H

Hallwag Kümmerly+Frey AG (Switzerland). The origins of the map publisher Hallwag Kümmerly+Frey AG date from 1707, when Niklaus Emanuel Haller and Franz Rudolf Fels founded a book printing business in Bern, Switzerland. In 1912, the firm became Hallwag AG (from the names Haller and Wagner) after merging with Otto Richard Wagner's publishing house, founding publisher in 1905 of Europe's earliest automotive magazine, *Automobil-Revue*. Periodicals about other subjects followed despite poor business during World War I and the 1930s Depression. After World War II, the increased production of books covered topics like automobiles, horses, cooking, wine, and mountaineering, the last of these often authored by the firm's director, Walter Schmid. Hallwag AG also pioneered paperback publication in Europe. During the 1960s and 1970s Hallwag AG, with 700 employees, was among the largest printing and publishing houses in Switzerland.

The company began publishing maps in 1912 for automobile travel guides, produced in cooperation with the Automobil Club der Schweiz and the Touring Club Schweiz. The base maps for their products were purchased from the Swiss Landestopographie (today the Bundesamt für Landestopografie swisstopo) and city maps from the cartographic firm of Kümmerly+Frey, Bern. In 1933 Hallwag AG began producing its own maps and city guides, a program expanded after World War II. Hallwag's map covers were printed first in red and later in red and yellow, contrasting with the blue maps produced by Kümmerly+Frey, its larger map publishing competitor. Sometimes departing from maps for travelers, Hallwag published a map of the moon in 1967, showing the visible side at 1:5,000,000-scale and the far side at 1:15,000,000-scale, which received favorable reviews (Anonymous 1968).

A cartographic boom in the mid-1970s followed new leadership of Hallwag AG and its cartographic department. New titles were added, and publication of pocket atlases and city maps increased (fig. 354), as did cooperation with foreign partner publishers and worldwide marketing and distribution. While cartography remained a sideline for Hallwag AG, it was an important and popular one.

In 2000 Hallwag AG was acquired by the Mair Group (Stuttgart, Germany) and became a subsidiary of MairDumont. Hallwag AG shed nearly all its divisions between 1998 and 2001. At the end of 2001 it still consisted of the departments of cartography and fundraising. Both departments, moved to new business facilities in Schönbühl near Bern in November 2001.

In December 2001 Hallwag AG acquired the bankrupt Kümmerly+Frey's cartographic department, along with rights, programs, map stock, and the company name. On 11 March 2002 a new company, Hallwag Kümmerly+Frey AG, was formed. However, their two cartographic product lines were still marketed as separate brands and represented a comprehensive and very successful range of travel maps (table 19). Although publishing paper maps remained Hallwag AG's major activity, the firm also entered the electronic field by publishing touring maps on a DVD with plans for more to follow (Born 2010).

HANS-ULI FELDMANN

SEE ALSO: Atlas: (1) Thematic Atlas, (2) World Atlas; Marketing of Maps, Mass

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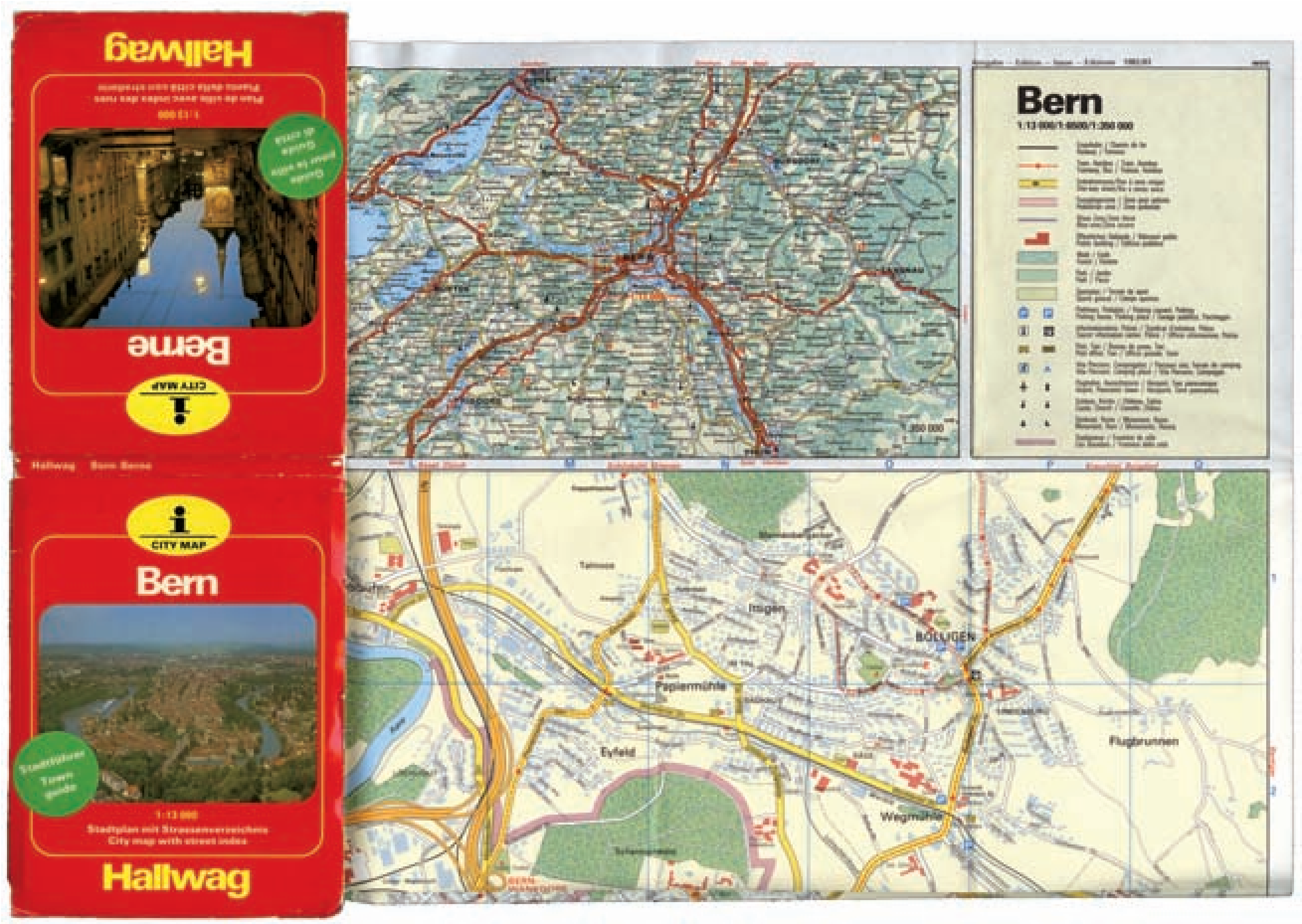

FIG. 354. DETAIL FROM HALLWAG'S *BERN/BERNE* 1:13,000, 1983. City map with public transport routes, map of surroundings. Protected by its glossy card cover printed in Hallwag's signature red and yellow, this map unfolds to show the city and to aid the traveler further with inset maps at various scales, a multilingual key to symbols, and a street index. Size of the entire map, unfolded: 67.5 × 82.7 cm; size of detail: 29.5 × 41.8 cm. Permission courtesy of Hallwag Kümmerly+Frey AG, Schönbühl.

TABLE 19. Map output of Hallwag Kümmerly+Frey, first decade of the twenty-first century

Map Type (total)	Hallwag	Kümmerly+Frey
Road maps (57)	19	38
European regional road maps (39)		39
Road atlases (14)	14	
City maps in conventional folding format (33)	25	8
City flash maps in accordion-fold format (17)	17	
Hiking maps (58)	25	33
Bicycle maps (21)		21

Hammond Map Company (U.S.). Caleb Stillson Hammond, a former sales representative for Rand McNally & Company, founded C. S. Hammond & Company in 1900, allegedly because of a salary dispute with the Chicago publisher. Within a decade his New York firm became one of the leading map publishers in the United States, issuing maps, atlases, globes, and "geographical appliances" of every description. Hammond, who was born in Vienna, Austria, on 27 November 1862 and died in New York City on 14 December 1929, formally incorporated his company in 1901, just after he issued his first publication, *The Handy Cook Book*. The author, Marion Harland, a celebrated writer and household expert, had passed the zenith of her fame, and the volume did not meet great success. This experience perhaps pushed Hammond to focus on publishing maps, a business in which he had twenty years of experience. In 1903 he produced two of his early maps, *Hammond's Complete Map of [the] Republic [of] Panama* and *The Clyde Steamship Co. Map of Florida Showing Routes and Railroad Connections*. Both were folded maps, and each heralded a key ingredient in the firm's later success: supplying popular maps of places in the news and producing maps on demand for a variety of commercial ventures.

