of control of the land (Furtado 2011, 114–19).

Another difficulty encountered in the representation of indigenous peoples on maps was a linguistic diversity not always perceived or understood by Europeans. The expression of place-names in a variety of local languages often complicated the reproduction of these locations on maps. Indigenous names were frequently corrupted by Jesuits and explorers and then by geographers based in Europe. According to d'Anville, geographers should "know, of the dominant nations, the proper terms that designate the nature of places, rivers, mountains, islands, etc." (d'Anville 1777, 81) so that the nomenclature on maps might be reliable. He proposed rigid rules for place-names, advocating respect for older orthographies even when changes to names had been made later. He carefully transcribed indigenous place-names on his *Amérique méridionale* (1748), and even advocated particular methods of pronunciation: "to best read or pronounce Indian names, it should be advised that all final 'é's are closed." Despite his care, however, some nuances of local languages escaped him (Furtado 2012, 364–69). These errors did not go unnoticed by contemporaries. Regarding d'Anville's *Amérique méridionale*, the Portuguese pedagogue António Nunes Ribeiro Sanches warned that "many names of rivers and places that appear in the Treaty [of San Ildefonso] cannot be found on Mr. d'Anville's map, either because they are written in a foreign language or because this geographer was not familiar with them" (quoted in Kantor 2009, 44, 47).

Disagreements among Europeans over lands to be colonized were also replicated in intertribal arguments in which diverse tribes took opposing sides in order to benefit from rivalries among the colonizers. This type of information frequently appeared in cartography, such as on *L'Amerique meridionale* (1700) by Delisle, which noted that the people who inhabited the valley of the Paranaíba River in the Amazon were allies of the Portuguese. On the same map, Delisle also noted which nations were enemies and friends of the Spanish and which had been exterminated by the French. Even the cartography produced by the Amerindians themselves revealed similar arguments. A map produced by the Chickasaw in 1737 and copied by the French engineer Alexandre de Batz with the title "Nations amies et ennemies des Tchikachas" showed the alliances and disagreements between the various tribes inhabiting the modern region of Alabama in the United States (Waselkov 1998, 208–9; Lewis 1998b, 101–3). The "Plano corografico é hidrographico, delas provincias deel Nuevo Mexico" by Francisco Álvarez Barreiro (ca. 1728, now in the Hispanic Society of America, New York), produced in the context of disputes between France and Spain over the region of Texas and New Mexico, provided details about local indigenous tribes considered important for Spain in the context of the territorial dispute between the two nations (Codding 2018, 250–52). Further to the north the *Carte de la Nouvelle France, où se voit le cours des grandes rivières du S. Laurens & de Mississipi aujour d'hui S Louis* (171–), produced by the Compagnie de la Louisiane for the purpose of controlling the territory and monopolizing the tobacco industry in the region, displayed knowledge about indigenous populations according to the interests of the French. Similarly, the cartouche of the "Mapa de una parte del rio Yapvrá: comprehendida desde la boca del rio Apaporis hasta el Salto Grande, ò cachoeira de Vuia" (1788), surveyed by the military engineer Francisco Requena, commander of the Spanish party of the joint Spanish-Portuguese boundary commission to survey the Amazon Basin resulting from the Treaty of San Ildefonso (1777), demonstrated the attention paid by Iberian cartographers to indigenous economic activities that might concern Europeans, displaying native abilities for hunting and agriculture.

A hierarchical ethnographic view of the world that placed Europeans at the top of the pyramid is reflected in the way that maps represented native peoples, maps that were frequently accompanied by observations about their characteristics or customs. The *Carte nouvelle de la mer du Sud* by Andries de Leth and Hendrik de Leth (1720) included the observation that the people inhabiting Benin and the Guinea Coast were black, walked naked, and ate raw meat and drank palm wine. The Indians of Mexico, for their part, were worthy of an illustration that portrayed their manner of dress, mining technology, and religious customs, which included human sacrifice. The printed *Le Bresil*, by Pieter van der Aa (1714), includes a comment about the Tapuia who lived in northern Brazil and their linguistic and cultural diversity. D'Anville's *Carte de la Guïane françoise ou du gouvernement de Caïenne* (1729, manuscript and print), pointed out the Armaboutous people who lived in the interior and had "large ears hanging down over their shoulders and many holes in their face."

Nevertheless, a great transformation in the representation of indigenous peoples emerged in Luso-Brazilian cartography during the second half of the eighteenth century. The 1750 Treaty of Madrid, which redefined the border between the Crowns of Portugal and Spain in America, was based on the idea of *uti possidetis*, supporting the rights of possession of the territories that had been colonized. In 1755, under the aegis of the marquês de Pombal during the reign of José I, the Pombaline Reforms eliminated the jurisdiction of the Jesuits over the indigenous missions. From that point on, native people were considered subject to the Portuguese Empire. They were represented as such in the cartography of the period and no longer simply by the scattering of names of indigenous tribes across the interior. In this way, Portugal constructed South America's cartographic image to justify its own dominion over the territory, claiming that these areas were inhabited by Portuguese subjects, even though those lands had previously been considered uninhabited. This strategy was very common in the frontier territories between the two Crowns in America, such as in the captaincies of Mato Grosso, Goiás, and the Amazon. Furthermore, this strategy was used to justify the demarcation of the interior borders of the Portuguese captaincies themselves. This is evident in the "Mappa da capitania de Minas Geraes" (1778) made by Rocha. This map respected several conventions and sought to make a uniform geographical representation. Urban centers are represented using more or less complex symbols and include less populated settlements, which were placed in the hierarchy with other inhabited places. According to this concept, the indigenous tribes—the Maxacalis, the Monaxós, and the Capoxes—are called Indian villages (*aldeias de gentio*) and are represented only by an agglomeration of red dots; chapels are represented by a red circle over a cross; parishes by a square around a red circle with a cross; villages by a small church with a side tower; and cities by a larger church with a center tower, with both villages and cities also including a small red center circle. By inserting fixed indigenous settlements into a hierarchy of urban centers in Minas Gerais, the cartographer represented the territory that belonged to the captaincy and justified the annexation of outlying indigenous settlements into the jurisdiction of local political authorities, according to the norms of the Pombaline Reforms.

To understand the complex relationship between indigenous populations and both the small-scale printed cartography by European map publishers and the larger-scale manuscript cartography of military engineers, explorers, and religious orders, three things must be considered. First, indigenous peoples in all parts of the globe invested in a wide variety of mapping activities that used various, often ephemeral, media. The results of their mapping efforts were often recognized and translated by European mapmakers into the idiomatic conventions of the European map, usually drawn or printed on paper and exhibiting those features that were becoming standard in Europe—scale, orientation, and grid of latitude and longitude. Second, indigenous populations also informed European mapmaking orally; their verbal accounts, when understood, offered geographic and ethnographic information to Europeans. These graphic and verbal "translations" were neither perfect nor did they always do justice to the information held by the indigenes. Finally, indigenous populations were themselves the subject of geographical inquiry and of the mapmaker's attention. Because many indigenous populations were nomadic, their fixed locations, preferred by the European idiom, were often fictive from the moment the ink dried. In spite of these errors and losses, indigenous peoples played a significant role in the creation of European maps of their lands that served European interests and purposes throughout the eighteenth century.

JÚNIA FERREIRA FURTADO AND NEIL SAFIER

SEE ALSO: Anville, Jean-Baptiste Bourguignon d'; Economy, Cartography and the; Enlightenment, Cartography and the; Geographical Mapping; Hudson's Bay Company (Great Britain); Society of Jesus (Rome); Thematic Mapping

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Instruments, Astronomical. The primary astronomical instruments associated with Enlightenment cartography, and especially geodetic surveying, were the telescope, quadrant, zenith sector, and the transit and equal-altitude instruments, described in turn below. Constant efforts by astronomers and instrumentmakers led to a steady increase in the precision of the large fixed instruments used in observatories, from one minute of arc (1′) in 1660 to just half a second of arc (0.5″) in 1800 (Chapman 1983, 135; 1995); field instruments were similarly improved, but their smaller size meant that they could not be so precise.

Improvements began with the telescopes that were fitted to quality astronomical instruments after 1650. The original refracting telescope invented in the Netherlands in 1608 used a lens to gather and focus the light; it suffered from chromatic aberration, as there was inevitably a slight variation in how the objective lens refracted different parts of the spectrum. Three strategies were pursued to correct for the problem. First, chromatic aberration could be reduced by lengthening the telescope’s focal length. The four very long telescopes at the Paris Observatory, with lenses made in Rome by Giuseppe Campani, were between twenty-six and fifty-two meters in length and required complex pulley systems to be hoisted into position, as described and illustrated in Francesco Bianchini, *Hesperi et phosphori nova phaenomena* (1728). Yet such large and unwieldy telescopes were quite unsuitable for attachment to a graduated circle to measure angles. Second, opticians developed achromatic lenses that eliminated aberration and increased the telescope’s power; that perfected by John Dollond in London in the 1750s composited flint and crown glasses. Third, new designs were proposed, and first implemented by Isaac Newton in 1668, that used parabolic mirrors to focus the light; such reflecting telescopes came into widespread use only in the mid-eighteenth century and would be used in the field for observations of eclipses of Jupiter’s satellites in the determination of longitude (King 1955).

Since antiquity astronomers have used the quadrant—a graduated quarter circle equipped with sights—to measure the altitude of the stars and sun as they transit the observer’s meridian. Large mural quadrants, so named because they were mounted on walls aligned along the meridian, permitted greater precision in their gradations, and their long telescope reduced chromatic aberration. For example, John Flamsteed first equipped the Greenwich Observatory in 1676 with a 10-foot (3 m) radius quadrant (see fig. 343), which would be replaced by a series of later instruments, including the two 8-foot (2.4 m) radius mural quadrants made by George Graham and John Bird and installed, respectively, by Edmond Halley in 1725 and James Bradley in 1750 (Bennett 1987, 114–16). In the field, portable altazimuth quadrants were mounted on pillars so that they could be positioned vertically to measure altitudes, horizontally to measure azimuths, and at any orientation between to measure other angles; this instrument was especially favored by French geodesists for angle measurement, beginning in 1669 with Jean Picard’s onemeter-radius instrument (Bennett 1987, 119–23) (see fig. 265).

Picard also introduced a new, specialized instrument, the zenith sector, for determining latitude (fig. 396). This instrument comprised a vertically mounted refracting telescope, 10 pieds (3.25 m) long, with an attached 20° arc, graduated to 1′, set up so that the telescope and arc swung in the meridian (Picard 1671, 21). The observer moved the telescope to sight a star as it transited the meridian close to the zenith and, using the plumb line against the graduated arc, observed the angular distance (zenith distance) from zenith to star. The zenith sector had two benefits: first, at the zenith, atmospheric refraction is zero, thereby eliminating this still uncertain cause of error that otherwise plagued astronomers; second, latitude is readily calculated, as the star's declination plus the zenith distance. Starting in the 1720s, British astronomers used wall-mounted zenith sectors with much longer telescopes, in the order of 24–36 feet (7.3–11.0 m), to study the fine apparent motion (parallax) of stars (Bennett 1987, 118–19). Their refinements to the instrument were applied to the portable zenith sectors made for geodetic surveys (see fig. 435). Zenith sectors were also put to other uses: Charles Mason and Jeremiah Dixon used a 6-foot (1.8 m) zenith sector by Bird to trace a parallel of constant latitude as the boundary between Maryland and Pennsylvania in 1763–67 (Reeves 2009, 330); Nevil Maskelyne used a 10-foot (3.0 m) sector, with a refined mounting for the plumb line, in order to measure the deviation of the plumb line caused by the gravitational attraction of mountains, at Schiehallion in Scotland in the 1770s (Reeves 2009).

The transit, as originally created and installed by Ole Rømer in the Paris Observatory in 1675, was simply a long refracting telescope mounted on a horizontal axis so that it could move up and down in the plane of the meridian. The transit became a standard item of equipment in eighteenth-century observatories as, by timing with a pendulum clock the precise moment when a star transits the meridian, astronomers could determine the star's right ascension (Bennett 1987, 117–18).

An equal-altitude instrument, first described by Pierre-Charles Le Monnier (1741, lxxvi–lxxxiv), is a small, portable transit equipped with a graduated vertical half-circle, as well as a reticle with not one but three equally spaced vertical wires (fig. 397). The multiple cross hairs permitted stars, or the sun, to be observed and their transits timed at consistent intervals, and at equal altitudes, to both east and west of the meridian. If a star's right ascension was known, then these double observations permitted local time to be determined more reliably in order to regulate a pendulum clock for use in other tasks, such as timing the eclipses of Jupiter's moons. An implicit part of setting up the instrument—by adjusting it so that the

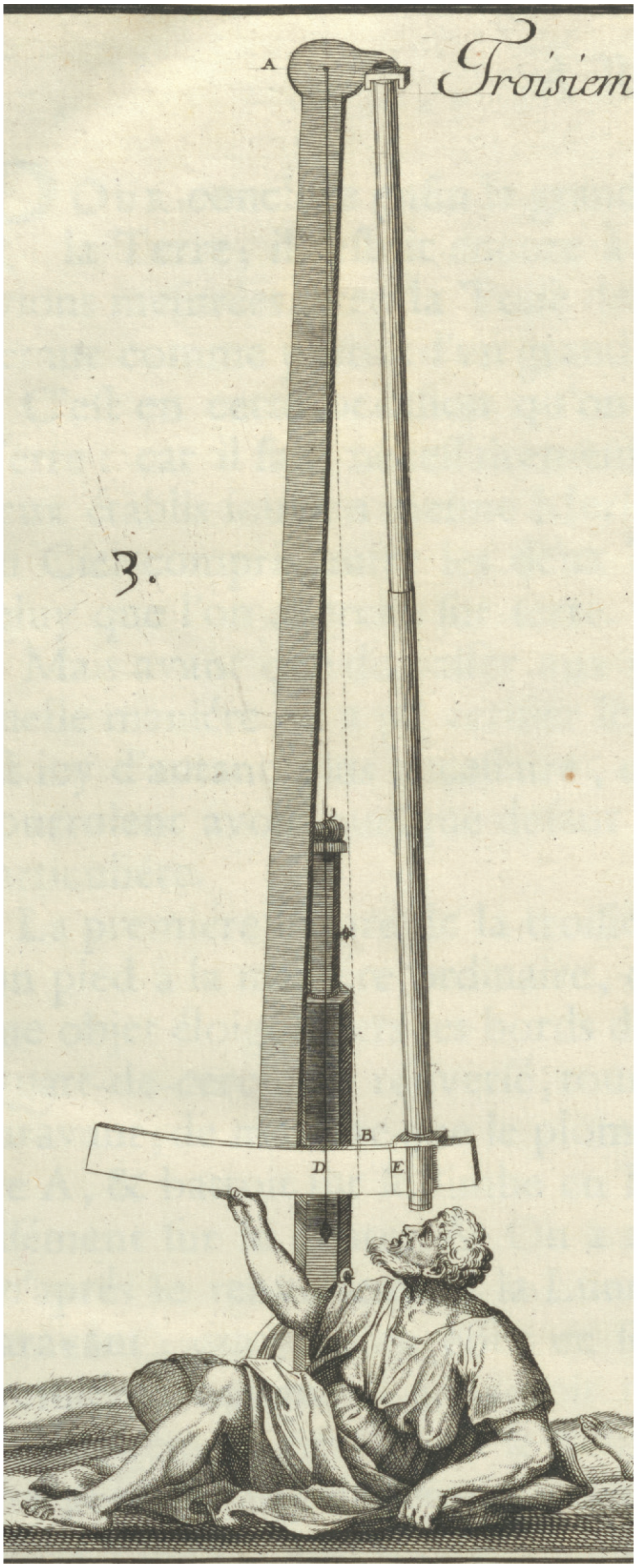

FIG. 396. JEAN PICARD'S ZENITH SECTOR, 1671. The telescope was 10 pieds (3.25 m) long. The orientation of the instrument required the observer to lie on the ground. Detail from Picard 1671, fig. 3 on pl. 3.
Image courtesy of the Division of Rare and Manuscript Collections, Cornell University Library, Ithaca.