During the first decade of the company's existence it published a variety of cartographic products, including a *New and Complete Map of Cuba* (1906), a *Complete Map of [the] Panama Canal* (1907), *Hammond's Atlas of New York City and the Metropolitan District* (1907), *Hammond's Alaska-Yukon-Pacific Atlas* (1909, in several versions, including one for the Bon Marche department-store firm), and *Hammond's Atlas of the State of Washington*, published for D. A. Hollowell in 1909, a substantial volume of over a hundred pages featuring both maps and pictures.

The Crossroads of the Pacific, a wall map on rollers attributed to Hammond and dated about 1908, is a circular map of the Pacific Ocean with Honolulu in the center, dramatically highlighted by the lines of shipping routes extending in every direction. This map, "Compiled for the Hawaii Promotion Committee," included data from 1907 in the marginal notes and utilized the Mercator projection to exhibit a design quality far exceeding a similar, but much smaller, map on page 54 of *Hammond's Commercial and Library Atlas of the World* (1912). The atlas version, *The Pacific Ocean Showing Distances between Hawaii and Principal Ports*, straightened the lines of the shipping routes, cluttered the image with detail, and assumed the look of a mechanically produced map rather than an artistic rendering. However bland, the atlas version pointed out the direction Hammond would go over the next century: producing ready-made commercial maps for the mass market following a rather ordinary standard format rather than carefully designed custom-made maps designed for particular projects (fig. 355). Atlases in particular propelled the publishing house into national prominence.

It appears that Hammond issued its first general atlas, a small (33.5 × 26 cm), 144-page collection of 142 color maps, in 1905. Subsequent editions of *Hammond's Modern Atlas of the World* appeared yearly up to 1932. By then the firm regularly produced a complete list of atlas products addressing a variety of reference needs and

FIG. 355. PHOTOGRAPH OF THE HAMMOND EDITORIAL DEPARTMENT. Size of the original: 10.4 × 17 cm. From *Maps* 1950, 13.

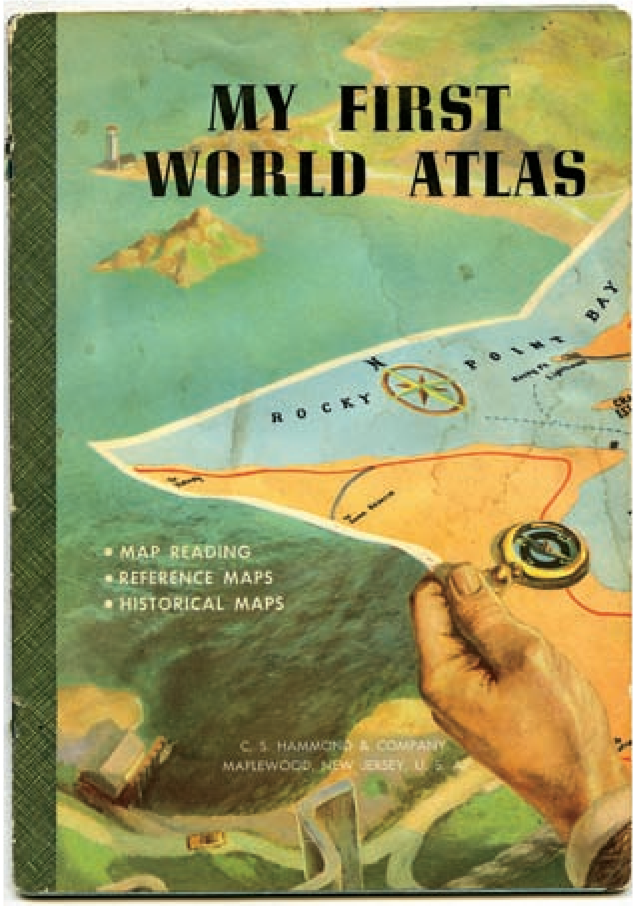

FIG. 356. COVER OF *MY FIRST WORLD ATLAS*, 1963. Size of the original: 25.4 × 17.9 cm. From *My First World Atlas* (Maplewood, N.J.: Hammond, 1963).

many budgets (fig. 356). The *Commercial and Library* atlas, which included the Hawaii map mentioned above, was an expensive, deluxe edition that combined several Hammond products, including a 1907 pamphlet on the Panama Canal.

In 1911 Hammond opened a retail store in the Hudson Terminal to sell a variety of books and maps from other publishers as well as its own products. Among the latter, its *General Catalogue of Maps, Atlases, Maprouting Systems, etc.* (1916) reached 228 pages, and was soon joined by a series of special catalogs featuring the firm's own productions, including war maps (1917), school maps (1920), and globes and map cabinets (1923). In the 1920s Hammond & Company became second only to Rand McNally as a publisher of maps for American audiences, regularly issuing road maps, reference atlases, globes, and a variety of specialty cartographic items for schools, newspaper stands, tourists, businesses, and libraries. In 1971 its seven trade-book atlases had an initial press run of 400,000 copies compared to the equivalent initial printing of 633,000 atlases by Rand McNally. In that year Hammond turned out about a billion maps of all sorts, but only a fifth of the total for the Chicago publisher, which then dominated the field of highway maps. In contrast to Rand McNally, which had its own printing facilities, Hammond did little production work at its own small plant and outsourced the printing of its major atlases.

Located at the center of American book publication, Hammond regularly supplied maps to other publishers for their encyclopedias, yearbooks, dictionaries, textbooks, and reference books of every description. A series of small, simple maps helped a number of stationery printers dress up their otherwise bland diaries. Hammond's "diary maps" proved to be quite profitable and found many uses in a wide variety of publications. They were regularly updated so that publishers of every description could obtain them at a moment's notice.

The "Hammond look" of its "ready-made" maps and atlas pages featured an abundance of place-names, soft colors, railroad routes in red, contour lines highlighted by different shades of coloring, and an overall mechanical look. Hammond atlases tended to be less expensive than competing volumes, which led to widespread distribution and impressive sales figures if not cartographic excellence. As a promotional venture in October 1971, Hammond offered a free pocket atlas to anyone who supplied a stamped, self-addressed envelope. Even so, the top-of-the-line atlases produced by Hammond were often deluxe editions. In 1971, for example, its 672-page *Medallion World Atlas*, weighing a hefty nine pounds, sold for $24.95, in contrast to Rand McNally's premium *Cosmopolitan World Atlas*, which had only 428 pages in a larger format and sold for $19.95. In that same year Hammond also offered a Hallmark atlas in a fancy binding for $39.95, a small fortune at the time. The major selling point of Hammond maps was their scientific accuracy, asserted by such design features as extending the contour lines of physical maps several miles offshore to mark the continental shelf.

In 1950 the firm's Publisher's Map Service Division issued a thirty-two-page prospectus outlining its services and reprinting sample maps from a dozen series of plates that it kept up-to-date for regular use by other publishers. The pamphlet emphasized the accuracy of the maps, their ready availability in a variety of sizes and formats, the ease of overprinting, the ability to vary the coloring, various ways simple maps could be enhanced by adding color plates, and the firm's employment of a modern indexing system using an IBM Electric Punched Card Sorting Machine. Hammond even stocked a series of maps in Spanish "to satisfy a considerable demand in Spanish America" (*Maps* 1950, 29). When the firm sent its archive to the Library of Congress in 2002, a file of over 12,000 cards documented the extent to which Hammond produced maps for other companies. Its small map of Jerusalem in biblical times, for example, appeared in dozens of publications.

When Caleb D. Hammond, Jr., grandson of the company's founder, took over the presidency of the firm in 1948, he brought with him a degree in mechanical engineering. His interest in new technologies and the digital production of maps pushed the company in those directions until it produced, in 1993, the first world atlas entirely generated by computer. Although the firm had traditionally been headquartered in New York City, some of its early imprints reported its home as Brooklyn. In the early 1950s the company relocated to Maplewood, New Jersey. Caleb Jr. stepped down as president in 1967 and retired as chairman in 1974, but in the mid-1980s, when some family members wanted to sell the firm, he and his son C. Dean Hammond III acquired a controlling interest and orchestrated a large investment in electronic technology. In 1999 the Langenscheidt Publishing Group purchased the privately held company and renamed it the Hammond World Atlas Corporation, afterward located in Springfield, New Jersey. At the time Langenscheidt also owned several major American regional map publishers.

In 2002, Langenscheidt donated the Hammond archives to the Library of Congress. The nearly 3,000 atlases and maps with the Hammond imprint in the library's collections, and the many thousands of books containing Hammond maps, attest to the firm's success in reaching its goal to publish "maps of every description for every conceivable purpose" (*Maps* 1950, 12).

GERALD A. DANZER

SEE ALSO: Atlas: (1) Thematic Atlas, (2) World Atlas; Marketing of Maps, Mass; Rand McNally & Company (U.S.); Road Mapping: Road Mapping in Canada and the United States; Wall Map; Wayfinding and Travel Maps: Indexed Street Map

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Rosenwein, Rifka. 1987. "Hammond Inc.'s New Chief Wants to Keep Map Maker in the Family." *Wall Street Journal*, 2 March, 1.

Harley, J(ohn) B(rian). The British historical geographer Brian Harley became the leading proponent of the post-1980 move toward the critical study of cartography. He demonstrated the validity of a multicultural approach to map history through the early volumes of *The History of Cartography*, coedited with David Woodward, and he influenced scholars in many disciplines with his passionate and provocative essays on cartography as the product of social power relations (most reprinted in Harley 2001). His intellectual trajectory exemplifies the changing intellectual climate of map studies in the second half of the twentieth century (see Edney 2005, 133–43, for a comprehensive bibliography).

Several obituaries and biographies narrate Harley's personal history (Woodward 1992; Edney 2005, 13–14; Laxton 2010). Born in 1932, he entered the University of Birmingham in 1952 after national service in the army. He completed the BA in 1955 and the PhD in 1960; his dissertation addressed medieval settlement patterns. He taught at University of Liverpool (1959–69), worked briefly as a sponsoring editor for David and Charles Publishers (1969–70), and then returned to academia at the University of Exeter in 1970. In 1986 he moved to the University of Wisconsin–Milwaukee. He died in Milwaukee in 1991.

As a young lecturer, Harley created a new academic niche: the study of the large-scale topographical maps of England and Wales that promised rich, largely unexplored evidence for the reconstruction of preindustrial landscapes. Specifically, he examined English county maps (1750–1835) and the official Ordnance Survey mapping (after 1790); he would also come to study the large-scale mapping undertaken during the American Revolution (1775–83). Harley evaluated their limits as sources of geographical evidence by exploring the careers of their makers, the surveying techniques behind their production, the reasons for their preparation, and their consistency in representing each category of geographical feature (fig. 357). His goal was a refined appreciation that geometrical and topographical error potentially stemmed from multiple factors, not simply from negligent observation and measurement. He produced a substantial scholarly corpus. In addition to essays and monographs on particular surveys and maps, he prepared facsimile publications with lengthy introductions to make the maps available to other researchers and guides to map history for lay researchers. He also prepared innovative methodological statements that sought to codify the traditional processes of map interpretation according to historians' established canons of criticism (Edney 2005, 19–31).

In the 1970s, historical geographers' use of early maps to reconstruct the geographical concepts held by past peoples attracted Harley's attention. In order to provide method and rigor to such studies—so as to ensure the validity of arguments that certain maps represent a cul-

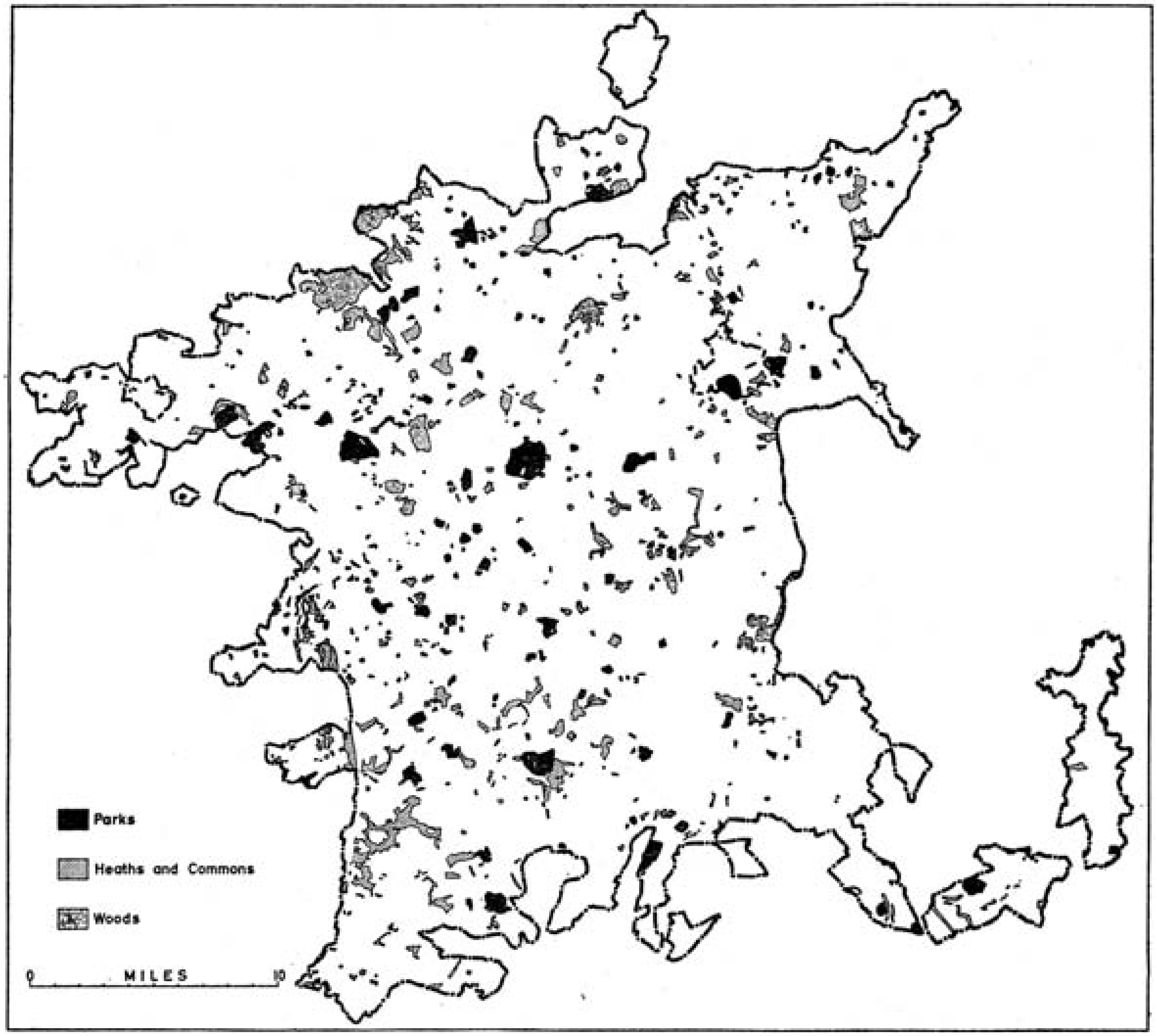

FIG. 357. LAND USE IN WORCESTERSHIRE, 1822. Harley's reconstruction of early nineteenth-century land use in Worcestershire exemplifies his initial focus on assessing the worth of large-scale maps as evidentiary sources for historical geographers and other historians.

Size of the original: 13.8 × 15.3 cm. From J. B. Harley, *Christopher Greenwood: County Map-Maker, and His Worcestershire Map of 1822* (Worcester: Worcestershire Historical Society, 1962), 45 (fig. 8). Permission courtesy of the Worcestershire Historical Society.

tural or social mind-set—Harley faced the problem of inducing valid generalizations about map use from scattered and partial archival evidence. The models of cartographic communication then in vogue were not helpful: they conceptualized a closed system between mapmaker and map user. By contrast, Harley sought to understand differential access to maps, and that required the modeling of an open, social system. Lacking guidance in such modeling, Harley could only prepare a preliminary categorization of types of map use as suggested by the empirical record (Edney 2005, 33–50).

Already dissatisfied with the character of the history of cartography as a field of study, Harley's growing appreciation of cartography as an open system could only persuade him further of the need for reform. By 1977 he and Woodward had decided to prepare a comprehensive and inclusive work of reference around which a well-structured discipline might coalesce. The result was *The History of Cartography*, a multivolume work that would become the cornerstone of a sociocultural approach to map history (Edney 2005, 51–56).

Harley also began to think about defining a more formal and less pragmatic conceptual foundation for the field. Prompted by the example set by other historical geographers, Harley now began to adapt theoretical frameworks from other fields in order to understand cartography as an open system. His first attempt, in 1979, featured Roman Jakobson's structuralist model of language (Edney 2005, 57–62). Collaborating with geographer M. J. Blakemore, Harley soon reconfigured this precise model into the general principle that cartography functions as a kind of language. Only by keeping this principle in mind could map historians avoid the undeniable flaws of traditional approaches to map history. Blakemore and Harley (1980) rejected any direct analogy between "map language" and spoken language and posited that maps function in a manner akin to the graphic structures of Renaissance art by embodying both literal and symbolic meaning. Maps should therefore be studied through Erwin Panofsky's art historical methodology of iconography (Edney 2005, 63–78).