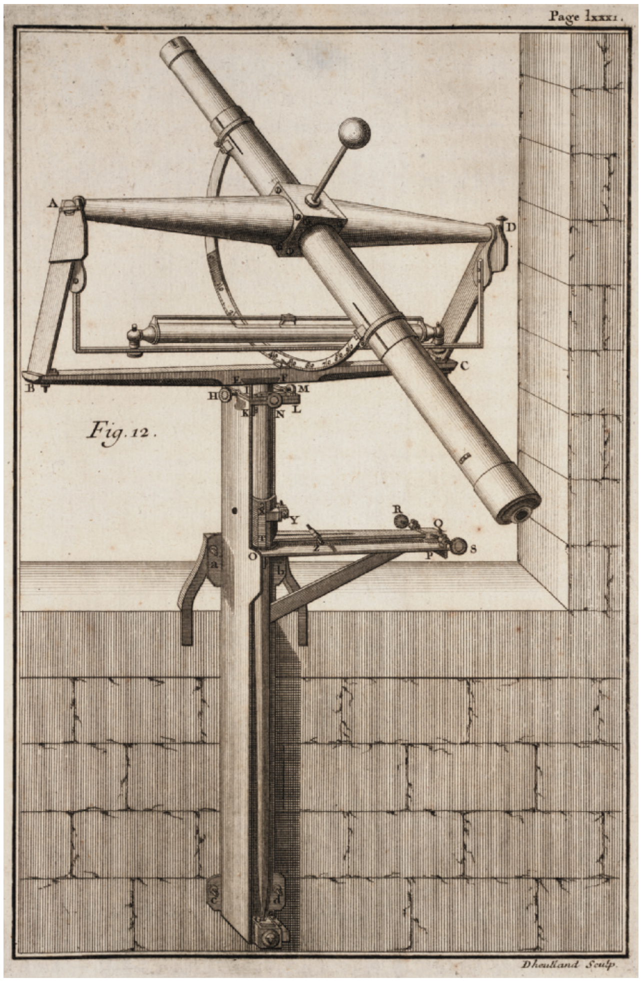

FIG. 397. PIERRE-CHARLES LE MONNIER'S *INSTRUMENT DES PASSAGES*, OR EQUAL-ALTITUDE INSTRUMENT. Although shown as installed on a window sill at the Paris Observatory, its supporting pillar could easily be turned into a portable stand. The instrument comprised a telescope (here 2 pieds [0.7 m] long) fixed in the plane of the meridian, the horizontal axis corrected by a long spirit level, with a graduated half-circle below to define altitudes. From Le Monnier 1741, fig. 12, opp. lxxxi.
Size of the original: 22 × 15 cm. Image courtesy of the Linda Hall Library of Science, Engineering & Technology, Kansas City.

time taken by a star to pass between the cross hairs was the same to both east and west of the meridian—meant that the telescope defined the direction of the meridian, a point of crucial importance in a geodetic triangulation. The graduated half-circle was too crude to measure altitudes with the precision needed for geodetic operations but allowed the observer to set the telescope at the right angle to see the desired star quickly and efficiently and also to check that the telescope maintained proper alignment between the observations.

Graham made the first equal-altitude instrument for the French geodetic expedition to Lapland; Le Monnier, who had been a member of this expedition, described a similar instrument that had been made by Graham's apprentice, Jonathan Sisson. Bird in turn used this account to make the instrument used by Mason and Dixon in Maryland and Pennsylvania. In addition to using the instrument to regulate their clock and to define the direction of the meridian, they also used it to keep straight the line that they measured directly on the ground in determining the length of a degree (Mason and Dixon 1768, 274–76). William Roy similarly used his own equal-altitude instrument to guide the measurement of his baseline on Hounslow Heath (Roy 1785, 422), and it seems that its suitability for defining straight lines later made it a favored instrument, under the name of transit, in the fledgling United States.

DEBORAH JEAN WARNER

SEE ALSO: Celestial Mapping; Geodetic Surveying; Instruments for Angle Measuring: Precision Devices for Angle Measurement

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Instruments for Angle Measuring.

BACK STAFF
PLANE TABLE
MARINE COMPASS
CIRCUMFERENTOR
PRECISION DEVICES FOR ANGLE MEASUREMENT
OCTANT AND SEXTANT
THEODOLITE, GRAPHOMÈTRE, AND SIMILAR INSTRUMENTS
REPEATING CIRCLE (REPEATING THEODOLITE)
GREAT THEODOLITE

Back Staff. European navigators in the sixteenth century adopted the cross staff, or Jacob's staff, to measure the altitude of stars or the sun to determine latitude, but

FIG. 398. AN UNSIGNED ENGLISH BACK STAFF, OR DAVIS QUADRANT, CA. 1700. The frame is made from lignum vitae, the arcs and vanes from boxwood, the fittings from brass. The sight vane was originally equipped with a Flamsteed lens (now missing). The sixty-degree or shadow arc (upper left) is graduated in 1° intervals from 0° to 65°; the thirty-degree or sight arc (right, with carved grip) has a transversal scale from 0° to 25° in 5′ increments that can be read to 1′.
Size of the original: 1.7 × 67.2 × 36.0 cm. © National Maritime Museum, Greenwich, London (NAV0045). The Image Works.

to use it the mariner had to look directly at the sun. John Davis described an alternative instrument in which the navigator stood with back to the sun in *The Seamans Secrets* (1595); George Waymouth included an illustration of a fully developed instrument in his 1604 mathematical manuscript, "The Jewell of Artes" (New Haven, Yale University, Beinecke MS 565). Davis simply called the device a "staff," but the English soon came to call it either the "back staff" or "Davis quadrant," while the French called it *le quartier anglais* (Forty 1986, 259).

The back staff comprises a triangular frame, about two feet long, with an arc at either end (fig. 398). The larger radius, "thirty-degree" or sight arc (generally graduated to 25°), has a carved grip by which the instrument is held and a sliding sight vane with a pinhole sight; the smaller radius "sixty-degree" or shadow arc (generally graduated to 65°) bears the sliding shadow vane. At the very end of the frame, at the center of curvature of both arcs, is the fixed "horizon vane," with a horizontal slit. The observer stands with his back to the sun and adjusts the shadow vane so that its shadow falls on the slit of the horizon vane; at the same time, he adjusts the sight vane until the horizon is seen through both the sight and horizon vanes. Adding the values indicated on the arcs by each vane gives the sun's altitude.

Back staffs were commonly made of a hard wood, such as pear or rose, with graduated arcs made of boxwood or inlaid with ivory or, later in the eighteenth century, brass. Some replaced the shadow vane with a convex lens to focus a point of light on the horizon vane, especially useful when hazy conditions dispelled shadows. This lens is known as a "Flamsteed glass" because Jonas Moore attributed its invention to the British astronomer John Flamsteed (Moore 1681, 250; Bennett 1987, 35–36).

Surviving examples, many of which are marked with a serial number and date as well as the names of the maker and original owner, indicate that both the cross staff and the back staff remained in widespread use throughout the seventeenth and eighteenth centuries, even after the introduction of John Hadley's reflecting octant in 1731, likely because of the lower cost and mariners' innate conservatism (Stimson and Daniel 1977, 3; Forty 1986, 259). A study of back staffs signed, dated, and numbered by American craftsmen identified fifty-seven instruments made between 1676 and 1788, almost all from New England. Comparison of their dates with the surviving records of instrumentmaker Clark Elliott of New London, Connecticut, and correlating the dates to serial numbers suggests that American craftsmen made as many as 3,000 back staffs, and that although most (thirty-seven) of the surviving instruments date from after 1760, most American back staffs were actually made before that year. Probate records suggest that usage among American navigators dropped off significantly in the 1780s (Warner 1988).

DEBORAH JEAN WARNER

SEE ALSO: Longitude and Latitude; Navigation and Cartography

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Plane Table. The plane table is a drawing instrument by means of which a map can be drawn in the field without using other instruments to measure angles. It consists of a flat drawing board mounted on a tripod on which the board can turn and be clamped in any position. A sheet of paper can either be pinned to the board or held in place by a frame with graduations to help measure bearings. An alidade, or ruler with sights, sits on the board. A magnetic compass and some kind of level could also be added to the instrument.

The plane table had developed by the end of the sixteenth century as the simplification of early angle-measuring instruments. Abel Foullon affixed a *triquetum* (three graduated staffs hinged together) onto a table to make his *holomêtre*, first described in 1555. This instrument could be adapted to many types of surveying, but it was too complicated for easy use. Removing the encumbrances left the table "plain"; indeed early English writers called it a "plaine" or "playne" table. In France, the plane table was known simply as a *planchette*. But in Germany and Italy it was often called the *mensula* (or *tabula*, *tavoletta*, etc.) *Praetoriana*, because Daniel Schwenter, writing in 1626, attributed the instrument's design, in about 1590, to his teacher Johannes Prätorius (Kiely 1947, 220–35; Richeson 1966, 77–81; Lindgren 2007, 486, 493–94, 498–500). The instrument rapidly became popular, as can be seen from seventeenth-century surveying textbooks. Aaron Rathborne illustrated its use on the title page of his text *The Svrveyor* (1616). His instrument consisted of three parallel boards, held together by two more at right-angles along the length of the table, which was 36.8 centimeters long and 27.9 centimeters wide. Rathborne described how to fold up the table into a box after use and to store loose papers and small tools (Bennett 1987, 46–48). William Leybourn (1653, 42–44) described a plane table of similar dimensions, but also suggested some changes, including adding a graduated semicircle to one side of the frame so that the instrument could be used to take altitudes as well. He also recommended that the two sights of the alidade be made the same height rather than having one twice the length of the other. This made it possible to take backsights without turning the table 180 degrees. Sébastien Le Clerc's popular *Traité de geometrie* (1690) included detailed instructions on how to use the plane table. In his 1723 edition of Nicolas Bion's *The Construction and Principal Uses of Mathematical Instruments*, Edmund Stone described the form of plane table that remained standard in the British Isles throughout the eighteenth century: an oak table on a tripod, with a compass attached in an octagonal box, a boxwood frame or surround divided in degrees, and a brass rule with engraved scales and plain sights. In the 1710s, Johann Jakob Marinoni made several improvements to the plane tables used in the Austrian monarchy, improvements that he eventually described in his treatise *De re ichnographica* (1751); he advocated for a larger board and a complex mechanism that permitted the board to both rotate, for orientation, and move laterally, for centering (fig. 399). Toward the end of the century, alidades with telescopic sights placed on vertical arcs were made, but were not commonly used.

The advantage of the plane table was that it was possible to mark bearings directly onto paper in the field. This meant that much surveying could be done graphically with a minimal understanding of mathematics and geometry, and that the surveyor would be able to sketch a map directly. Ease of use carried with it dangers of complacency, and Rathborne warned that "simple and ignorant persons . . . who hauing but once obserued a Surueyor, by looking ouer his shoulder . . . within a small time after, you shall heare them tell you wonders, and what rare feats they can performe" (1616, preface).

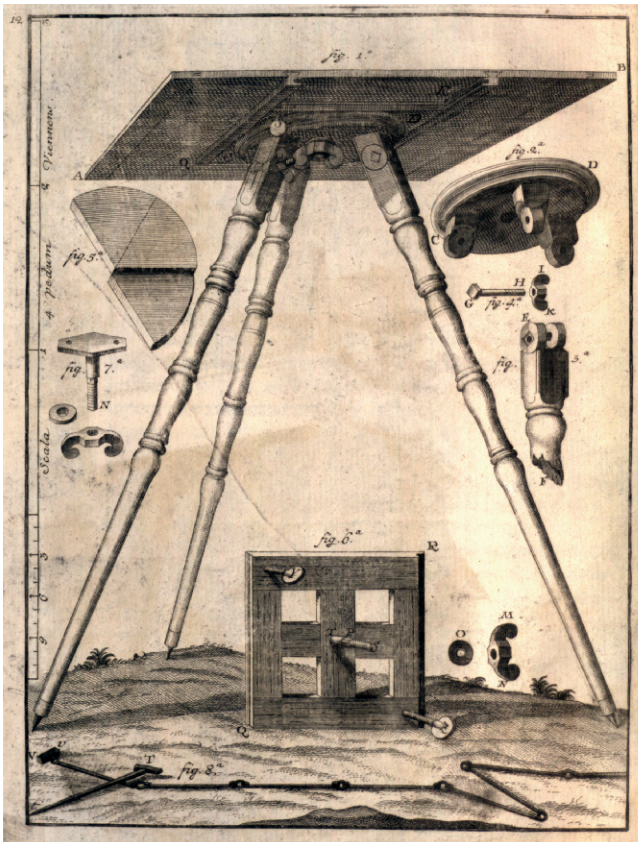

FIG. 399. MARINONI'S IMPROVED *TABULA PRAETORIANA* (PLANE TABLE) DEVELOPED IN THE 1710s. From Johann Jakob Marinoni, *De re ichnographica, cujus hodierna praxis exponitur, et propriis exemplis pluribus illustratur: Inque varias, quæ contingere possunt, ejusdem aberrationes, posito quoque calculo, inquiritur* (Vienna: Leopoldum Kaliwoda, 1751), facing 13. View from beneath, showing construction of the mechanism joining the tripod to the table. Size of the original: 20.5 × 15.3 cm. Image courtesy of the Department of Special Collections, Memorial Library, University of Wisconsin–Madison.

The first step in using a plane table was to place it over the starting point, orient it north, and then screw the tripod firm. Then a second point was viewed through the sights of the alidade, and a line was drawn between the two. The distance between the two points was measured using a chain. If the area to be surveyed was small and all points of change in the boundary could be viewed from the first point, they could all be sighted by rotating the alidade and the distances to them measured by chain and plotted to scale. Traversing involved taking observations from successive instrument stations and orienting the table by backsighting to the previous station (see fig. 873). Intersection required the accurate measurement of a line between two points, which became the baseline. Points to be surveyed were sighted from both ends of the baseline and were fixed by the intersection of rays drawn from both points.

An inexpensive instrument and easy to use, the plane table contributed to the growth of land surveying in the seventeenth and eighteenth centuries. It was particularly useful in large-scale mapping of landscapes with many landmarks and was often favored by military topographers on the Continent for its ease of use in topographical sketching.

SARAH BENDALL

SEE ALSO: Marinoni, Johann Jakob; Property Mapping; Topographical Surveying; Triangulation Surveying

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Marine Compass. The close relationship between the marine chart and the sea compass was emphasized by the term used in France, up to and including the nineteenth century, for the plotting of a measured or estimated position and a course: *compasser la carte* or *pointer la carte*. From the beginning of the nineteenth century, the expression was progressively replaced by *faire le point*, still used today.

In the historical division of the horizon and the compass into sixteen or thirty-two graduations (of 11°15′, originally from the designation in the Mediterranean of the winds on the wind rose), a rhumb could designate two things: the space between lines and each of the thirty-two lines themselves, as drawn on the face of the compass. As lines of the compass drawn on charts, the rhumbs were the traces of the close connection between the compass card and the marine chart. This link also assumed concrete form in the wind rose (or compass rose), a star with thirty-two points corresponding to these thirty-two wind directions.

From the end of the seventeenth century, important research into terrestrial magnetism was matched by studious efforts of instrumentmakers who improved compasses (Marguet 1931, 91–95), both the steering compass, indicating the ship's heading, and the variation compass, the forerunner of the hand bearing compass. The latter was used to take the bearing of sea marks, to assist in the estimation of leeway, and to check the steering compass (as long as the variation compass was not brought too close to the steering compass). These two instruments nonetheless remained of quite poor quality. The graduation on the cards was still imperfect (especially on the variation compass), and, in particular, the copper used in fabrication was contaminated with iron. Great Britain achieved greater mastery of the production process in the workshops controlled by the Royal Navy, which made the compasses destined for ships of the state (Chapuis 1999, 61). France tried to imitate Great Britain's process on the eve of the French Revolution.

The installation of compasses on board ships also posed serious problems, especially the alignment of the "lubber's line," against which the bearing of the ship's head was read, with the fore and aft axis of the ship. The movements of the ship greatly disturbed the compass needle and card. Above all, although the theory of deviation due to magnetic masses had been known from the seventeenth century (and by some Portuguese from the sixteenth century) when iron was increasingly employed in ships, it was not always clearly distinguished from magnetic variation and was not completely understood in the eighteenth century (Chapuis 1999, 62). The practice of placing two compasses in the same binnacle continued, and while this was a practical arrangement enabling the helmsman to always have a compass in sight whatever his position, it was regularly denounced by knowledgeable officers. Eighteenth-century navigators did not yet compensate for compass deviation errors caused by magnetic masses on board, even though William Wales, astronomer to James Cook, noticed that they varied with the heading of the ship. It was necessary to await the curves of deviation produced by Matthew Flinders and published in 1814. Flinders noted that for any compass installation, the deviation changed not only as a function of the displacement of magnetic masses on board the wooden ships, but also according to the heading of the ship (Chapuis 1999, 660). These problems with magnetism were well-defined only after 1815 and were not completely resolved through compensation until much later.