Key to Harley's tentative reading of both structural linguistics and iconography was his understanding that the symbolic level of map meaning was ideologically determined. Given that most modern mapping had roots in the activities of states and their constituent social groups, Harley began to address the institution of the state as the primary determinant of cartographic ideology (Edney 2005, 78–83). This argument was first clearly manifested in the conclusion to volume one of *The History of Cartography* (1987), where it served as a filter by which Harley and Woodward could summarize the volume. Even so, this commentary was couched only in the most general of terms because linguistic and iconographic models cannot give insight into social structures.

Led by other geographers' engagement with social theory, Harley finally began to work with conceptual frameworks that permitted cartography to be understood as an open system and so began to explore the relationship between cartography and social power. Starting with "Maps, Knowledge, and Power" in 1988 (Harley 2001, 51–81), in which he introduced map historians to Michel Foucault's analyses of the workings of power, Harley quickly produced several provocative essays. He grew quite polemical, as when he exposed modern cartography's ideological underpinnings in his most renowned essay, "Deconstructing the Map," published in 1989 (Harley 2001, 149–68). In all of this work Harley sought to answer basic questions about how maps express power relations and what have been the social effects of that expression, both in the past and in the present. His work commanded the attention of cartographers and historians and demonstrated the necessity of a critical approach to cartography (Edney 2005, 85–111).

With hindsight, we can identify several problems with Harley's cherry picking of concepts and quotations from Foucault, Jacques Derrida, and other social and cultural theorists (Belyea 1992; Wood 1993; Edney 2005). For example, he confused terribly Foucault's basic distinction between juridical power and power/knowledge. He also remained convinced that the mapmaker, not the map user, determines each map's meaning, and he therefore failed to develop a sophisticated understanding of discourse. He remained committed to interpreting two levels of map meaning, the literal and the ideologically symbolic, rather than the single level posited by poststructuralist theory.

Yet in 1990 the general paucity of theorizing about maps meant that there were few cartographers or historians of cartography who could level such criticism. Map scholars could only react. Those committed to studying cartography as a closed system mostly rejected Harley's arguments as irrelevant to their concerns (e.g., J. H. Andrews in Harley 2001, 1–32). Those who already appreciated that cartography formed part of a larger sociocultural system found Harley's arguments revelatory: Harley justified their misgivings and gave them license to pursue critical studies. Perhaps most important, Harley's essays revealed to scholars in other fields that cartography was not some esoteric technical specialty but could be analyzed like any other aspect of human culture; Harley made maps intellectually accessible and a valid subject of study across the humanities and social sciences. Ultimately, the lasting value of Harley's later work lies not in what he wrote but in the example he set as a trail-blazing and reform-minded critic.

MATTHEW H. EDNEY

SEE ALSO: Academic Paradigms in Cartography; Historical Geography and Cartography; Histories of Cartography; History of Cartography Project; Social Theory and Cartography; Woodward, David

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Woodward, David. 1992. "J. B. Harley (1932–1991)." *Imago Mundi* 44:120–25.

Harrison, Richard Edes. Richard Edes Harrison was born on 11 March 1901, in Baltimore, Maryland. Harrison redefined the intersection among the art, science, and rhetoric of cartography. His prolific career, spanning the 1930s to the 1970s, shaped the theory and practice of journalistic cartography. Harrison is best known for stunningly creative maps that captured the popular imagination. He received an undergraduate degree in zoology from Yale College in 1923 and a second degree in architecture from the Yale School of Fine Arts in 1930. Between programs he worked as a scientific illustrator and architectural designer and draftsman. On graduation in 1930, Harrison worked for an interior decorator in New York City, designing everything from houses to ashtrays. The *Fortune* maps he designed generated "a distinctive and original style of mapmaking, which set the pattern for American journalistic cartography" (Ristow 1957, 375). His maps are remarkable achievements in geographic visualization, designed with a free-thinking graphic flair, impeccably executed with precise linework, and underpinned by an exquisite color sense.

Harrison's "accidental" cartographic career began with a 1932 map for *Time*. He referred to the map as a "little turkey" and wondered why his "cartographic career wasn't nipped in the bud" (Ristow 1957, 384). Despite a lack of formal training in either geography or cartography, Harrison became a preeminent freelance cartographer, staff cartographer, and consultant in business, education, and government. His work appeared in *Time*, *Fortune*, and *Life*; he made maps for books, atlases, and school texts; and he was a consultant for the Office of Strategic Services and *The National Atlas of the United States of America* (fig. 358). Harrison was lauded by peers with the American Geographical Society's Miller Medal in 1968 and appointed map supplement editor for the *Annals of the Association of American Geographers*. He died in New York City on 5 January 1994. (For further biographical details see Zelinsky 1995).

For Harrison, geography was the mother science of cartography, and his goal was to foster the geographical imagination (Harrison 1944). He saw maps as powerful and persuasive ways of illustrating geographic ideas. By breaking with traditions of American cartography that had inculcated an unthinking "map conditioning," Harrison developed a characteristic style for unorthodox maps by reintroducing projections and putting them to new uses. His polar azimuthal projection for the August 1941 *Fortune* became emblematic of the air age view of the world. The orthographic projection for the May 1943 *Fortune* pioneered a tradition of maps with near-photographic verisimilitude to the globe. He varied viewing angles and azimuths through an "eye in the sky" approach (fig. 359). These maps gave over-the-horizon views, with the horizon arc broken by exaggerated relief depicted with hill shading and hypsometric graded color tints. Among the clever touches were small globes showing the portion of earth's surface represented by the map outlined in red, together with an arrow indicating viewing azimuth. Harrison saw his maps as ways of expressing new geostrategic relationships and as complements to, not substitutes for, traditional maps (Henrikson 1975).

FIG. 358. DETAIL OF U.S. NORTHWESTERN COAST FROM *SHADED RELIEF*, 1969, BY RICHARD EDES HARRISON.

Size of the entire original: ca. 42.5 × 65.1 cm; size of detail: 13 × 8.4 cm. From U.S. Geological Survey, *The National Atlas of the United States of America*, ed. Arch C. Gerlach (Washington, D.C.: [Department of the Interior], 1970), 56–57.

Harrison's work was distinctive because of formal training in graphic design. He was flexible and creative, willing to experiment in the process of map design. While he saw himself as an iconoclastic maverick, forcefully expressing views on everything from atlas design to the training of mapmakers, he earned the respect of most fellow cartographers. He blended innovation with tradition, using air brushes to apply color and yet decrying the influence of lettering guides, preferring the discipline of hand lettering.

Harrison is perhaps the preeminent practitioner of

FIG. 359. RICHARD EDES HARRISON, *EUROPE FROM THE EAST*.
Size of the original: 34.6 × 55.3 cm. From Richard Edes Harrison, *Look at the World: The Fortune Atlas for World Strategy* (New York: Alfred A. Knopf, 1944), 30–31.

the art of mid-twentieth-century cartography (Schulten 1998). He influenced other cartographers, notably Erwin Raisz and Hal Shelton, and drew base maps for R. Buckminster Fuller's "Dymaxion World" (see fig. 739) and Irving Fisher's icosahedron Likaglobe. His work predates satellite-based remote sensing and yet foreshadows its impact. His approach to map design is based on the intuitive eye of the self-taught cartographer: "If it looks right, it is right." His style is artistic and yet grounded in the science of projections: it is expressive and yet scientifically accurate and precise.

Harrison's impact is mixed: despite few students, and therefore no disciples, he had—and has—many admirers. In a sample of three popular American college-level cartography textbooks, one contains no reference to him, a second has one image, and a third has three references. Even so, Harrison's work stays with us through the emblem of the United Nations (see fig. 22): the design, by Donal McLaughlin, is based on a Harrison map. For one who believed in the power of the geographical imagination, this is a fitting memorial.