OLIVIER CHAPUIS

SEE ALSO: Navigation and Cartography; North, Magnetic and True

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Circumferentor. A circumferentor—known in America as a surveyor's compass—is a magnetic compass equipped with vertical sights, designed so that one can measure the bearings of distant objects with respect to magnetic north (fig. 400). The circumferentor was probably derived from marine compasses. Steering compasses, without sights, had long been used at sea, and John Fitzherbert, in *Here Begynneth . . . the Boke of Surueyeng and Improume[n]tes* (1523) had advised that they be used on land to establish the alignment of parcels of land (Richeson 1966, 31–35). Sixteenth-century mariners added sights to make the azimuth compass, sighting on the sun or stars when due south permitted the mariner to determine magnetic variation. The earliest reference to a circumferentor was made by Ralph Agas in *A Preparative to Platting of Landes and Tenements for Surueigh* (1596) (Richeson 1966, 81–83); the earliest dated example was made in Dublin in 1667 (Warner 2005, 372–74). Indeed, some early circumferentors had a similar form to the mariner's compass in that the compass card was glued directly on top of the needle so that both remained stationary as the sights were turned. This arrangement was replaced by the later seventeenth century by placing the card under the needle. The circumferentor thus differs from the theodolite and other devices in that its sights and compass card together revolve about the stationary needle (Bennett 1987, 41, 48–49, 52–53, 149).

FIG. 400. JOSEPH HALSY, CIRCUMFERENTOR, BOSTON, 1747. Samuel Lane, a New Hampshire surveyor, acquired this instrument in 1747 and used it until it was damaged in 1754. The thick sights with two apertures each permitted the surveyor to take back sights without reversing the instrument. The compass card was printed from a woodblock and hand colored. Wood with glass face.
Size of the original: ca. 11.0 × 12.5 × 23.0 cm. Image courtesy of the New Hampshire Historical Society, Concord (Object ID: 1992.040.01 a-b).

Circumferentors were not particularly reliable. Their cards were marked to no greater than individual degrees (each quadrant was generally incremented separately, from 0° to 90°). Variations in the earth's magnetic field by both location (especially when locally distorted by iron deposits) and over time meant that circumferentors had only uncertain accuracy. They were accordingly favored in settings where land was surveyed in large tracts and where speed was of the essence; the circumferentor was, for example, the basic instrument used in the Down Survey of Ireland (1655–59), and it was the most common angle-measuring device in eighteenth-century colonial America (Warner 2005). Some Irish and American instruments were equipped with an "outkeeper," a dial that helped the surveyor keep track of the number of times ("outs") a chain had been run. Circumferentors were also used underground, where they were known as miner's dials.

Most circumferentors were made in Ireland and the American colonies. They were originally constructed from wood, as befitted a craft tool, and featured manuscript or printed compass cards, but by 1700 they were largely being made in brass; engraved brass rings in the mid-1700s could be graduated to half a degree. Conversely, it seems that there was insufficient metal available to meet the great demand for circumferentors in eighteenth-century New England, and locally manufactured instruments were almost all made from wood until the nineteenth century (Bedini 1964).

By 1780, the increasing desire to eliminate the vagaries of magnetic variation led instrumentmakers in Britain and especially the United States to equip circumferentors with circles that could be adjusted by means of a vernier (see fig. 402). Once the surveyor had determined local magnetic variation, by solar or stellar observations, he could adjust the circle by an equal amount so that all measurements were automatically made with respect to true north. As the more sophisticated instrument became known in the United States as a vernier compass, the simpler version became known as a plain compass (Warner 2005, 381–82).

DEBORAH JEAN WARNER

SEE ALSO: Property Mapping; Topographical Surveying

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Precision Devices for Angle Measurement. The direct instrumental measurement of angles depended on the ability to engrave or otherwise permanently mark a circular arc with consistently spaced graduations for degrees and even minutes. The basic technique of dividing circular arcs into individual degrees or perhaps half-degrees—through a combination of simple geometrical and trial-and-error processes—had been well-established by the mid-sixteenth century and continued to be used well into the 1700s for angular instruments of ordinary quality. Such precision was quite adequate for common surveying, but observational astronomy and detailed topographical mapping required still finer precision and that in turn required further techniques (Sorrenson 1995). As discussed in this entry, Enlightenment scientists and craftsmen introduced vernier scales and micrometers in place of the earlier system of transversal scale (Michel 1913; Chapman 1995, 22–23,40–45, 69–75). Simultaneously, individual eighteenth-century craftsmen achieved ever finer primary divisions of the arcs on high-quality instruments. They did not reveal their trade secrets until the British longitude commissioners paid John Bird to publish his technique of dividing small angular arcs, as used on sextants and octants, down to five-minute intervals in *The Method of Dividing Astronomical Instruments* (1767) (Daumas 1972, 193–96). To produce high-quality instruments in sufficient quantities for mariners and engineers, instrumentmakers in France and Britain also sought to build engraving machines to automate the process; Jesse Ramsden first perfected such a device in 1774 (McConnell 2007, 41–43; Daumas 1972, 196–204).

The initial solution to obtaining greater precision in measurement was the transversal (or diagonal) scale. First described by Levi ben Gerson in the early fourteenth century, and in print by Thomas Digges in his *Alæ sev scalæ mathematicæ* (1573), the transversal scale was popularized by Tycho Brahe. Linear transversal scales were commonly used on back staffs in the seventeenth and eighteenth centuries and also on rulers used by draftsmen in plotting maps to plot to fine fractions of an inch (fig. 401). Circular transversal scales were slightly more complex in construction and were used on a variety of high-precision instruments through the end of the seventeenth century (Daumas 1972, 189–91; Smith 1986, 29–33) (see fig. 407). The transversal scale on the quadrant that Jean Picard used in triangulating the meridian of Paris allowed the precise measurement of angles to a single minute of arc (see fig. 265).

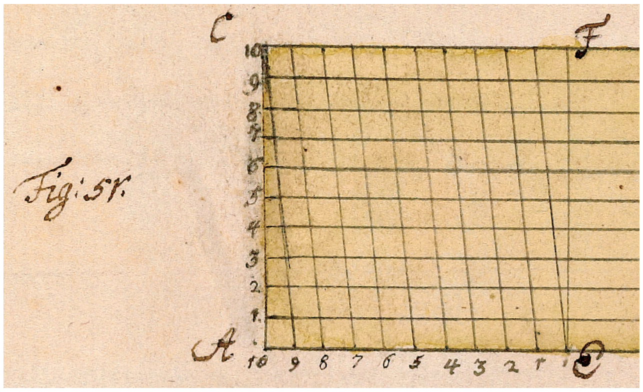

FIG. 401. TRANSVERSAL SCALE. From Johann Christoph Schlönbach, "Practische Anleitung zum Feld-Messen" (1759), fol. 21. Shown here is a detail of the left end of an exemplar linear scale, from a German surveyor's manual, of *Decimal Fusse* (decimal feet, ten to a Ruth [rod]). The main, horizontal scale is repeated ten times, in uniform intervals, with diagonal (transverse) lines each drawn across the range of a single graduation (here, one decimal foot). The intersection of each transverse line with a horizontal scale represents an increment of one-tenth of a single graduation. Such transversal scales were also applied to the graduated arcs of angle measuring instruments.

Image courtesy of the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland (OML-1759-9).

The more compact vernier scale was first described by Pierre Vernier, a Burgundian mathematician and an official with the government of the Spanish Netherlands, in *La constrvction, l'vsage, et les proprietéz dv qvadrant nouveav de mathematiqve* (1631). He described a quadrant in which the main scale, graduated in half-degree increments, could be read to just one minute of arc by means of a second scale, with slightly variant units, that moved with the sight. Johannes Hevelius used verniers on some of his large astronomical instruments and described them in *Machinæ coelestis, pars prior* (1673). Although Robert Hooke criticized the vernier along with other aspects of Hevelius's work in his *Animadversions on the First Part of the Machina coelestis* (1674), the introduction of telescopic observation prompted finer precision in measurement so that by the early eighteenth century verniers were common equipment on astronomical, surveying, and navigational instruments; by 1800 they were all but standard (fig. 402). With verniers, it became possible to read angles to five or ten seconds of

FIG. 402. DETAIL OF THE VERNIER SCALE ON A SEXTANT. The main arc (here showing from 75° to 60°) is graduated in intervals of 20 minutes of arc; the vernier scale, above, permits those 20 minutes of arc to be read to a precision of half a minute, or 30 seconds of arc. The vernier scale moved with the sextant's telescope, with the final precise adjustment being made by a finely tuned screw (not shown here; see fig. 404). To read the angle, the mariner looked for the exact coincidence of one mark on the vernier scale with another on the main scale; here, the coincidence is between 65°0′ on the main scale and 6′0″ on the vernier, for a final value of 65°6′0″. Brass sextant made in London by Edward Nairne and Thomas Blunt, ca. 1780; the engraved mark on the main scale indicates that the circle was divided on Jesse Ramsden's dividing engine. Size of the original: 38.0 × 35.8 × 11.0 cm. © National Maritime Museum, Greenwich, London (NAV1110). The Image Works.

arc and, on large astronomical instruments with a seven- to eight-foot (over two m) radius, even up to half a second of arc (Daumas 1972, 191–93). (In Britain it was common in eighteenth and nineteenth centuries to call a vernier scale a "nonius," although the nonius is actually a variant of the transversal scale, little used after 1650, and named after its inventor, the sixteenth-century Portuguese mathematician Pedro Nunes.)

The rise of telescopic observation was accompanied by a third strategy for measuring fine angles: the insertion into the telescope's eyepiece of a micrometer. With origins in the early seventeenth century, the micrometer was perfected by Adrien Auzout and Picard in the 1660s (Brooks 1991). In this device, the focal plane of the eyepiece has two metal pointers or wires that are moved together or apart by means of a screw; a divided scale attached to the screw indicates the precise extent of the separation. Auzout and Picard developed their micrometer to take the angular diameters of the sun, moon, and planets. With the improvement of optical techniques and the increasing availability of high-quality lenses in the eighteenth century, increasingly reliable and versatile filar micrometers were attached to many astronomical and geodetic instruments, especially zenith telescopes. The micrometer was especially useful in increasing the resolution and discrimination of the observer's vision.

DEBORAH JEAN WARNER

SEE ALSO: Geodetic Surveying; Instruments, Astronomical

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Octant and Sextant. At the end of the seventeenth century, the instrument most commonly employed to ascertain the altitude of heavenly bodies during navigation was the sea quadrant, which the French often called the *quartier anglais* (or *anglois*). It was a quarter circle, similar to the quadrant commonly used in terrestrial astronomy, though the latter instrument, not intended for use in the dynamic shipboard environment, was often larger in diameter. A precursor, the Jacob's staff (or cross staff), which had been in use since the beginning of the fourteenth century, had not completely disappeared as a measuring device, a sign of the reluctance of mariners to abandon their old habits, especially when simple and inexpensive tools lent themselves to proven techniques (Chapuis 1999, 54). With the sea quadrant, also known as the back staff, the observer stood with his back to the heavens, measuring the shadow that it cast on the instrument.

From the end of the seventeenth century, however, research in optics carried out by a number of scholars and craftsmen, notably Isaac Newton and Robert Hooke, led to marked improvements in reflecting instruments. In 1731 the Englishman John Hadley presented to the Royal Society of London his double-mirrored octant, with an arc (limb) that measured an eighth of the circumference of the circle (hence the name octant) or forty-five degrees, though it was divided for facility into ninety degrees (or the equivalent of a quarter circle) (Hadley 1733). It permitted the measurement of the alti-

FIG. 403. PEAR-WOOD FRAME OCTANT WITH BRASS FITTINGS BY BENJAMIN COLE, CA. 1750. The octant has a brass stop on the index arm moving over an inlaid boxwood transversal scale.
Size of the original: 7.5 × 42.0 × 50.5 cm. © National Maritime Museum, Greenwich, London (NAV1303). The Image Works.

tude of heavenly bodies by day or night with about one minute of error. At the same time, in Pennsylvania, the American optician Thomas Godfrey had also invented an instrument using double reflection.

Double reflection combined direct and reflected images using a small mirror that was covered with tin on half of its surface. Thus, a hitherto unknown ability was brought to an observer who stood on the bridge of a moving ship. The mirror allowed the observer to see the stars and the horizon in the same view, even in a cloudy sky. This was a great advantage because the mirror showed a small point on the horizon above and below its reflected image with precision (Chapuis 1999, 54).

Jean-Baptiste-Nicolas-Denis d'Après de Mannevillette was one of the first to use the octant in France. In his treatise *Le nouveau quartier anglois* (1739), he emphasized that the best navigators would now be able to measure their latitude to within a minute, even if longitude continued to be out of reach (Chapuis 1999, 55–56). However, most navigators would not adopt the octant until several decades later.

The manufacture of instruments using reflection remained a British specialty throughout the eighteenth century. So much so that the French used English instruments in their most prestigious scientific expeditions, such as the sextants of Jesse Ramsden on the Lapérouse expedition (1785–88). The French *ministre de la Marine* even rewarded officers for the quality of their observations with instruments made in Great Britain. The other great maritime nations of Europe also lagged behind in instrument manufacture (Chapuis 1999, 57). In the second half of the eighteenth century, when the octant (in wood and brass [fig. 403] or iron and brass) had been continuously improved by various craftsmen in England and France, with the addition of a telescope, for example, the solution of the problem of longitude was to favor the emergence of other new instruments.

Since the calculation of longitude from lunar distances often involved angular values greater than ninety degrees (Cotter 1968, 81), larger than those involved in measuring the heights of heavenly bodies, instruments capable of responding to these new demands were required. The sextant of John Campbell appeared in 1757. Often made of mahogany and brass, with a limb of ivory, its design was identical to the octant, but its limb was enlarged to 60 degrees (instead of the octant's 45 degrees) making it capable of measuring angles up to 120 degrees. Moreover, this instrument was soon equipped with an achromatic telescope and a vernier scale, as progress was made in metalworking (fig. 404). Among the great maritime powers of the period, the sextant became a necessity for enlightened navigators from the last quarter of the eighteenth century onward as the

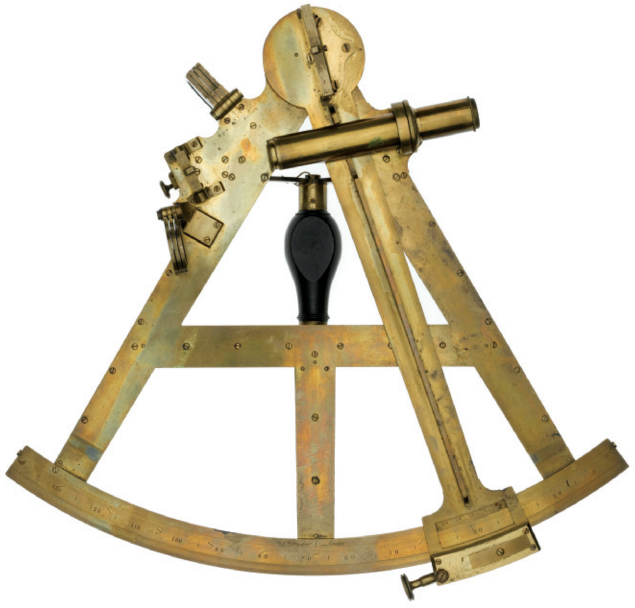

FIG. 404. BRASS SEXTANT BY JESSE RAMSDEN, CA. 1790.
Size of the original: 12 × 40 × 37 cm. © National Maritime Museum, Greenwich, London (NAV1105). The Image Works.

method of lunar distances became established practice for these elite practitioners.

At the end of the eighteenth century, the sextant was cast from a single piece of brass, equipped with an achromatic telescope, a vernier, and a tangent screw. It assumed its definitive form at the end of the 1780s, even though the diversity among models was still great. Its radius was much smaller than that of the bulky octant. Therefore, the sextant was lighter and more maneuverable, and hydrographic surveyors were able to use it more easily in the horizontal mode. However, the use of brass, an alloy of copper and zinc, and iron, posed problems because the expansion rate of the two metals differed. Yet these metals held a clear advantage over copper, whose light weight made it prone to deformation. The obstacle of unequal expansion would be resolved at the beginning of the nineteenth century.

OLIVIER CHAPUIS

SEE ALSO: Longitude and Latitude; Navigation and Cartography

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Theodolite, Graphomètre, and Similar Instruments. Early modern surveyors and instrumentmakers developed a family of angle-measuring instruments with an alidade that rotated around a static, graduated circular arc. Many were described by instrumentmakers in manuals (e.g., Bion 1709; Adams 1791); Nicolas Bion's pioneering account was the basis for descriptions of these instruments in the era's encyclopedias. These instruments could be used to measure horizontal angles (azimuths) and/or vertical angles (altitudes). Historians have identified four basic forms: the circle, the graphomètre, the quadrant, and the theodolite (Bennett 1987, 83–96, 145–49; Wynter and Turner 1975, 154–71).

Most such instruments were made of brass, although some had wood or iron bases supporting the graduated brass arc. The circular arc was typically rather small so that the instruments could be readily used; most had a radius of less than 0.4 meters. The sights were initially open. While Jean Picard had put telescopes on his large quadrant by 1670 (see fig. 265), telescopic sites did not appear on common surveying instruments until the 1720s, and they were not standard until the end of the century. As telescopic sights were adopted, so too were transversal and especially vernier scales for reading the graduated circles with greater precision; this in turn required the addition of spirit levels to permit the instruments to be leveled properly.

Most static-circle instruments had a pair of fixed sights in addition to the rotating alidade with which the surveyor read the graduated circle. The fixed sights provided a check that the instrument had not moved. The surveyor would set the fixed sights to a reference object, lock the circle, and then use the rotating alidade to sight onto distant objects and record the angles; at any time the surveyor could check that the instrument remained in proper alignment by looking to see that the fixed sights continued to point to the chosen reference object (Adams 1791, 311–14). Many of these instruments were fitted with a compass. This could be used to orient the instrument; or, along with the fixed sights, it would convert the instrument into a circumferentor. The surveyor could rotate the instrument so as to sight onto features with the fixed sights and read their bearings with respect to magnetic north. This last practice complicates the principled distinction between static-circle instruments and mobile-circle circumferentors.

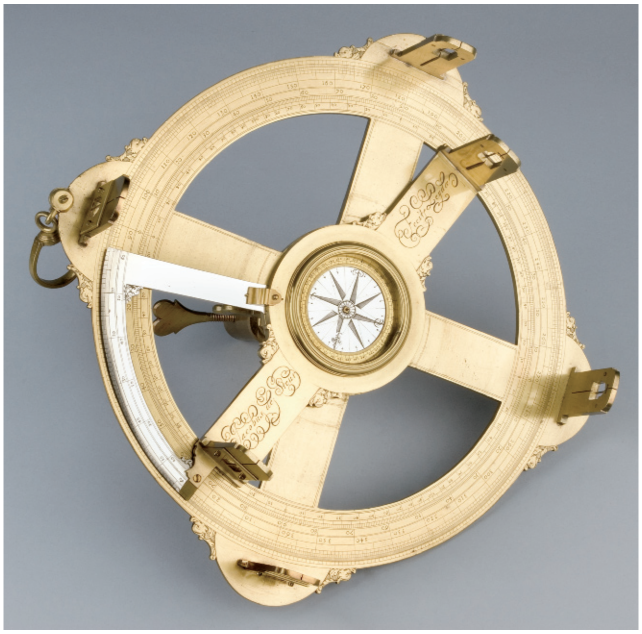

FIG. 405. HOLLAND CIRCLE BY JACOBUS DE STEUR, LEIDEN, CA. 1670. The outer circle of this brass instrument is graduated to fifteen minutes; the inner circle was marked with scales useful to military engineers. It came supplied with several attachments, including a sighting bar that can fit over the sights on the alidade.

Size of the original: 6.2 × 32.6 × 36.0 cm. Image courtesy of the Collection of Historical Scientific Instruments, Harvard University, Cambridge (Inv. # DW0674a).

Surveyor's circles—defined by the full graduated circle—had been produced since the sixteenth century; they are sometimes called "diopters" after the instrument described by Heron of Alexandria. The variant described by Jan Pietersz. Dou in 1612 was widely adopted in the Netherlands. Now known as the "Holland circle" (Kiely 1947, 161–62), it consisted of a full graduated circle with four fixed sights making a cross, a movable alidade with sights, and an inset compass. The four fixed sights allowed the instrument to be used as a surveyor's cross (or *equerre d'arpenteur*) to lay out perpendicular lines (see fig. 678). A late-seventeenth century example (fig. 405) reveals the form's origins in the astrolabe: the ring outside one of the fixed sights permitted the instrument to be suspended so that the surveyor could measure vertical angles with the movable alidade or use the other fixed sights to define the horizon. In Britain, the circle was called the theodolite, after the "Theodelitus" described by Leonard Digges (1571, first book, chap. 29 [unpaginated]); it was further qualified as the common or simple theodolite with the development of the altazimuth theodolite. In France, the circle was called a *planchette* or later, to distinguish it from the plane table, a *planchette ronde*. The large circle with two telescopes designed by the Swedish instrumentmaker Daniel Ekström could be used either in the horizontal or vertical plane (fig. 406).

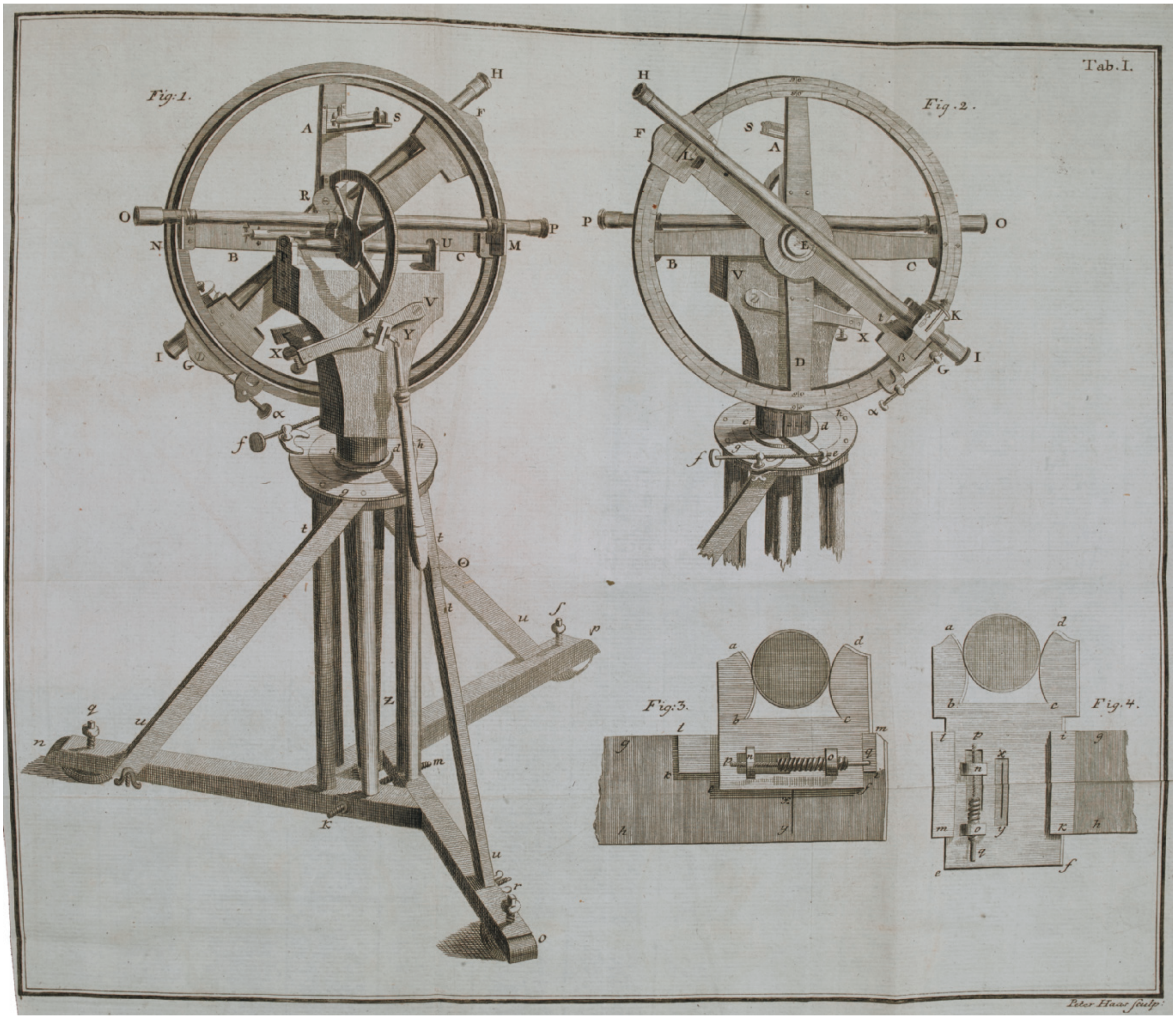

FIG. 406. JOHAN AHL'S 1764 IMPLEMENTATION OF THE "GEOGRAPHICAL CIRCLE" DESIGNED BY HIS TEACHER, DANIEL EKSTRÖM. From Thomas Bugge, *Beskrivelse over den opmaalings maade, som er brugt ved de danske geografiske karter* (Copenhagen: Gyldendals Forlag, 1779), pl. 1. With the circle in the vertical, as here, telescope OP was set in the horizontal with a spirit level, permitting the second telescope IH to measure vertical angles.
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FIG. 407. BRASS GRAPHOMÈTRE BY MICHAEL BUTTERFIELD (PARIS, CA. 1700). Note the transversal scale applied to the instrument's entire arc; the main division of the arc reads to 1°, the transversal to 10′ of arc. Size of the original: 18.1 × 27.6 × 13.3 cm. Image courtesy of the Metropolitan Museum of Art, New York (Accession number: 03.21.12).

FIG. 408. A COLONIAL GRAPHOMÈTRE IN ITS PINE CARRYING BOX. Made in Boston, ca. 1775, this instrument served as a compact equivalent to the circumferentor. Such colonial instruments had trench compasses for orientation, two spirit levels, and a brass semicircle and alidade, all generally set into a wooden base. Here, the simple north arrow on the compass card is in manuscript, and the base is mahogany.
Size of the original: 30.5 × 15.0 cm; diameter of brass alidade and measuring limb: 22.7 cm. Image courtesy of the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland (OS-1775-29).

Philippe Danfrie introduced a variant in his *Declaration de l'usage du graphometre* (1597). Known as a graphomètre (graphometer) or demi-cercle, this had a graduated semicircle with a pair of fixed sights at either end of its base diameter and a movable alidade. Many had an inset compass (fig. 407). The graphomètre was the preferred instrument among French surveyors, but it was used by others as well. Several simple compact half-circles, often misleadingly called semicircumferentors, were produced in British North America (fig. 408). Note that graphomètres were generally not used to measure altitudes.

To achieve greater precision in angle measurement it would have been possible to increase the radius of the circles, but this would have increased the weight and made

FIG. 409. EARLY THEODOLITE BY JONATHAN SISSON, 1737. The 6.5-inch (16.5 cm) diameter horizontal circle and 5.5-inch (14 cm) diameter vertical arc were both graduated to one-degree increments and both were equipped with vernier scales. The brass instrument was housed in a large octagonal wooden box. The telescope is a modern replacement.
Size of the original: 17.0 × 16.3 cm. © National Maritime Museum, Greenwich, London (NAV1451). The Image Works.

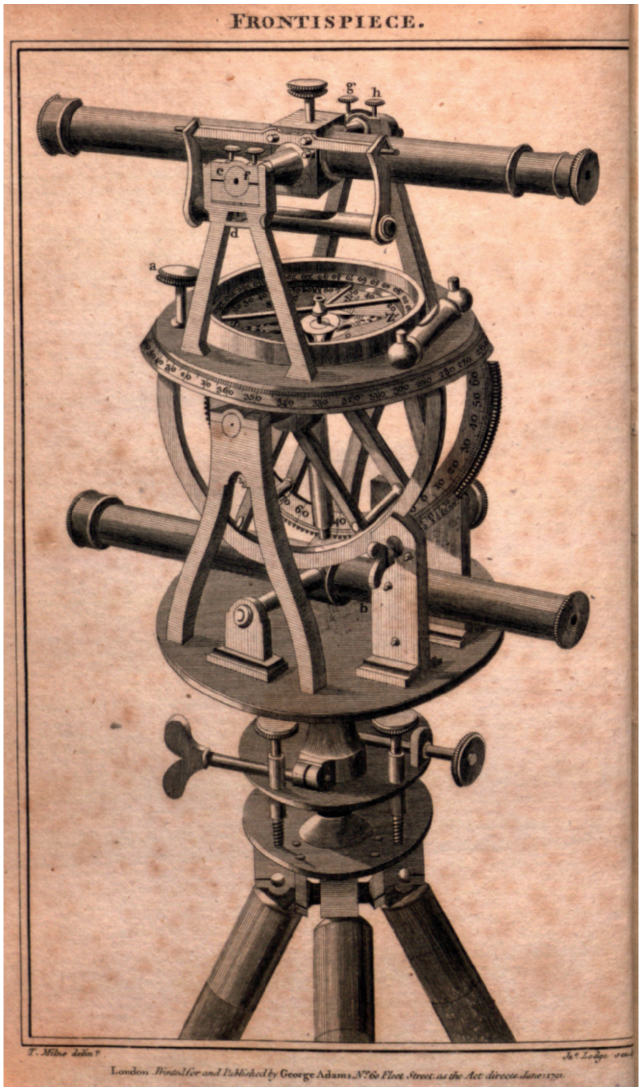

FIG. 410. RAMSDEN THEODOLITE, 1791. Jesse Ramsden's design for the altazimuth theodolite was adopted by other instrumentmakers, in particular George Adams (1791, frontispiece).
Size of the original: 18.5 × 11.0 cm. Image courtesy of the Department of Special Collections, Memorial Library, University of Wisconsin–Madison.

the instruments unwieldy. Larger instruments adapted from the quadrants—quarter circles—were used by astronomers in the observatory and field (Turner 2002). Picard used a large quadrant for the triangulation of the Paris meridian. It had a radius of 38 pouces (1.03 m), a fixed and a movable telescope, a transversal scale that could be read to one minute of arc (see fig. 265), and a support that allowed it to be used both horizontally and vertically. Smaller quadrants were commonly used by surveyors and engineers in France, Italy, and the German states.

Several sixteenth-century commentators had proposed, and some craftsmen made, an azimuth circle with a vertical arc for altitudes, so that both angles could be measured without having to reconfigure the instrument. A functional altazimuth instrument—i.e., the theodolite per se—was only developed in the 1720s by the London instrumentmaker Jonathan Sisson (fig. 409). Other makers followed suit, although the theodolite was, for several decades, the tool less of the working land surveyor and more of the interested landowner. Yet by century's end, the altazimuth theodolite was recognized in Britain (fig. 410), France, and the German states (Brachner 1983, 87–101) as the quintessential surveying instrument for the modern age.

DEBORAH JEAN WARNER

SEE ALSO: Property Mapping; Topographical Surveying

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Repeating Circle (Repeating Theodolite). In the 1750s astronomer Tobias Mayer was working in Göttingen on the repetition of angle measurements in surveying. His method was to take a bearing several times on a circle divided in such a way that each measurement could be added to the preceding measures. Only two readings were made, at the beginning and at the end of the operation. The difference between the readings was then divided by the total number of observations. This allowed a proportional reduction in the effects of instrumental error, such as might result, for example, from an irregularity in the graduation marking of a limb (Borda 1787, 5–6; Cassini, Méchain, and Legendre [1791], 34). Nevil Maskelyne edited and published Mayer's new lunar tables after Mayer's death, and they appeared in London in 1770. In this work, Mayer proposed using this complete circle for measuring distances from the moon to the sun and to various stars and provided a drawing of its execution. Jean-Charles Borda, an officer from the Génie who transferred to the Marine and an eminent scholar-technician of his time, was directly inspired by Mayer's work (Cassini, Méchain, and Legendre [1791], 24) to update his own instrument (Chapuis 1999, 265–66).