ROGER M. DOWNS

SEE ALSO: Air-Age Globalism; Journalistic Cartography; Oblique and Perspective Views

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Harvard Laboratory for Computer Graphics and Spatial Analysis (U.S.). In its twenty-six-year history, the Harvard Laboratory for Computer Graphics and Spatial Analysis contributed to the theory and practice of cartography in diverse ways, including: (1) pioneering computer mapping packages (SYMAP, SYMVU, CALFORM, ASPEX, and ODYSSEY); (2) innovative theories of geographic surfaces; (3) development and demonstration of the theory of topological cartographic data structures and related software (ODYSSEY) that provided basic building blocks for modern geographic information systems (GIS), including polygon overlay; (4) graphic techniques for displaying spatial-temporal data using time-lapse movies and holograms; (5) conferences for practicing professionals and case study descriptions of applications of automated cartography; (6) public promotion of automated cartography through example maps in national publications; and (7) demonstration projects using the Laboratory's cartographic software to serve clients within the university as well as external public and private organizations. The Laboratory developed and distributed some of the earliest and most widely used computer mapping software and cartographic databases of the 1970s and 1980s.

Howard T. Fisher founded the Laboratory for Computer Graphics in spring 1965 with a $294,000 grant from the Ford Foundation. The grant recognized a computer mapping package known as SYMAP (for displaying surface and choropleth maps on a line printer), which Fisher had developed in 1964 at Northwestern University's Technological Institute. Initially affiliated with Harvard's Department of City and Regional Planning, the Laboratory functioned as a teaching and service organization to academic departments in the Graduate School of Design (GSD). Joint academic appointments were provided for senior members of the Laboratory in three GSD departments: City and Regional Planning, Landscape Architecture, and Architecture. The Laboratory's computer mapping research and service activities were located in the basement of Harvard's Memorial Hall, where work on the refinement of SYMAP led to other mapping software, including SYMVU (for rendering perspective and orthographic views of three-dimensional surfaces on a pen plotter) (fig. 360), CALFORM (for displaying choropleth maps on a pen plotter), and ASPEX (for displaying surfaces interactively). In addition to distributing its software, the Laboratory devel-

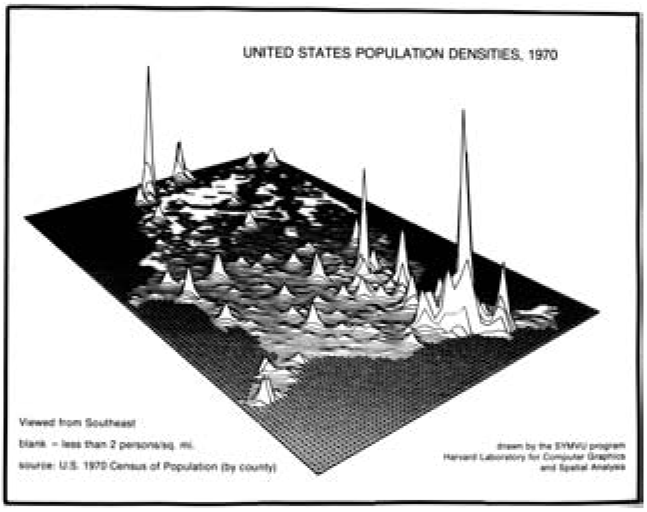

FIG. 360. *UNITED STATES POPULATION DENSITIES, 1970*, SYMVU.
Size of the original: 19.9 × 25.3 cm. From Harvard Laboratory for Computer Graphics and Spatial Analysis, *Lab-Log*, July 1978, inside front cover. Permission courtesy of the Frances Loeb Library, Harvard University Graduate School of Design.

oped a correspondence course and undertook service contracts to demonstrate applications of its software. The Laboratory published an annual *Red Book* and the occasional newsletter *Context*, both of which featured examples of its research and service projects. Training programs were offered at Harvard as well as at remote sites such as Manila (1976) and The Hague (1978).

After Fisher's retirement in July 1968, the Laboratory was renamed the Laboratory for Computer Graphics and Spatial Analysis. Under the direction of William Warntz, it became a part of a new Harvard Center for Environmental Design Studies within the GSD. Research focused increasingly on theoretical geography and the theory of surfaces and networks as they related to spatial structures and processes. The Office of Naval Research (ONR) and the National Science Foundation (NSF) funded this research. In 1971 Warntz moved to the University of Western Ontario, and Allan H. Schmidt was appointed acting director. In October 1972 the Laboratory moved to Gund Hall. Work was supported by a combination of local and federal government contracts, plus income from the sale of the Laboratory's software, cartographic databases, and publications, all listed in the Laboratory's direct mail catalog *Lab-Log* (fig. 361). Correspondence courses, user conferences, and professional continuing education programs and seminars provided additional income.

In 1975 Brian J. L. Berry was named the director and Schmidt the executive director. Additional NSF grants supported the work of Nicholas R. Chrisman, Thomas K. Peucker (later Poiker), and Schmidt. Research focused on topological cartographic data structures as a foundation for GIS. Schmidt developed an early (1967) animated time series map (online, YouTube "SYMAP Time Lapse Movie Depicting Growth of Lansing, MI 1850–1965"). Another contributor, Scott Morehouse, worked on ODYSSEY GIS software (fig. 362), and later worked for Environmental Systems Research Institute (ESRI) while Geoffrey Dutton contributed in the areas of animated holographic mapping, automated information retrieval, and statistical time series. Dutton went on to found Spatial Effects, a firm formed to help clients analyze spatial data. The Laboratory expanded its software dissemination, professional education programs, and publication activities. As computer technology evolved in the 1960s and 1970s, the Laboratory kept pace with developments by moving from printer symbol output to line plotters (both ink and film), and interactive cathode ray tube (CRT) displays.

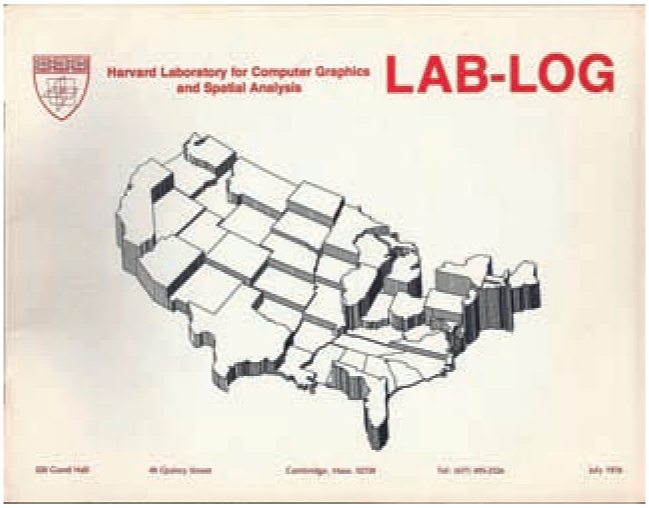

FIG. 361. *FIRST AND SECOND GENERATION IMMIGRANTS, 1970*, PRISM.
Size of the original: 21.6 × 27.7 cm. From Harvard Laboratory for Computer Graphics and Spatial Analysis, *Lab-Log*, July 1978, front cover. Permission courtesy of the Frances Loeb Library, Harvard University Graduate School of Design.

Numerous public and private organizations supported the Laboratory's work. A key sponsor was the Ford Foundation, which provided initial funding as well as support for Fisher's book *Mapping Information* (1982). Between 1968 and 1971 the ONR and the NSF funded research on the geography and properties of surfaces undertaken by Warntz, Michael J. Woldenberg, and Carlos Ernesto S. Lindgren. In the 1970s the NSF funded Chrisman's and Peucker's work on topological information systems, Eric Teicholz's joint research with Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), and several conferences, including the First International Advanced Study Symposium on Topological Data Structures for Geographic Information Systems, held in October 1977, and the International Users' Conference on Computer Mapping Software and Data Bases, held in 1978 and organized by Schmidt. Other sponsors of the symposium included the U.S. Geological Survey (USGS), the U.S. Census Bureau, and the American Society of Photogrammetry. Data structures and data sources evolved in concert with federal programs and standards, such as the USGS, the Department of Defense, and the Census Bureau, which called on the Laboratory's expertise when improving its Dual Independent Map Encoding (DIME) files. From 1975 to 1980, national publications such as *Newsweek*, *National Geographic*, the *Boston Globe*, *Harvard Business Review*, the *Wall Street Journal*, *Time*, and *Business Week* reported on the Laboratory's work.

The Laboratory also promoted its work through its own publications. Its *Red Book*, published annually from 1965 until 1974, contained a total of 125 narrative and graphic project descriptions. In 1978–79, Dutton edited the *Harvard Papers on Geographic Information Systems*, an eight-volume set based on the previously mentioned Symposium on Topological Data Structures.