Borda designed two types of repeating circles (Chapuis 1999, 294–96). The first was called a reflecting circle (*cercle à réflexion*) and was equipped with two mirrors (like an octant or sextant), for it relied on the principle of double reflection. It was used particularly for astronomical sightings, especially lunar distances (it could make large angular measurements) or for taking simple meridian altitudes. Because it could be turned and used vertically or horizontally, it facilitated rapid hydrographic measurements by determining the points of intermediate stations, explaining its much later name, the hydrographic circle (Chapuis 1999, 714–15). Borda completed his conception of the reflecting circle in 1775, and Étienne Lenoir began to construct it in 1777.

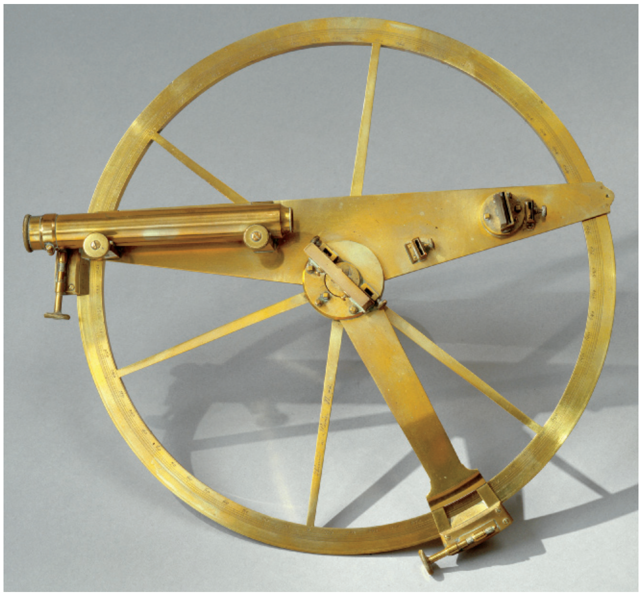

FIG. 411. ÉTIENNE LENOIR, *CERCLE À RÉFLEXION N^{O} 75* (PARIS, [1786]). This model is identical to those reflecting circles that accompanied Joseph-Antoine-Raymond Bruny d'Entrecasteaux on his voyage. The reflecting circle is made entirely of brass and molded in a single piece. It is light and manageable, characteristics that balance the lack of precision due to its modest size and the reduction of gradations along the limb; its modest dimensions prevent any deformation from twisting or expansion, always a concern with copper; because it was small, it was less expensive.

Diameter of the original: 30 cm. © Musée national de la Marine, Paris/A. Fux (N° inv. 11 NA 21).

On the reflecting circle the graduated circle, or limb, is mounted on a handle perpendicular to its plane. Two alidades move independently around the same axis (fig. 411). The principal alidade has a stationary telescope for astronomical sightings and a small half-silvered mirror (covered with tin on half its surface) and a vernier held on with a tangent screw. The smaller alidade has a large mirror (center) and a similar vernier attached with tangent screw. Borda's innovation of ca. 1775 was very important because the screw along the tangent was a worm screw, by contrast to the setscrews and adjusting screws that limited the movement of the alidade along the limb during a reading. With a reflecting circle, the angle between two observed objects (astronomical, in the case of lunar distances, or geodetic, for hydrographic use) corresponds to the angular difference read on the limb between the two alidades, thanks to the two verniers and to the fact that the limb was a complete circle (by contrast to the octant or sextant).

Borda created a second circle, the astronomic circle, with a diameter of thirty-two centimeters (see fig. 541). Jean-Dominique Cassini (IV) called this the repeating circle (*cercle répétiteur*); it was first used for the triangulation survey between the Greenwich and Paris meridians in 1787 (Chapuis 1999, 271–73). Its two eyepieces permitted the simultaneous sighting of two points, whose angular difference one measured. Also operating on the principle of repeated measurements, it could be used vertically for astronomy and horizontally for terrestrial triangulation, which demanded great precision.

Borda was the precursor of a new hydrography from an instrumental and methodological point of view (Chapuis 1999, 265–71), as seen in the expedition (1785–88) of Jean-François de Lapérouse, who employed Borda's *cercle à réflexion*. However, its first systematic user in hydrography was Charles-François Beautemps-Beaupré in the course of the d'Entrecasteux expedition (1791–93) (Chapuis 1999, 511–20).

OLIVIER CHAPUIS

SEE ALSO: Geodetic Surveying: (1) Enlightenment, (2) France; Marine Charting; Topographical Surveying

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Great Theodolite. The few "great theodolites" made in London after 1784 were a particularly British solution to the problem of the high degree of accuracy required for angle measurement in high-level geodetic surveys. They were not the culmination of some progressive enlargement of lesser surveying instruments. Rather, Jesse Ramsden created the first great theodolite de novo for a specific event, the Greenwich-Paris triangulation, which had promoted a nationalistic competition over the quality of instrumentation (Widmalm 1990, 192–95).

The primary constraint on any angle-measuring instrument was the quality of the divisions inscribed by hand around the edge of the brass circle. One solution—implemented in the repeating circle adopted by French geodesists—was to make multiple observations of the same angle on different portions of the circle, then take the arithmetic mean to eliminate instrumental error. Ramsden pursued an alternative solution: he had in 1775 perfected, to great acclaim, a machine that automated the division of a circle (Chapman 1995, 66–81, 108–37; McConnell 2007, 39–51). The immediate purpose of the so-called dividing engine was to perfect the Hadley octant, but it was of course applicable to any angle-measuring instrument. Faced with the need to make an accurate instrument for William Roy to use on the British portion of the triangulation, Ramsden constructed a very large theodolite: the larger the horizontal circle, the finer the angles subtended by its smallest divisions and the more precise the instrument.

Ramsden's first great theodolite was indeed large (fig. 412). The horizontal (azimuth) circle was three feet (0.914 m) in diameter—a size previously used only in high-end instruments installed in observatories—and read angles to one minute of arc; the one-foot (0.305 m) diameter vertical (zenith) semicircle read angles to three minutes. The fineness of the engraving required microscopes to read both circles. The primary achromatic telescope permitted clear vision and highly accurate measurement over one hundred miles (161 km); a second telescope, set in the base, established the origin of each round of observations. A confusion of screws and spirit levels set up and adjusted the whole. To keep the theodolite rigid, Ramsden constructed it from inflexible metal cones rather than simple rods; the whole instrument was mounted on a sturdy mahogany frame. It weighed some 200 pounds (91 kg), or ten times the weight of the French repeating circle. The size and complexity of the first great theodolite evidently gave Ramsden trouble; he finally delivered it to the Royal Society in 1787, having worked on it for three years (Roy 1790, 135–60; Daumas 1972, 186–87; Chapman 1995, 118–19; McConnell 2007, 200–203, 223–30).

The first limitation of a great theodolite was cost. George III had to buy Ramsden's first great theodolite for the Royal Society. When the directors of the East India Company commissioned a second three-footer from Ramsden with which to measure the geodetic arcs in India urged by Roy, they baulked at his final asking price. The Board of Ordnance purchased it instead in 1791, for the princely sum of £373.14s (Insley 2008), for use in a projected military survey of Britain (which would eventually develop into the Ordnance Survey); in January 1799, the board also received the loan of the first instrument from the Royal Society. A third three-foot theodolite was commissioned from Ramsden in 1792 by Ferdinand Rudolf Hassler in Switzerland; delivered in 1797, its use was curtailed by the French invasion in March 1798 (McConnell 2007, 215–18). The East India Company finally commissioned another three-foot theodolite in 1799, for use in southern India, but this was a cheaper copy made by William Cary.

The second limitation was size. Roy had to have a special sprung-suspension carriage made to convey the first theodolite and its associated gear, pulled by two or four horses; in India, the Cary theodolite would be carried by large teams of porters. It was also difficult to get the theodolites to the tops of tall buildings and

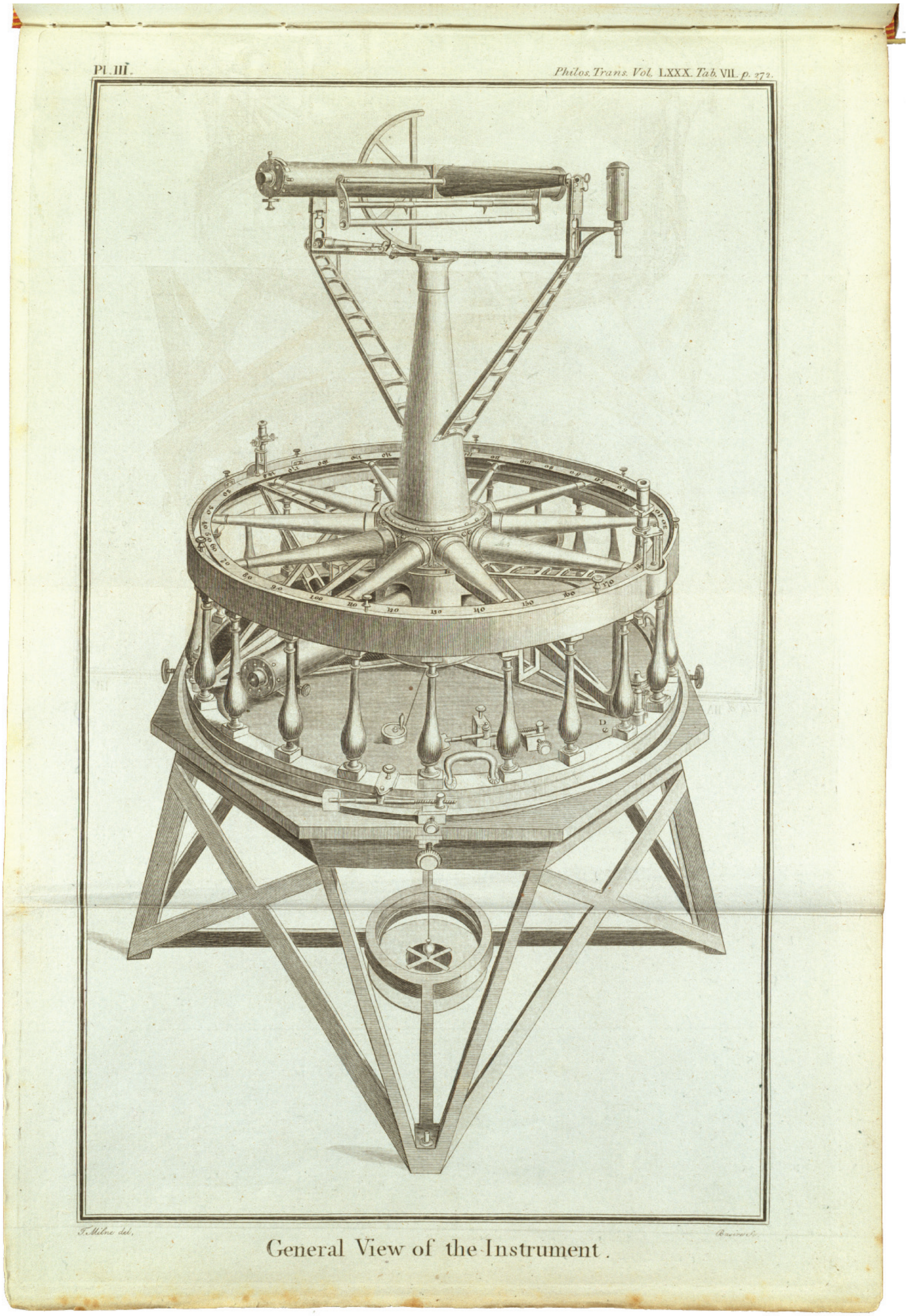

FIG. 412. THE "GENERAL VIEW" OF JESSE RAMSDEN'S FIRST GREAT THEODOLITE. As used by William Roy on the Greenwich-Paris triangulation; from Roy 1790, pl. 3. Image courtesy of the Science Museum/Science & Society Picture Library, London.

mountains, as needed in high-level geodetic surveys; Roy had built special scaffolds for his great theodolite (see fig. 262). Certainly, great theodolites were practicable only for institutions like the military engineering corps that possessed the necessary logistical resources to move them around (Widmalm 1990). The solution was to make smaller instruments with the same basic structural design, such as the 18-inch (0.458 m) theodolite of Ramsden commissioned by the Board of Ordnance in 1792 and delivered in 1795. In the nineteenth century, as the precision of engraving increased, the great three-footers were steadily replaced by smaller, more easily used, but equally precise theodolites.

MATTHEW H. EDNEY

SEE ALSO: Geodetic Surveying: (1) Enlightenment, (2) Great Britain

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Instruments for Distance Measuring.

CHAIN
PERAMBULATOR
LEVEL

Chain. Since antiquity, surveyors have measured the dimensions of portions of land with ropes and cords or with wooden staffs or rods (fig. 413). Their ropes were generally 15–30 meters in length, the rods—or poles, perches in French—much shorter at 3–5 meters. Rods became so common in medieval Europe that they lent their name to the common linear measure for land. The length of the physical rods, and so the length of the measure, was regulated within each community and accordingly varied widely. Although attempts were made as early as the thirteenth century to establish standard lengths for the rod by statute, local practices proved resilient. But in the early modern period, landowners, lawyers, and state officials variously promoted the use of statute measures through the use of a new tool: the measuring chain (fig. 414). Each chain comprised a series of

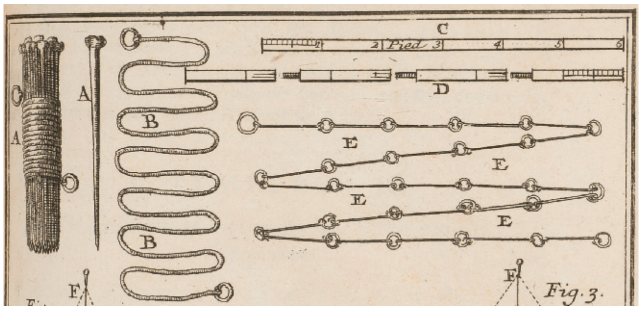
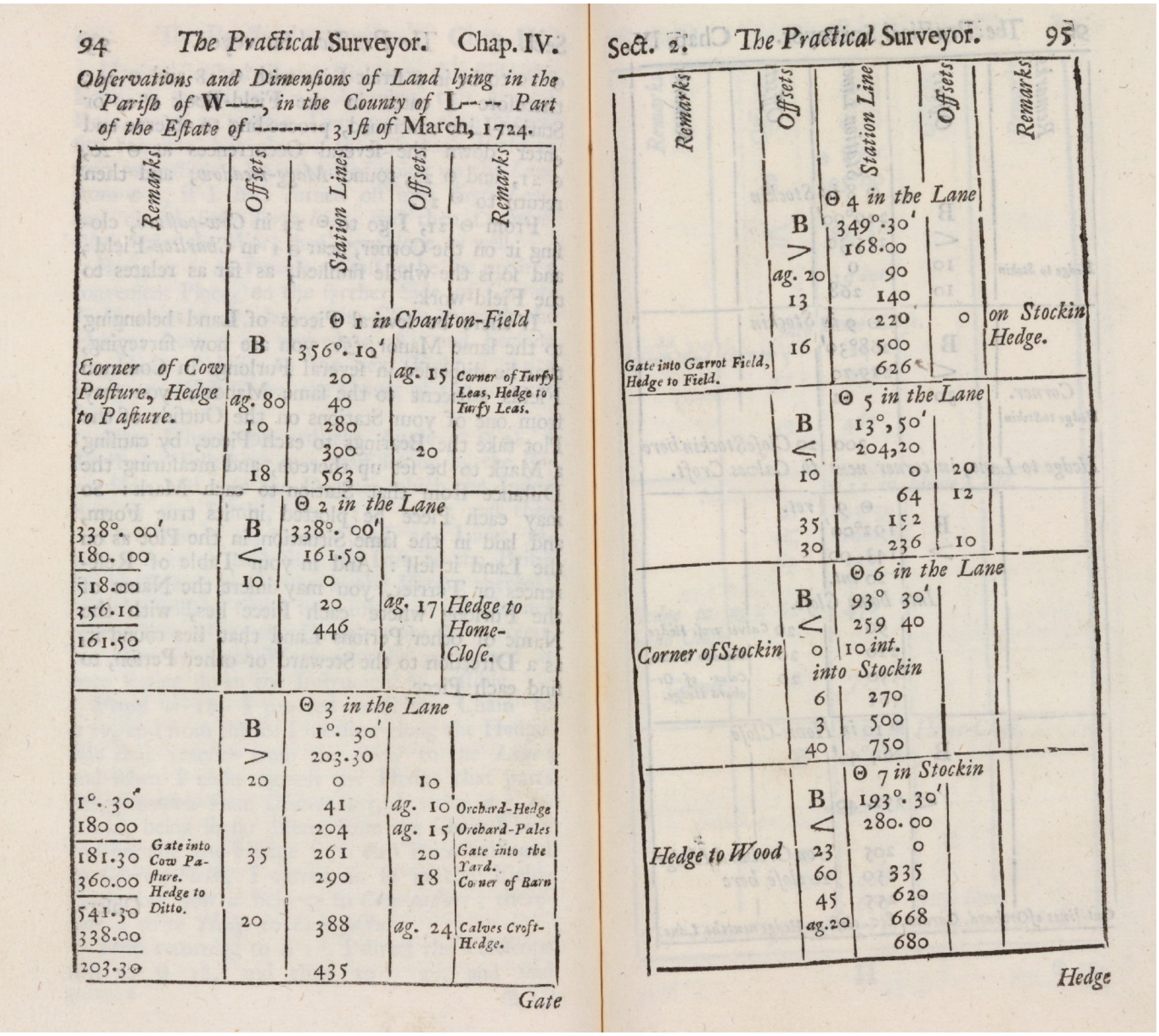


FIG. 413. CHAINS AND RELATED MEASURING DEVICES. Detail showing a measuring rope and picket (labeled A and B), a toise measuring stick (C), and a chain (E). From Bion 1709, pl. XI, opp. 128.
Image courtesy of the Bibliothèque nationale de France, Paris.

FIG. 414. SURVEYORS MEASURING A FIELD WITH A CHAIN. From Tobias Mayer, *Mathematische Atlas, in welchern auf 60 Tabellen alle Theile der Mathematie vorgestellet* (Augsburg: Johann Andreas Pfeffel, [1745]), frontispiece. In this detail note the use of stakes (also known as arrows or pickets) set up in a straight line to guide the chain.
Image courtesy of the Osher Map Library and Smith Center for Cartographic Education at the University of Southern Maine, Portland (OS-1745-5).



94 The Practical Surveyor. Chap. IV.

Obſervations and Dimenſions of Land lying in the Pariſh of W——, *in the County of* L-- -- *Part of the Eſtate of* -------- 3 1*ſt of* March, 1724.

Remarks	*Offsets*	*Station Lines*	*Offsets*	*Remarks*
		Θ 1 *in Charlton-Field*		
	B	356°. 10′		
Corner of Cow Paſture, Hedge to Paſture.		20	*ag.* 15	Corner of Turfy Leas, Hedge to Turfy Leas.
	ag. 80	40		
	10	280		
		300	20	
	18	563		
		Θ 2 *in the Lane*		
338°. 00′	B	338°. 00′		
180. 00	<	161.50		
518.00	10	0		
356.10		20	*ag.* 17	*Hedge to Home-Cloſe.*
161.50		446		
		Θ 3 *in the Lane*		
	B	1°. 30′		
	>	203.30		
	20	0	10	
1°. 30′		41	*ag.* 10	Orchard-Hedge
180 00		204	*ag.* 15	Orchard-Pales
181.30 Gate into Cow Paſture. Hedge to Ditto.	35	261	20	Gate into the Yard.
360.00		290	18	Corner of Barn
541.30	20	388	*ag.* 24	Calves Croft-Hedge.
338.00				
203.30		435		

Gate

Sect. 2. The Practical Surveyor. 95

Remarks	*Offsets*	*Station Line*	*Offsets*	*Remarks*
		Θ 4 *in the Lane*		
	B	349°.30′		
	>	168.00		
	ag. 20	90		
	13	140		
		220	0	*on Stockin Hedge.*
	16	500		
Gate into Garrot Field, Hedge to Field.		626		
		Θ 5 *in the Lane*		
	B	13°, 50′		
	<	204,20		
	10	0	20	
		64	12	
	35	152		
	30	236	10	
		Θ 6 *in the Lane*		
	B	93° 30′		
	<	259 40		
Corner of Stockin	0	10 *int.*		
	into Stockin			
	6	270		
	3	500		
	40	750		
		Θ 7 *in Stockin*		
	B	193°. 30′		
	<	280. 00		
Hedge to Wood	23	0		
	60	335		
	45	620		
	*ag.*20	668		
		680		

Hedge

FIG. 415. EXEMPLAR FIELDBOOK FOR CHAIN SURVEYING. From Samuel Wyld, *The Practical Surveyor, or, The Art of Land-Measuring, Made Easy* (London: Printed for J. Hooke . . . and J. Sisson, 1725), 94–95. "Observations and Dimensions of Land lying in the Parish of W——, in the County of L—— Part of the Estate of ——— 31st of March, 1724." In the center column, the surveyor recorded the bearings between each station Θ (representing a dot in a circle), the chained distances along the line from one station to the next; in the inner columns, the lengths of the offsets are recorded to the features described in the outer columns.
Size of the original: ca. 20 × 21 cm. Image courtesy of the National Library of Scotland, Edinburgh.

metal links of consistent length and were subject to less stretching than ropes. Eventually, the widespread adoption of physical chains led to the establishment of the new measures of "chain" and "link."

The use of chains for measuring land apparently began in the Netherlands. A request made to the Hof van Holland in 1557 mentioned that Simon Berthelmeesz. used a *reax* (chain) to measure land in Noord-Holland in 1534 or 1535. In a border dispute between Holland and Utrecht in 1539, surveyors had used a *lantmetersketten van vijf roeden Hollantsche mate*, that is, a land surveyor's chain of five Dutch roeden in length. Johannes Sems and Jan Pietersz. Dou described a surveyor's chain in *Practijck des lantmetens* (1600), noting that it would be either five or ten roeden in length, and each of its links would measure half a foot (Pouls 1997, 123).

In England, Cyprian Lucar mentioned "wyerlines" (wire lines) that measured two, three, or four rods in length and noted that they could be had from several dealers in London; his illustration of such a wyerline shows that is indeed a chain (Lucar 1590, 10, fig. between 2-3). Aaron Rathborne described a chain that was two English statute rods (33 ft. or 10.06 m) in length, divided into twenty equal "primes" (ten per rod), each prime into ten "seconds" (Rathborne 1616, 131–33). Edmund Gunter, professor of astronomy at Gresham College, London, suggested the use of a chain of four English statute rods (66 ft. or 20.12 m) comprising one hundred links because ten such chains make a furlong and ten square chains make a statute acre; surveyors only needed to know decimal arithmetic to calculate areas directly from their measurements (Gunter 1623, 37 [2d pagination]). While the more complex notation required of Rathborne's two-tier division made it unsuitable in this regard, it was still in use in the later seventeenth century (e.g., Blome 1686, 60). But by 1700, it would seem that all land in Britain was being measured by Gunter's chains, or at least by more manageable fifty-link chains two rods in length. Conversely, engineers commonly used a longer chain of one hundred feet (30.5 m). It is therefore important to distinguish between the physical chain and the abstract unit of length.

In France, Nicolas Bion (1709, 116) recorded that chaînes were generally one perche in length, each link being one pied (foot) long. The problem was that there was no standard length for the perche, varying as it did from eighteen to twenty-two pieds according to region. In southern Italy and Sicily, both urban architects and rural land assessors adopted chains of various lengths and subdivisions, from the four-perche (8.259 m) catena in Palermo to the Neapolitan catena of ten paces (18.457 m) (Zupko 1981, 88–99). Overall, outside of Britain, the length of the perche, and so the chain, was not rationalized until the introduction of the metric system after 1800.

When undertaking a detailed survey with a chain, the surveyor would measure both distances along the main lines and perpendicular "offsets" to distant features. The process is evident from the surveyor's fieldbook (fig. 415). To ensure that the offset was indeed perpendicular, surveyors could use either a cross—simply two fixed sights set at right angles—mounted on a pole (as with a *squadro*; see fig. 678) or the fixed sights of a surveyor's (or Holland) circle (see fig. 405).

It was well known throughout the eighteenth century that chains inevitably stretched through use. The links wore as they rubbed together, becoming thinner, so that the overall chain grew longer. Few people seem to have worried about this source of error, probably because it was much less than the errors caused by simply laying the chain directly on uneven ground, and certainly less than the errors caused by the stretching of ropes. But geodesists were concerned and so used wooden rods for the precise measurement of their baselines. Jean Picard, for instance, used four pike staves, each two toises long, that were joined together with screws (Picard 1671, 3). William Roy (1785), however, found in the measurement of a baseline for the Greenwich-Paris triangulation, that changes in humidity made wooden rods shrink and expand uncontrollably. After experimenting with glass rods, Roy finally settled on Jesse Ramsden's brand new chain, carefully laid out in coffers and with a sophisticated mechanism to pull it straight.

DEBORAH JEAN WARNER

SEE ALSO: Property Mapping; Topographical Surveying

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Perambulator. The perambulator—a wheel equipped with a mechanical counter to record directly the distance traveled—was widely adopted in the eighteenth century for the quick and efficient measurement of long distances. Perambulators were used, together with a compass for bearings, to survey roads and rivers for itineraries and route maps. Multiple route surveys provided the basis for regional surveys, such as those by James Rennell in Bengal in 1765–77. Perambulators were not intended for precise work: they measured not only distances up and down hills but also the horizontal movements of surveyors as they sought to negotiate the holes and mud of sprawling, unpaved roads; in compiling the routes into larger maps, geographers corrected for the resultant overmeasurement by arbitrarily reducing the distances by 10–15 percent (Edney 1997, 92–96, 100–102).

Terminology can be confusing. In addition to "perambulator" or "surveyor's wheel" (*roue d'arpenteur* in Denis Diderot and Jean Le Rond d'Alembert's *Encyclopédie*, 1751–72), the name of the counter was often applied to the whole instrument: whether "odometer" (*odomètre* was apparently the primary French label, although *perambulateur* can be found) or waywiser (an odometer applied to a carriage wheel). Some contemporaries also used "pedometer" (*pédomètre* or *compte pas*) for both odometers and perambulators, although properly speaking they are devices to count paces.

The later Renaissance practice of applying odometers to carriage wheels—multiplying a wheel's circumference by the number of its revolutions gave the distance traveled (Lindgren 2007, 490)—continued after 1650. In the 1720s, for example, Adam Friedrich Zürner in Saxony and Henry Beighton in Warwickshire both fixed odometers to carriages to measure road distances but, as Zürner's own depiction of this carriage suggests, such contrivances were limited to roads and good weather (see fig. 954). Surveyors could use chains for terrain that would bog down a carriage, but chains were simply too laborious to use over long distances. The solution, perhaps developed independently across Europe, was to attach an odometer to a single wheel that might be easily handled and guided by a surveyor (Costa 2002, 222). John Ogilby thus extolled the accuracy and ease of use of the perambulator for road surveys in the preface to his *Britannia* (1675).

The physical form of perambulators did vary. English perambulators typically featured a single stock attached to a small wooden wheel with a circumference of just half a pole or rod (8.25 ft., 2.5 m) (fig. 416). Other perambulators were larger: that depicted by Zürner had a wheel of about twice the circumference of the English standard; Beighton disparaged the small wheel used by Ogilby and advocated a wheel of a bit more than thirteen feet (3.96 m) circumference, as depicted on his 1728 map of Warwickshire (Costa 2002, 223–24) (see fig. 834). These more unwieldy perambulators were pushed like wheelbarrows. Still larger wheels seem to have been used in British India, held by handles that extended directly from the axle (Aris 1982, 67).

DEBORAH JEAN WARNER

FIG. 416. A TYPICAL ENGLISH PERAMBULATOR WITH A SINGLE STOCK, CIRCUMFERENCE OF 8.25 FEET. Two silvered brass dials record distances in increments of furlongs and poles on one and miles on the other. It was made in London by Thomas Heath and Tycho Wing sometime between 1751 and 1773.
Circumference of the wheel: 8.25 feet (0.5 pole). Image courtesy of the Graphic Arts Collection, National Museum of American History, Smithsonian Institution, Washington, D.C. (PH*318294).

SEE ALSO: Property Mapping; Topographical Surveying

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Level. A level is an instrument that determines a horizontal line, that is, a line along which the force of gravity is constant. Levels had been used since antiquity by masons and architects and by engineers building waterworks; when used with vertical, graduated measuring staffs, levels could also be used to measure differences in height. The horizontal line can be determined by one of two means: either a plumb bob is used to define the vertical, perpendicular to the horizontal, or the surface of a liquid defines the horizontal directly. Both techniques were employed during the Enlightenment (fig. 417).

Renaissance engineers used water levels featuring long water-filled troughs derived from the *chorobates* described by Vitruvius in his *De architectura* (first century B.C.) (Kiely 1947, 129–34), but these were little used after 1650. In 1684, Jean Picard described a balance level, in which a combination of telescope and plumb bob was hung from a stable frame, that he had used in laying out the water supply for Versailles. Christiaan Huygens and

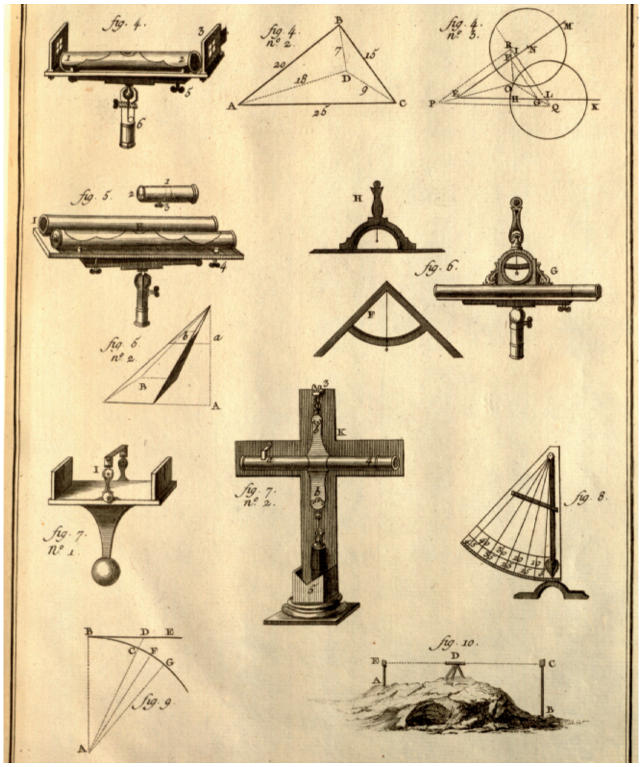

FIG. 417. DIAGRAMS OF DIVERSE LEVELS. Detail from Denis Diderot and Jean Le Rond d'Alembert, eds., *Encyclopédie, ou, Dictionnaire raisonné des sciences, des arts et des métiers,* 17 text vols. and 11 plate vols. (Paris: Briasson, David, Le Breton, Durand, 1751–72), *Recueil de planches, sur les sciences, les arts libéraux, et les arts méchaniques, avec leur explication*, plate vol. 5 (fourth installment) (1767), "Arpentage & Nivellement," pl. 1. Of particular interest are: some simple plumb levels (*niveaux simples*), the A-frame being an ancient design (fig. 6, middle right); Huygens's balance level (fig. 7, no. 2, middle center); two telescopic spirit levels (*niveaux d'air*), both simple (fig. 4, top left) and double (fig. 5, top left); and a simple diagram indicating how to use a level to observe in both directions to measure difference of height (*nivellement*; fig. 10, bottom right) (see also fig. 352).
Size of the entire original: 35.0 × 21.3 cm; size of detail: ca. 25.5 × 21.5 cm. Image courtesy of the Department of Special Collections, Memorial Library, University of Wisconsin–Madison.

Ole Rømer described similar instruments at about the same time (Kiely 1947, 141–42, fig. 73; Daumas 1972, 55–56, pl. 38).

Such instruments were simplified with the replacement of the plumb bob by a spirit level—a bubble of air trapped in a vial of liquid. Melchisédech Thévenot had described a spirit level in 1661 (Wess 1998, 352), and William Leybourn, in his *The Compleat Surveyor* (3d ed., 1674), mentioned having seen a telescopic level with a spirit level "contrived by Mr. R. Shotgrave" (Kiely 1947, 134). Once the sealing of the spirit bubble had been perfected, the telescopic spirit level became common. In London, Jonathan Sisson made an improved instrument, depicted on the frontispiece to Samuel Wyld's *The Practical Surveyor* (1725); a screw allowed the user to tilt the telescope until the spirit level indicated that it lay in the horizontal. In 1731, Thomas Heath advertised a double level with two telescopes, enabling the surveyor to sight both forward and backward without having to move and reset the instrument. Sisson responded, in 1734, with a Y level, in which a single telescope was placed in two Y-shaped supports; the telescope could thus be easily reversed without disturbing the instrument's overall adjustment. Refined by Georg Friedrich Brander in Augsburg and Jesse Ramsden in London, Sisson's new design proved enduring and would be used well into the nineteenth century (Bennett 1987, 151–52; Wess 1998).