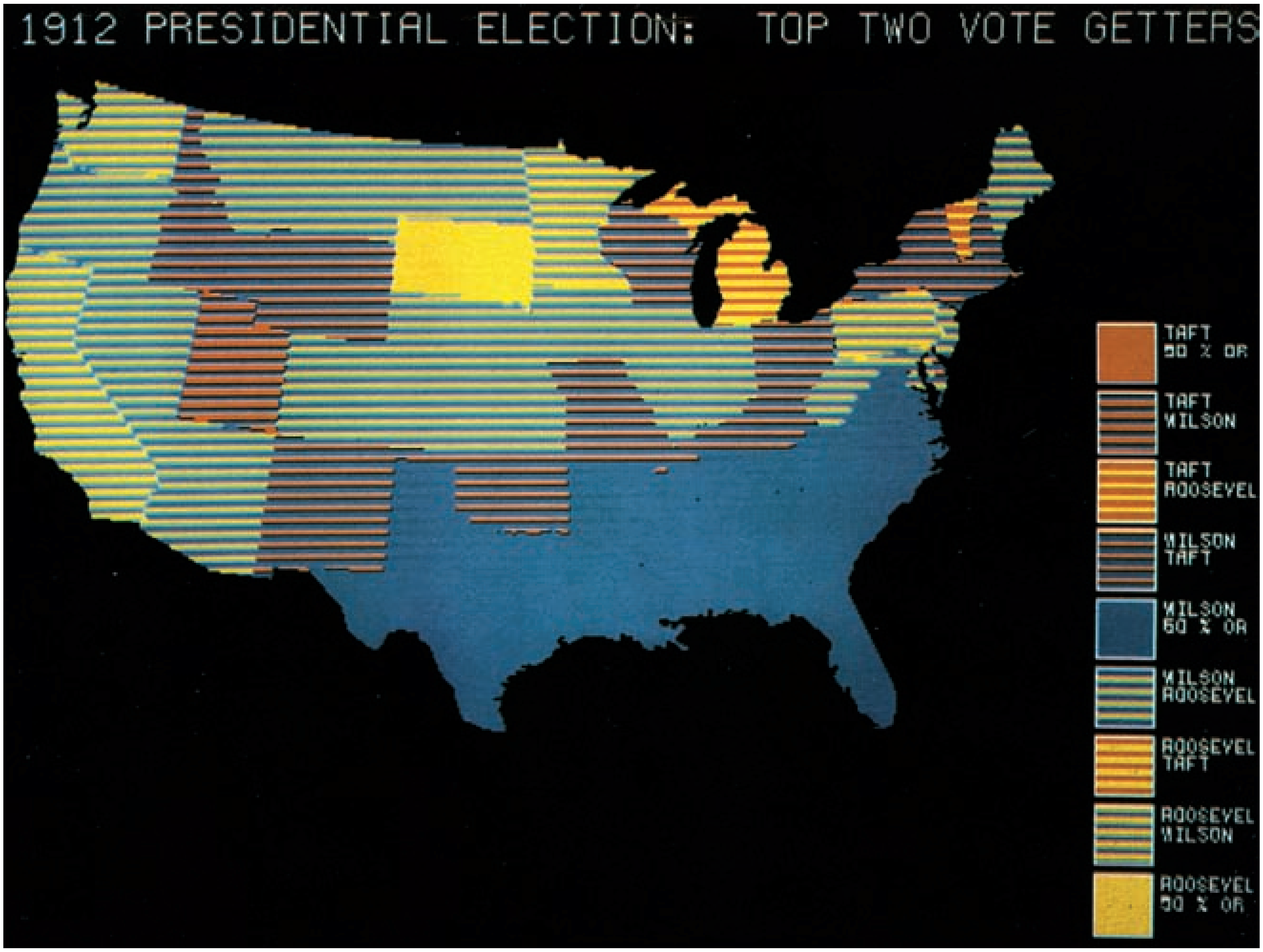

FIG. 362. *1912 PRESIDENTIAL ELECTION: TOP TWO VOTE GETTERS*, ODYSSEY. Work in the late 1970s and early 1980s produced hundreds of color maps using ODYSSEY, which was capable of drawing multilayered shades. Size of the original: 12.5 × 16.6 cm. From Harvard Laboratory for Computer Graphics and Spatial Analysis, *Lab-Log*, 1980, from color centerfold. Permission courtesy of the Frances Loeb Library, Harvard University Graduate School of Design.

Further publications included the *Harvard Library of Computer Graphics Mapping Collection*, an eleven-volume set of heavily illustrated papers produced for the annual Harvard Computer Graphics Week conferences in 1979 and 1980. A second edition, published in 1981 as a nineteen-volume set edited by Patricia A. Moore, contained 255 case studies from the Harvard Computer Graphics Week conferences from 1979 through 1981. The Laboratory also published an occasional newsletter, *Context*, from 1968 to 1983.

The character and tempo of the Laboratory changed noticeably in the 1980s. In 1980 Gerald M. McCue was appointed dean of the GSD, and Berry resigned in November 1980. In 1982 Schmidt's contract was not renewed, and McCue appointed a new director of the Laboratory, Daniel L. Schodek, a structural engineer who had been director of the Department of Architecture and had led an NSF-funded project for which Laboratory staff produced an innovative cartographic analysis of earthquake risk in Boston. That study combined soil characteristics with building type vulnerabilities.

Chrisman wrote POLYVRT in 1974, a program that enabled conversion between various data structures and formats, focusing on the database rather than the display. In 1990 Denis White and Jonathan Corson-Rikert developed and demonstrated online topological digitizing software (ROOTS and PALMS). A number of Laboratory staff members relocated to other academic and commercial organizations to continue development and distribution of GIS technology. Research expanded to include cartographic data structures and GIS. Cartographic representation of time series data was explored, developed, and demonstrated in film animation, perspective views of 3-D statistical surfaces, and holographic representations of historical time series data.

The Laboratory benefited enormously from its ties to

Harvard, whose undergraduate students were a source of ideas and intellectual stimulation. Fisher recruited students like Donald Shepard, who rewrote the SYMAP contouring algorithm, and James A. Dougenik, who rewrote the SYMAP manual and source code. Dougenik was a critical member of the ODYSSEY development team in debugging the polygon overlay algorithm. Carl Steinitz tested SYMAP for his doctoral research and also designed an improved strategy for analyzing gridded data. David F. Sinton introduced the GRID program for analysis and display of gridded data. The Harvard Business School also had an impact on the Laboratory. Maurice D. Kilbridge, a Business School faculty member who served as GSD's dean from 1969 to 1980, was a supporter of the Laboratory's work and did not micromanage. The Business School's case study teaching philosophy inspired Schmidt to model his Computer Graphics Week Users' Conferences on presentations of actual application experiences rather than idealized future outcomes. Dean Kilbridge supported Schmidt's attempt to commercialize ODYSSEY (Cooperman 1980), but Dean McCue did not. The Laboratory ceased operation in 1991.

ALLAN H. SCHMIDT

SEE ALSO: Electronic Cartography: (1) Intellectual Movements in Electronic Cartography, (2) Conferences on Computer-Aided Mapping in North America and Europe, (3) Conferences on Computer-Aided Mapping in Latin America; Oblique and Perspective Views; Software: Geographic Information System (GIS) Software; SYMAP (software)

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Hazards and Risk, Mapping of. Prior to the mid-twentieth century, cartographic products depicting hazards and risks were rare. Scientific researchers Christoph Hohenemser, Robert W. Kates, and Paul Slovic define hazards as "threats to humans and what they value" (1983, 379); risks are the probabilities associated with hazards. In the United States, on which this entry focuses, environmental laws and executive orders enacted in the wake of natural and technological disasters with heavy death tolls and property losses encouraged government, academic, and private research on and mapping of hazards and risks (table 20). These studies as well as promising developments in electronic cartographic technology and a growing electronic cartographic database led to a new genre of maps. Crucially important in battling western wildfires, tracking the Alaskan *Exxon Valdez* oil spill, and forecasting drought as well as responding to soil and groundwater contamination at Love Canal in New York, earthquakes in California, Hurricanes Andrew and Katrina in the Gulf States, flooding along the Mississippi River, and the Three Mile Island nuclear crisis in Pennsylvania, to name a few, these depictions gave civil administrators a sound foundation for environmental regulation, hazard mitigation, and emergency planning as well as a valuable tool for informing the public about the need for more responsible land use.

Electronic technology, particularly computer modeling, played a significant role in this new cartographic genre and largely accounts for the distinction between a hazard map, which shows the location pattern of a potential danger, and a risk map, which portrays the degree of risk a given hazard poses. In a study of seismic risk, for example, a map showing fault lines and areas within a given distance of a fault is a hazard map, whereas a map showing the severity of shaking with a 10 percent probability of occurring over a fifty-year period is a risk map (fig. 363). Similarly, a map of rivers and their floodplains is a hazard map, whereas a map of hundred-year flood zones is a risk map. Because risk maps require a concerted analysis of probabilities, typically with the utility of historical data amplified by computer modeling, the terms *risk map* and *hazard map* are not synonymous. Because of the inherent uncertainty in much of the hazard data accumulated through the end of the twentieth century, there have been very few risk maps in the strict mathematical sense. Most risk maps employ crude indications of relative risk, readily apparent in map keys describing level of risk as low, medium, or high.