DEBORAH JEAN WARNER

SEE ALSO: Height Measurement: Leveling; Property Mapping; Topographical Surveying: Enlightenment

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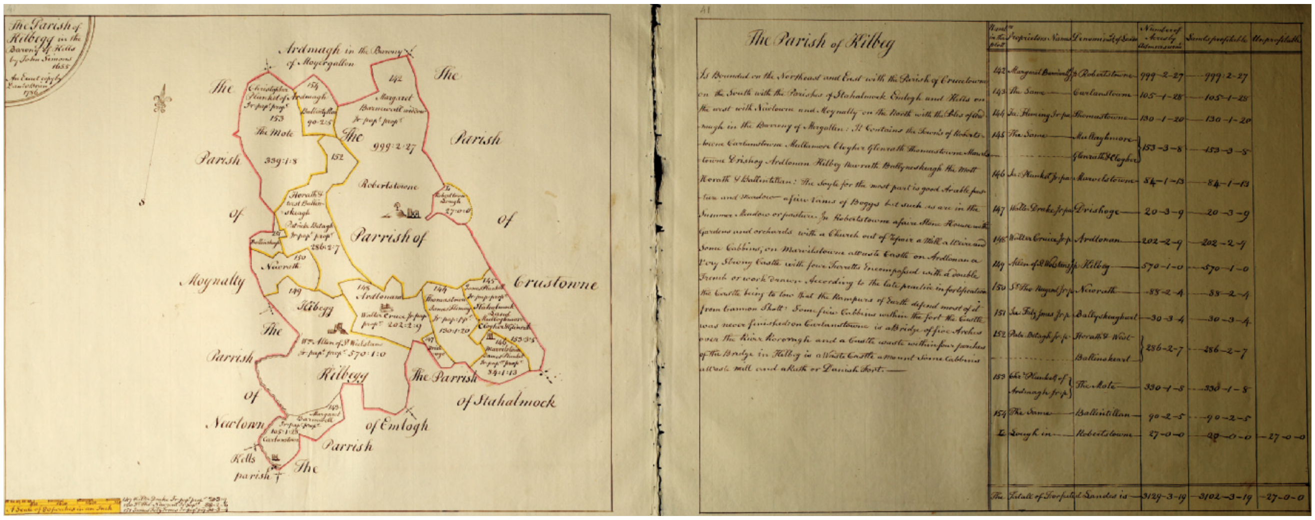
Ireland. See Great Britain

Irish Plantation Surveys. The normal method of dealing with the various rebellions that afflicted sixteenth- and seventeenth-century Ireland was to confiscate land from actual or potential rebels and redistribute it among new proprietors loyal to the English government, usually with the purpose of encouraging colonization or "plantation" by British immigrants. Inventories of landed property formed an essential part of such transactions, and it eventually became usual for these to include the taking of measurements and the drawing of large-scale maps. This was a process much facilitated by a nationwide mesh of ancient and irregularly shaped territorial divisions later known as townlands, smaller than a village or township in the English sense and larger than a single family farm. In most Irish plantation schemes, the land was forfeited in blocks large enough to be definable as one or more complete townland.

The first cartographic plantation surveys as defined above were made in the province of Munster between 1586 and 1589, using a "wire line" for distances and



The Parish of Kilbeg

Is Bounded on the Northeast and East with the Parish of Crucetowne on the South with the Parishes of Stahalmock Emlogh and Kells on the west with Newtowne and Moynally on the North with the [illegible] of Ardmagh in the Barony of Morgallen: It Contains the Towne's of Robertstowne Carlanstowne Mullamore Clogher Glenrath Thomastowne Marvelstowne Drishog Ardlonan Kilbeg Newrath Ballyneskeagh the Mott Herath & Ballintillan: The Soyle for the most part is good Arrable pasture and Meadow—a few lanes of Boggs but such as are in the Summer Meadow or pasture. In Robertstowne a faire Stone House with Gardens and orchards with a Church out of Repaire a Mill a Weire and Some Cabbins; on Marvelstowne a Waste Castle on Ardlonan a Very Strong Castle with four Turretts Encompassed with a double Trench or work drawn according to the late practice in fortification the Castle being so low that the Rampiers of Earth defend most of it from Cannon Shott: Some few Cabbins within the fort the Castle was never finished; on Carlanstowne is a Bridge of five Arches over the River Borongh and a Castle waste within four perches of the Bridge in Kilbeg is a Waste Castle a mount Some Cabbins a Waste mill and a Rath or Danish Fort.—

Numb. in the plott	Proprietors Names	Denominat. of Lands	Number of Acres by Admeasurem.	Lands profitable	Unprofitable
142	Margaret Barnwell pap	Robertstowne	999-2-27	999:2-27	
143	The Same	Carlanstowne	105-1-28	105-1-28	
144	Ja. Fleming Ir pap	Thomastowne	130-1-20	130-1-20	
145	The Same	Mullaghmore Glenrath & Clogher	153-3-8	153-3-8	
146	Ja. Plunket Ir pap	Marvelstowne	84-1-13	84-1-13	
147	Walter Drake Ir pap	Drishoge	20-3-9	20-3-9	
148	Walter Cruice Ir p	Ardlonan	202-2-9	202-2-9	
149	Allen of St Wolstans p	Kilbeg	570-1-0	570-1-0	
150	Sr Tho. Nugent Ir p	Newrath	88-2-4	88-2-4	
151	Ja. Fitz Jones Ir p	Ballyskeaghard	30-3-4	30-3-4	
152	Pat. Betagh Ir p	Herath & West Ballinskeart	286-2-7	286-2-7	
153	Chr. Plunkett of Ardmagh Ir p	The Mote	330-1-8	330-1-8	
154	The Same	Ballintillan	90-2-5	90-2-5	
L	Lough in	Robertstowne	27-0-0	00-0-0	27-0-0
The Totall of Forfeited Landes is			3129-3-19	3102-3-19	27-0-0

FIG. 418. DOWN SURVEY PARISH MAP AND TERRIER. "The Parish of Kilbegg in the Barony of Kells by John Simons 1655. An Exact Copy by Dan^l. Obrien 1786." This survey showed the boundaries and acreages of each block of land confiscated under the Cromwellian settlement together with the main natural and artificial features that were expected to influence its economic value or strategic significance. Landowners' names, acreages, property values, and sometimes further topographical information were given in written terriers accompanying the maps.

Size of the original: 23 × 28 cm (map); 23.5 × 28.2 cm (terrier). Image courtesy of the National Library of Ireland, Dublin (MS 715).

an unspecified "instrument" for angles (Andrews 1985, 34). They were not completely successful, largely owing to shortage of expert manpower, and for the next major confiscation scheme, in six counties of Ulster (1609–10), the maps were sketched from written lists of townlands and their "abutments," with estimated acreage figures that usually fell far short of the truth. A belated awareness of these deficiencies encouraged the adoption of more exact methods for a new series of plantation surveys, first in County Wexford (1611–17) and later in Counties Longford, Leitrim, and various parts of King's County, Queen's County, Tipperary, and Westmeath (1615–18). It was during this decade that the surveyor's chain makes its earliest appearance in the Irish documentary record.

In 1636–40, the earl of Strafford initiated an ambitious scheme for confiscating and mapping lands in the province of Connaught and adjoining areas. An early account of the Strafford Survey includes the phrase "surrounds made by the instrument" (Andrews 1985, 60). This is the first explicit evidence that the confiscated lands of seventeenth-century Ireland were measured by running a polygonal closed traverse around the townland boundaries.

The plantation surveys raise interesting questions of historical continuity. Ireland possessed an official surveyor general throughout the period of the surveys, but in practice this functionary had little to do with cartographic technicalities in either field or office. When extensive new surveys were necessary, they were directed by military engineers or academic scholars working on short-term contracts. Nor were the resulting maps preserved in any national repository. Many were lost, some at quite an early stage. The one authenticated common denominator between the earliest and the later surveys was the map scale of forty perches to an inch, first chosen in Elizabethan Munster and still in use (with a different perch) among Strafford's cartographers after half a century. Strafford's was also the first plantation admeasurement known to have a demonstrable influence on the famous parish-based Down Survey of 1655–59, which embraced nearly half the surface of the country and provides the earliest known Irish reference to the circumferentor or surveying compass. The Strafford-Down tradition was to resurface in the official surveys conducted by the Trustees for the sale of forfeited estates between 1700 and 1703. Both Down and Trustees maps were rather sparsely furnished, showing townland names, acreages, and boundaries, together with the divide between profitable and unprofitable lands, but not usually recording roads, fields, or any but the largest and most valuable buildings (fig. 418). They all included scales and north points but made no reference to latitude or longitude or to any general system of triangulation.

In personnel, techniques, and cartographic style the plantation surveys did much to influence private estate mapping in Ireland throughout the eighteenth century. They would have remained almost unknown to later map historians, however, but for the involvement in one of them of an original genius and polymath, Dr. William Petty. Much of Petty's achievement concerned the organization, staffing, and finance of the Down Survey. Cartographically, his importance lies in reforming the map of Ireland. Most of the earlier plantation surveys had been accompanied by small-scale regional index diagrams. Petty went further by having his surveyors measure the boundaries of 216 administrative divisions known as baronies (both forfeited and unforfeited) accurately enough to provide an adequate control network for a new and recognizably modern outline of the whole country. His national, provincial, and county maps were finally published by Petty himself in 1685, remaining the principal source for other small-scale maps of Ireland until the arrival of the Ordnance Survey in 1824.

J. H. ANDREWS

SEE ALSO: Administrative Cartography: Great Britain; Property Mapping: Great Britain; Statistics and Cartography

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Isobath. See Heights and Depths, Mapping of: Isobath

Isoline. The English definition of "isoline" is usefully given as: "A line along which values are, or are assumed to be, constant." Isoline may be considered a popular name for the more technical term "isarithm," derived from the Greek *isos* meaning equal and *arithmos* meaning number. An isarithm is defined as "a line which represents a constant value obtained from measurement at a series of points" (Neumann 1997, 184). (Note: isoline is a quantitative measure and is not appropriately used for qualitative attributes.) The isoline technique developed independently along two paths, both of which began in the sixteenth century (Wallis and Robinson 1987, 220–21). The utility of both paths received widespread acceptance and were put into regular use during the eighteenth century.

One line of development was that of the inferential technique of the isobath. After Philippe Buache's work on isobaths was published (illustrated by a map; see fig. 133) in the *memoires* of the Académie royale des sciences for 1752 (published in 1756), attention to the isobath greatly increased and its use for seas, coastlines, estuaries, and river bottoms expanded rapidly.

Another somewhat later use of this technique for describing heights rather than depths was to portray the topography of the land surface by means of contours. One could speculate that the problems of navigating the land surface were not as great and were different from sea navigation especially in critical coastal and port areas, and therefore contours were not as valuable information as isobaths for chart users. The other often cited reason for the time lag was the lack of collected data about elevations that could be used to create a meaningful contour map of the land surface (Wallis and Robinson 1987, 222). Some French engineers used isolines in a limited way on terrestrial maps following the manuscript memoir of Louis Milet de Mureau (1749) and teaching in the École du Génie de Mézières (1764) (Dainville 1958, 202–5). In 1782 Jean-Louis Dupain-Triel *père* published a diagram by Marc Bonifas, dit Du Carla, illustrating the theoretical concept of the contour as a method for showing the configuration of the land surface (fig. 419). The method was very well received, but the use of it was not widespread until just before the nineteenth century, when Jean-Louis Dupain-Triel *fils* published, in 1798–99, a map that tinted each layer between the isolines, an effect achieved through the use of aquatint (Robinson 1982, 213). This technique greatly enhanced the readability of isoline maps.

The second path of development of the concept of isolines arose from the mapping of lines of equal magnetic declination. By the early part of the sixteenth century, the variation between compass readings and true north-south lines was well known but still unexplainable. It became clear that if magnetic declination were systematic, then this information would be of value to navigators. Since magnetic declination, disregarding local anomalies, is systematic though not static, this potential aid to navigation became even more valuable for the numerous crossings of the large expanse of the Atlantic Ocean that began with the sixteenth century. The first map of the variation of magnetic declination is attributed to the Spaniard Alonso de Santa Cruz in 1536 (Robinson 1982, 84), and much attention to observing magnetic declination took place during the sixteenth and seventeenth centuries. The concept caught the imagination of scientists after Edmond Halley published a map of the magnetic declination of the Atlantic Ocean in 1701 (see fig. 348). Halley popularized the maps of "curve lines," his term for isogones. The greater number of curve line maps brought about by their utility led to an expanded study of geomagnetism throughout the eighteenth century. More voyages to obtain observations for the production of maps led to a world map of magnetic inclination in 1768 by Johan Carl Wilcke of Stockholm (Robinson 1982, 86) (fig. 420).

The increased attention to scientific measurement and the capabilities of sharing this information, characteristics of the Enlightenment, are thus visible in both lines of development of the isoline. From the publication of Halley's map in 1701 and Nicolaas Samuelsz. Cruquius's map of the Merwede River in 1729–30 (see figs. 33 and 801), both forms of isolines developed into regularly used cartographic techniques by the nineteenth century. Only after they were widely accepted was research directed toward their theoretical foundations; credit for recognizing the similarity between the two lines of development is given to Léon Lalanne in 1845 (Robinson 1982, 216–17). During the intervening period and since, literally hundreds of specialized terms such as "isobar," "isotherm," and "isohyet" have been defined (Gulley and Sinnhuber 1961), particularly in the fields of meteorology and climatology. The term "isoline" postdates the use of the technique by many years.

JOEL L. MORRISON

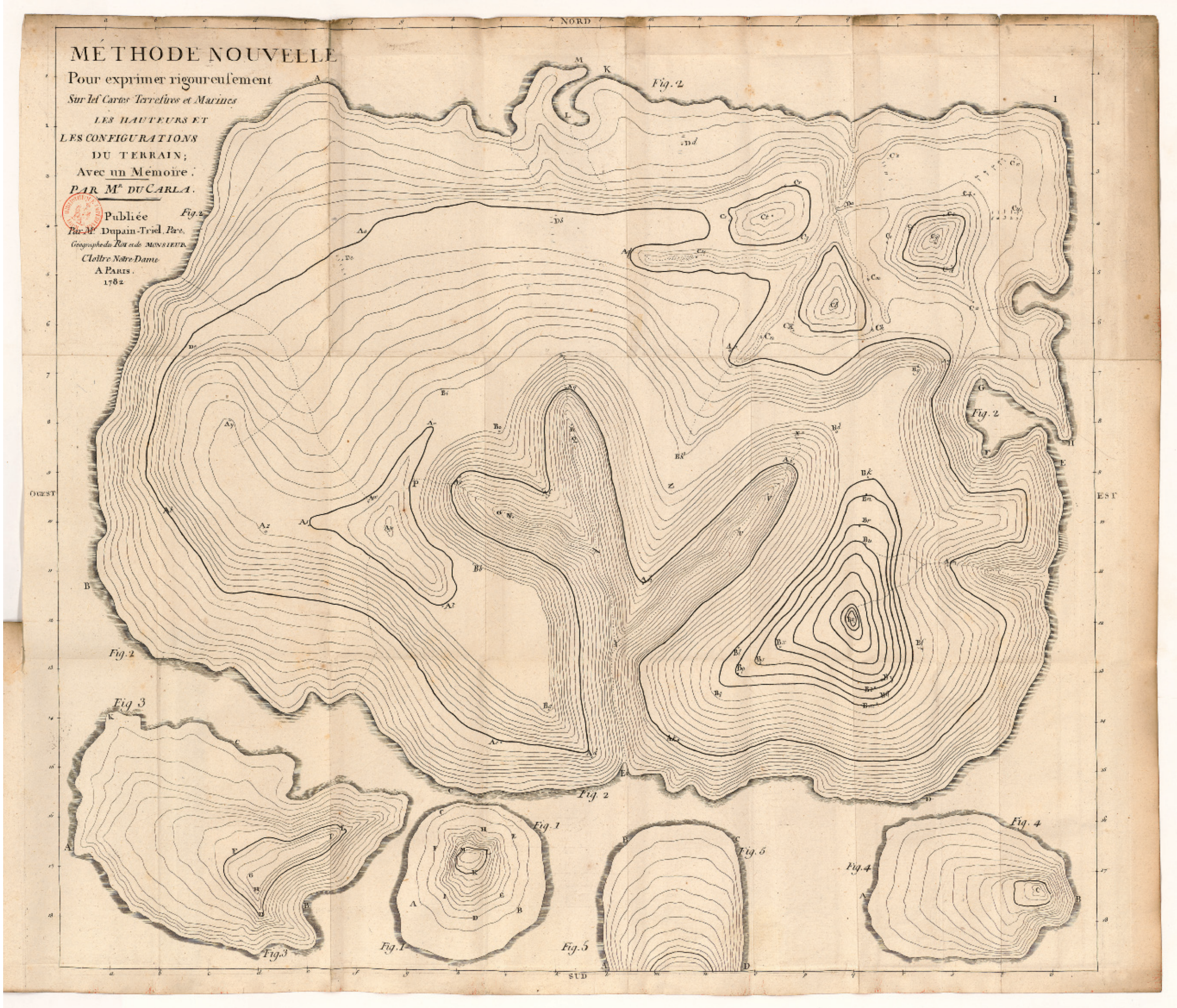

FIG. 419. MAP SHOWING DU CARLA'S PROPOSED METHOD FOR TERRAIN DEPICTION USING ISOLINE CONTOURS. The *Méthode nouvelle pour exprimer rigoureusement sur les cartes terrestres et marines les hauteurs et les configurations du terrain* was tipped into *Expression des nivellemens, ou Méthode nouvelle pour marquer rigoureusement sur les cartes terrestres & marines les hauteurs & les configurations du terrein . . . publiée par M. Dupain-Triel pere* (Paris: L. Cellot, 1782).
Size of the original: 54 × 71 cm. Image courtesy of the Bibliothèque nationale de France, Paris.