A related cartographic undertaking is vulnerability mapping, which considers the population at risk and its capacity to survive and recover. The vulnerability of a community to a given hazard reflects physical, social, economical, and environmental factors that increase its susceptibility to the hazard's negative impacts. Counterbalancing vulnerability, and preferably overcoming it, is capacity, that is, the positive factors that increase a community's ability to cope effectively with a hazard or

TABLE 20: Environmental legislation and executive orders that encouraged the mapping of hazards and risk in the United States

1948	Federal Water Pollution Control Act
1955	Air Pollution Control Act (Clean Air Act)
1966	Disaster Relief Act
1968	National Flood Insurance Program (NFIP) established
1970	National Environmental Policy Act (NEPA)
1970	Environmental Protection Agency (EPA) created
1972	Clean Water Act amended (reorganized and expanded under the EPA and amended almost every year thereafter)
1977	National Earthquake Hazard Reduction Program (NEHRP) established
1977	Executive Order 11988: Floodplain Management
1977	Executive Order 11990: Protection of Wetlands
1979	Executive Order 12148: formation of Federal Emergency Management Agency (FEMA)
1980	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as the Superfund Act
1986	Emergency Planning and Community Right-to-Know Act, also known as SARA (Superfund Amendments and Reauthorization Act) Title III
1988	Indoor Radon Abatement Act (IRAA)
1990	Amendments to the 1955 Air Pollution Control Act
1994	Executive Order 12906: creation of the National Spatial Data Infrastructure (NSDI)
1996	Weapons of Mass Destruction Act (Nunn-Lugar-Domenici amendment)
2002	Homeland Security Act

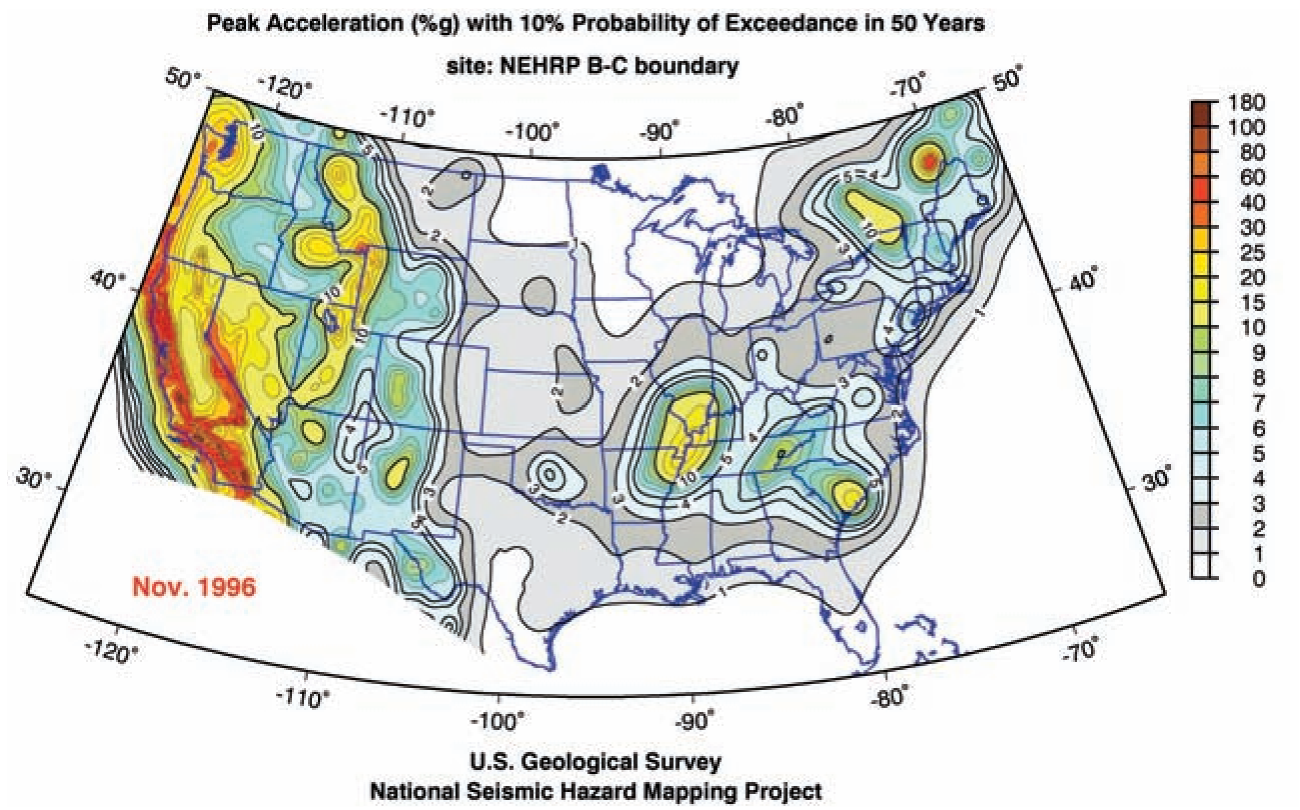


FIG. 363. RISK MAP EXEMPLIFYING STOP-LIGHT COLOR SEQUENCE. The map shows events with a 10 percent probability of occurring over a fifty-year period. The distribution mapped is horizontal acceleration expressed as a percentage of gravitational force. The map indices a likelihood of strong earthquakes in California, near the San Andreas and Hayward faults, in particular, and also in southern Quebec, just west of the border with Maine.
Image courtesy of the U.S. Geological Survey, Denver.

reduce its susceptibility to the negative impacts. Maps identifying "special needs" locations like elementary schools, nursing homes, and poverty-stricken neighborhoods where few households have cars are vulnerability maps, whereas maps showing levees and other flood control structures, highways with alternative signage designed to promote mass evacuation, and hospitals accessible to the hazard zone are capacity maps.

The relevance of this article to parts of the world outside North America varies enormously depending upon the mix of hazards a nation must confront and the expertise and resources available. Australia and Japan, for instance, have been world leaders in efforts to cope with wildland fire and seismic risk, respectively, and Western European countries with recurrent flooding have used mapping and modeling as part of a comprehensive strategy of floodplain management. At century's end, though, most less technologically developed countries vulnerable to earthquakes, tsunamis, severe flooding, drought, and environmental degradation had yet to implement the strategies described here, despite the efforts of various multidisciplinary research projects involving groups of nations, universities, and United Nations agencies to promote a culture of emergency planning, including the use of cartographic tools (Kasperson, Kasperson, and Turner 1995).

The lack of hazard and risk maps before 1950 is evident in the relative rarity of hazard maps in archives and the cartographic literature. Disease maps were the first hazard maps. The biological hazard of mosquito-borne viral yellow fever prompted the first disease maps in the late eighteenth and early nineteenth centuries, just as the thematic map was gaining acceptance as a multipurpose tool for locating phenomena in space and describing places. Thematic maps of cholera appeared as the pandemic that started in India in 1817 spread to Europe by 1831. John Snow's now-famous 1855 cholera map not only confirmed the existence of a biological/medical hazard in London but suggested approaches for epidemiological science and demonstrated the critical role mapping can play in controlling epidemics.

By the first decade of the twenty-first century, data were readily available for mapping the extreme events or conditions that comprise four major types of threats to life and property: natural hazards, which are generally hydrometeorological, geological, or biological in origin; technological hazards; intentional, human-induced hazards, including acts of terrorism; and environmental degradation. Of the three types of natural hazards, hydrometeorological hazards involving surface waters and oceans are by far the most common insofar as flooding affects two-thirds of the people touched by natural hazards. Other extreme hydrometeorological events are tropical cyclones (hurricanes in the western half of the globe and typhoons in the east), mudflows, storm surges, tornados, thunder/hailstorms, blizzards, melting permafrost, avalanches, heat waves, wildland fires, sand or dust storms, drought, and desertification. Geological hazards include earthquakes, tsunamis, volcanic activity and emissions, landslides, rock falls, underwater slides, liquefaction, fault activities subsidence, and surface collapses. Most maps of biological hazards, such as epidemic diseases, plant or animal contagions, or extensive infestations, are usually published as medical or epidemiological maps under the guidance of the Centers for Disease Control (CDC) or their state-level counterparts. Hazards not directly attributable to natural causes fall into one of three categories: accidental, intentional, or the result of long-term neglect—willfully knowledgeable or otherwise.