FIG. 420. JOHAN CARL WILCKE'S WORLD MAP OF INCLINATION, 1768. *Försök til en magnetisk inclinations charta,* 1:70,000,000, from Wilcke's "Försök til en magnetisk incinations-charta," *Kongl. Vetenskaps Academiens Handlingar* 29 (1768): 193–225, Tab. VI. Size of the original: 33 × 45 cm. Image courtesy of Ann-Sofie Persson/Kungliga biblioteket, Stockholm.

SEE ALSO: Eclipse Map, Solar; Heights and Depths, Mapping of: (1) Relief Depiction, (2) Isobath; Thematic Mapping

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Italian States. Signed in 1659 at the end of the Thirty Years' War, the Franco-Spanish "Peace of the Pyrenees" determined the new political structure of Italy. Most of the old states and dominions established by the 1559 Treaty of Cateau-Cambrésis were maintained, but there was a marked increase in Spanish control over the peninsula as a whole, with explicit Spanish hegemony being exercised over the Kingdom of Naples, the Kingdom of Sicily, Sardinia, and the State of Milan. As for the Papal States, their power in the north was extended with the annexation of the Duchy of Ferrara; the situation of the duchies of Parma and Modena and the two republics of Lucca and Genoa remained unchanged. Even further north, the Duchy of Savoy annexed the Marquisate of Saluzzo, while the fiefdom of Pinerolo was ceded to France.

This geopolitical framework underwent small but significant changes by the terms of the 1748 Treaty of Aix-la-Chapelle, which marked the end of the War of the Austrian Succession, itself the culmination of three long European conflicts: the Great Northern War (1700–1721), the War of the Spanish Succession (1701–14), and the War of the Polish Succession (1733–38). The Italian states sanctioned by this treaty remained in existence until the changes brought about by the Napoleonic Wars in the last decade of the eighteenth century. The major innovations sanctioned by the 1748 treaty were these: the independence of Naples and Sicily, which since 1734 had been united as the Kingdom of the Two Sicilies under the Bourbon monarch Carlo VII of Naples (Carlos III of Spain); the transfer of the State of Milan to Habsburg rule, which had initially taken place in 1706 and was then ratified by the Treaty of Utrecht in 1713; the recognition of Austrian influence over the Grand Duchy of Tuscany, which, due to the absence of a successor within the ruling dynasty, had in 1737 passed to Francesco Stefano, duke of Lorraine (later Francis I) and husband to Austrian empress Maria Theresa; and the extension of the Duchy of Savoy, which became the Kingdom of Sardinia and gained territory both on its French and Italian flanks (its territories extended as far as the River Ticino and also included the island of Sardinia, for which it had exchanged the island of Sicily, which was under Savoy rule from 1713 to 1721).

Despite small modifications of boundaries, certain changes in ruling houses, and, most significantly of all, constant economic and demographic growth in the capitals of individual states, overall stability prevailed from the mid-sixteenth century to the close of the eighteenth century. This situation led to the concentration of printing and publishing (hence cartographic) activities in a few centers of production. The high level of conflict between the Italian states themselves, plus the division of territory into the fiefdoms and estates of a few families, inevitably generated a large number of manuscript maps that not only defined landed property and boundaries but also served the various administrative ends of individual states and landowning families. When one considers who commissioned cartographic work and to what purpose, the division falls, broadly speaking, between manuscript cartography intended for political and administrative use and printed cartography serving more commercial or cultural purposes.

Italian archives, not only in the major cities (Turin, Milan, Venice, Modena, Parma, Genoa, Florence, Rome, and Naples) but also in almost all the communities that exerted some sort of territorial power, are particularly rich in the manuscript cartography created to meet the needs of the small but often complex machinery of state or local government. Commissioned chiefly by the old agents of state power (i.e., the large landowning families and the authorities responsible for the Church's landed properties), maps and *cabrei* produced at the beginning of this period still used cartographic techniques and symbols found in seventeenth-century or even late sixteenth-century work. Within these local contexts, modernization of the techniques and instruments of cartography came about slowly. The main concern was that the map be easy to read, hence the mapmaker frequently resorted to multiple systems of representation within the map itself, with the elevation of buildings shown flat against the surface of the drawing and perspective or axonometric renderings of small urban centers (and sometimes individual buildings). The authorities responsible for charting territory (boundaries, waterways, woodlands, roads) often trained their own draftsmen and surveyors, who then passed on this acquired heritage of techniques to their pupils.

It was only with the gradual establishment of geometrically based cadastres from the first quarter of the eighteenth century onward that the advent of techniques for precision surveying and detailed graphic rendition becomes apparent. These techniques not only changed cartography but also the very way in which the relation between the state and its subjects was envisaged, with the latter now seen as citizens and taxpayers. The subject of cadastres emerged as one of the great topics of debate in all Italian states during the eighteenth century, with illustrious economists, philosophers, and administrators all contributing to the discussion. In this way the Milanese *censimento* (Catasto Teresiano), ordered in 1718 by Charles VI of Austria, marks a turning point in topographical techniques and the methods used to survey open land and urban space.

Charged with the task of supervising the work on the Milanese cadastre and training the personnel involved, the Habsburg court mathematician, Johann Jakob Marinoni, created a corps of surveyors to His Imperial Majesty as well as perfecting the design of the plane table, which soon became the main instrument used in land surveying. Marinoni's "school" provided the training for some of the most important Italian cartographers of the eighteenth century, whose work spread a new expeditious method of draftsmanship. The survey of the city of Milan, carried out by the Venetian land surveyor Giovanni Filippini in 1720–22 and published as an engraving in 1734, was the first cadastral map of an Italian city, based on new principles of observation and measurement that could be repeated and checked. This effort was followed by Giovanni Battista Nolli's large map of Rome (1748; see fig. 609) and the map of Naples devised by Giovanni Carafa, duca di Noja, in 1750 and completed in 1775 (see fig. 880).

Though these latter works were not strictly cadastral maps, they were produced by men who had trained on the Milan cadastre. Another Milan surveyor, Andrea Chiesa, produced the twenty-sheet *Carta del Bolognese* (engraved in 1740–42), based on land surveying campaigns from 1732 to 1738 during which he used the plane table (Venturi 1992) (see fig. 843). One of Chiesa's pupils, Antonio Francesco Vandì, surveyed, drew, and engraved the first observed and measured map of the city of L'Aquila in 1753. In 1739–40, the Kingdom of Sardinia also undertook work on cadastral surveys, with similar projects following in Tuscany and the Duchy of Parma.

The manuscript maps in archives also include military cartography. Rarely translated into print, these maps were produced by the corps of engineer-geographers instituted during the course of the eighteenth century in various Italian states. The military engineer corps in Genoa was set up between 1710 and 1717, while that in the Kingdom of Sardinia, dating from 1738, formed the core of the nineteenth-century Ufficio Topografico in Turin. In Tuscany, the military engineer corps was established in 1739 and concerned itself almost exclusively with fortifications. The military engineer corps in the Duchy of Parma was established in 1760. With the advent of the Bourbon monarch Carlo VII, a corps of (primarily Spanish) military engineers was established in the Kingdom of Naples, whose primary task was the repair and maintenance of the kingdom's forts and fortifications.

Italian archives possess vast collections of maps produced by states or administrative bodies to serve political, military, or commercial ends. Examination of this material, which began in earnest in the 1980s, has already generated a number of catalogs, monographs, and exhibitions, resulting in a considerable reassessment of historical studies concerning Italian map production.

As for printed maps, the centers of production were the capital cities, especially Turin, Milan, Venice, Florence, Rome, and Naples—cities that had a monopoly on the production and sale of maps and atlases. These capitals also saw the first printed images of territory produced by local designers. For example, the *Carta generale de stati di sva altezza reale* (ca. 1:190,000; 1680) by the state engineer Giovanni Tommaso Borgonio was based on extant official maps of Piedmont combined with partial surveys of territory (see fig. 108). In 1692 in Naples, the first regional atlas of the kingdom, *Accuratissima, e nuova delineazione del Regno di Napoli*, was published (fig. 421) and appeared in two later editions, 1734 and 1794. Although a sizeable number of manuscript maps related to Venetian territory, the republic never assembled an overall regional map. However, the brothers Francesco Santini and Paolo Santini published numerous partial maps of the state in their *Atlas universel* (1776–80), as did Antonio Zatta in his *Atlante novissimo* (1779–85). Giovanni Antonio Rizzi Zannoni proposed mapping the entire Veneto in 1777, a project that came to nothing; however, he did carry out the surveys for and oversaw the engraving of the map of the environs of Padua (1779–81), the first geodetically based map at a topographical scale produced in Italy (fig. 422).

In Milan, despite the strong interest from the Austrian court, the creation of a printed map of the city's entire territory was lacking. Only in the last decade of the eighteenth century did the astronomers of the Brera Observatory, headed by Barnaba Oriani, use a large portion of the material from the cadastre to begin work on a map of Lombardy (ca. 1:86,400), of which only eight sheets under the title *Carta topografica del Milanese e Mantovano eseguita dietro le più esatte dimensioni geografiche ed osservazioni astronomiche* had been engraved by the time of the French invasion (see figs. 269 and 306). In 1798 the map was taken over by the Bureau topographique de l'armée d'Italie (the core of what subsequently became Milan's Deposito Generale della Guerra del Regno d'Italia); however, work on the project did not begin again until the following century.

Tuscany was among the few Italian states that had not established a proper cartographic institution until the Uffizio Topografico Militare in 1848. However, the accession of the house of Habsburg-Lorraine in Tuscany encouraged a growing jurisdictional reform movement, and the Habsburg regent, Emmanuel, comte de Richecourt, ordered a map of the territory to be prepared by Ferdinando Morozzi, a civil engineer who later served in one of the administrative offices of Grand Duke Pietro Leopoldo di Lorena (Leopold II). Over many years, Morozzi supervised the on-site surveying and compilation of the "Carta geografica del Granducato di Toscana" in twenty-four sheets, presented to the grand duke in 1784, a year before Morozzi's death. Lacking financial support, the map was prepared without any geodetic or astronomical observations and never printed except in small local extracts (Morozzi 1993).

The Papal States were the location of one of Italy's first major geodetic projects: the measurement of a large arc of meridian between Rome and Rimini by Jesuits Ruggiero Giuseppe Boscovich and Christopher Maire. That project was, in fact, linked with a survey of the entirety of the Papal States for the production of a three-sheet map, *Nuova carta geografica dello Stato Ecclesiastico* (1755, ca. 1:375,000; see fig. 90), the first regional

FIG. 421. *NUOVA ET ESATTISSIMA DESCRIZIONE DEL REGNO DI NAPOLI COLLE SVE XII PROVINCIE*, 1692. From Antonio Bulifon, *Accuratissima, e nuova delineazione del Regno di Napoli, con le sue provincie distinte* (Naples: A. Bulifon, 1692). A page from the first edition of the first regional atlas of the Kingdom of Naples. Engraved by Francesco Cassiano de Silva.

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FIG. 422. GIOVANNI ANTONIO RIZZI ZANNONI, *LA GRAN CARTA DEL PADOVANO,* 1780. Sheet three of the four published sheets (twelve were planned) of the map of the environs of Padua based on the survey by Rizzi Zannoni, prepared with triangulation and astronomical coordinates (ca. 1:20,000).

Size of the original: 47.7 × 64.3 cm. Image courtesy of Vladimiro Valerio. Private collection.

map based on astronomical and geodetic observations in the Italian states.

The eighteenth century witnessed the foundation of Italy's first national geographical (or topographical) institutions, whose legacy was particularly important for nineteenth-century Italian cartography. Turin and Naples were the first two capitals to set up agencies specifically designed to produce official cartographic depictions of the state; both, however, were established at different times and followed different procedures. First was the Ufficio di Topografia Reale of Piedmont, an important primary locus for the development of geographical knowledge. Although the actual date of its foundation is uncertain, it is likely that the first appointments of engineer-topographers in 1738 were early steps toward the establishment of the Ufficio, which became properly functional after the military campaigns of the 1740s. One of its first major projects was the preparation of maps of woodlands, carried out between 1752 and 1764 and involving some twenty-eight cartographers, including Antoine Durieu, one of the most important topographers in eighteenth-century Piedmont (Comba and Sereno 2002, 2:103–9, nos. 61–66; Pallière 2000, 128–37; Imarisio 1988). In 1777, official regulations reformed the Ufficio and established an institutionalized staff structure, with the agency becoming responsible not only for topographical surveys but also for the provision of training within a sort of internal school.

In Naples, the early core of a national topographical institute was founded in 1781, with the appointment of a Commissione per la Carta Geografica del Regno, under the scientific direction of Rizzi Zannoni

FIG. 423. GIOVANNI ANTONIO RIZZI ZANNONI, *NUOVA CARTA DELL'ITALIA SETTENTRIONALE*, 1799, CENTRAL SHEET. Responding to the needs encountered in the conflicts of the late eighteenth century, Rizzi Zannoni produced this five-sheet map of northern Italy in 1799. Size of the original: 62.4 × 93.8 cm. Image courtesy of Vladimiro Valerio. Private collection.

and administered by the economist Ferdinando Galiani. Initially set up as a temporary committee responsible for the revision of the map of the kingdom that had been engraved in Paris in 1769, in a few short years it became the state's official cartographic agency, producing all the cartographic works required by the court: not only a topographical map of the kingdom, the *Atlante geografico del Regno di Napoli* (1788–1812), and its first coastal charts, in the *Atlante marittimo delle Due Sicilie* (1785–92), but also the regional and geographical maps required by Neapolitan forces engaged in fighting within the territories of Italy (i.e., maps of boundaries with the Papal States, surveyed in 1794, *Nuova carta della Lombardia* [1795] and *Nuova carta dell'Italia settentrionale* [1799]) (fig. 423). Primarily due to the needs arising from the Napoleonic Wars in Italy, the Commissione was quickly transformed into a cartographic workshop, which under a variety of titles enjoyed a checkered career that continued right up to the unification of Italy in the latter half of the nineteenth century.

VLADIMIRO VALERIO

SEE ALSO: Academies of Science; Administrative Cartography; Boundary Surveying; Celestial Mapping; Geodetic Surveying; Geographical Mapping; Map Trade; Property Mapping; Thematic Mapping; Topographical Surveying; Urban Mapping

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