Any technology created by humans can become a technological hazard, a category that includes mundane hazards like lawn mowers and over-the-counter drugs, sudden extreme events like dam failure or the accidental release of radiation from a nuclear power plant, and comparatively gradual hazards like groundwater contamination and black lung disease among coal miners. In addition, humans intentionally cause disasters variously labeled massacres or acts of terrorism, depending upon the degree of planning and the political motives of the perpetrators. Among the most noteworthy examples is the 11 September 2001 attack on the World Trade Center in New York City, which led to the formation of the Department of Homeland Security and a plethora of activities intended to thwart diverse kinds of surprise attacks.

In 2002 the United Nations International Strategy for Disaster Reduction (UNISDR) added the category of environmental degradation. A combined 2002 and 2004 definition for environmental degradation describes it as processes induced by human activities that damage the natural resource base or adversely alter natural processes or ecosystems resulting in a reduction in the capacity of the environment to meet social and ecological objectives and needs (ISDR 2002, 2004). Examples include land degradation, deforestation, desertification; wildland fire; reduced biodiversity; pollution of land, air, and water; climate change and sea level rise; and ozone depletion, all of which blur the four-way typology insofar as environmental degradation can increase the frequency and intensity of natural hazards as well as the vulnerability of human populations. In the early twenty-first century ominous trends in climate change and sea level rise made it necessary to update maps of global climate, vegetation, and coastal environments. By 2007 rapid melting of polar ice had produced new islands and ocean channels not shown on existing maps.

Before Hurricane Andrew in 1992, geographic information had not been recognized as a vital ingredient in disaster management. Research at Clark University's

Center for Technology, Environment, and Development discerned three main processes of hazard management: hazard identification, risk estimation, and evaluation and resource allocation (Kates, Hohenemser, and Kasperson 1985). The diagram in figure 364 describes the relationship of these processes to the flow of spatial information after Hurricane Andrew. The upper portion represents risk-assessment activities that produce data on hazards and their attendant risks, the midportion outlines the use of this information in disaster management mapping, and various arrows underscore the role of hazard and risk maps as key ingredients in risk communication whereby public officials promote risk awareness with the hope of gaining public support for mitigation efforts as well as increased cooperation with evacuation and other response mechanisms.

Although mapping is a key component of hazard management, the scientists and engineers who produced the requisite geospatial data were often not involved directly in the parallel cartographic processes of map design and production, map use, and map dissemination. As with most maps produced by a government agency, the key factors in map design include the selection of symbols, content, and level of generalization, all related to the mapmaker's view of reality, as well as the selection of mapping software, which can affect many of these design elements. Because good design requires symbols that users can comprehend readily, without repeated reference to a map key or verbal explanation, maps showing relative risk have often employed the familiar traffic signal colors (red, yellow, green) to represent high, medium, and low levels of risk. Authors of risk maps leery that users might confuse low risk with no risk preferred a more limited range of hues, typically a red-orange-yellow sequence. Red's almost implicit association with danger in Western culture quickly became an overriding element in the design of hazard and risk maps. In the final decades of the twentieth century risk mapping ben-

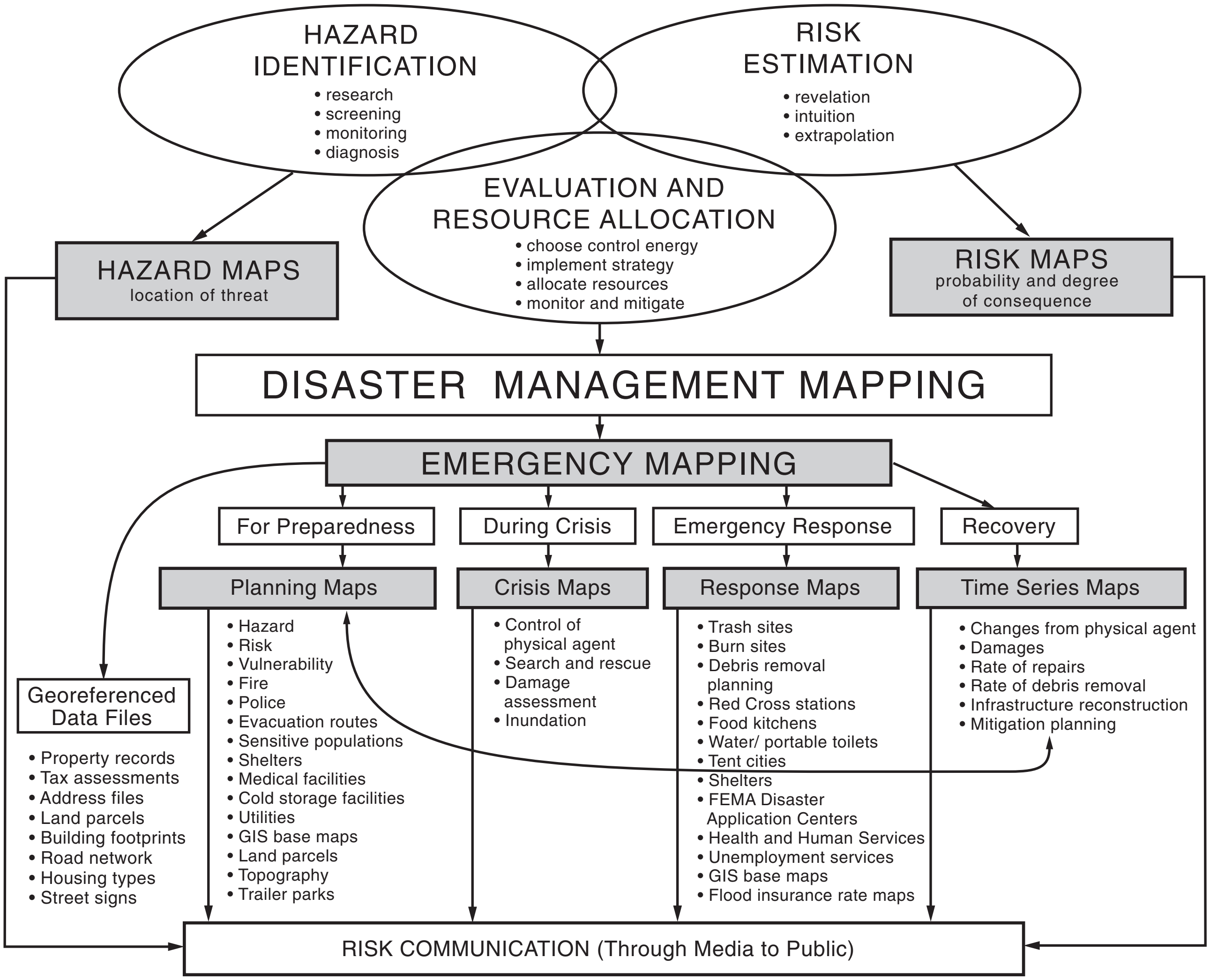


FIG. 364. HAZARD MANAGEMENT MAPPING DIAGRAM. After Winter 1997, 238.

efited from the increased availability and lower cost of color printing as well as the increased use of computers with color monitors for Internet access.

The map user's view of reality, including expectations and biases, can affect the knowledge gained by using the map as well as the mapmaking process directly—especially true when the user is an influential government official. Map use is important insofar as hazard and risk maps inform hazard prevention and mitigation efforts and a variety of related research activities. By contrast, map influence involves the dissemination of cartographic information that can affect the risk perception of various publics—examples include government officials, the media, industry stakeholder groups, environmental organizations, and the elderly—and influence their choices and decisions.

Maps drawn at different scales have been used to demonstrate how cartography can show different perspectives of a particular hazard. The small-scale maps of the six highly generalized hazard zones juxtaposed in figure 365 suggest that there is no risk-free region in the United States (Monmonier 1997, 3), and a *New York Times* news graphic that superposed multiple hazards on a single map (fig. 366) makes this point even more dramatically. By contrast, some of the most detailed maps produced by the federal government are the large-scale national flood insurance rate maps (FIRMs), which relate flood zones to individual structures at the neighborhood level (fig. 367). At century's end FIRMs relating flood zones to political boundaries, the street grid, and locally significant landmarks were still printed in a single color. Flooding is one of the most common natural hazards in the country, and however drab, FIRMS have been an integral part of the National Flood Insurance Program (NFIP), created in 1968 after much discussion of the research and writings of Gilbert F. White (*Human Adjustment to Floods*, 1945), who identified the salient characteristics of flooding in the United States and devised a workable strategy for floodplain management. This strategy uses stream-flow data and hydrological models to determine locations with a 1 percent chance of flooding in any given year. In addition to delineating the so-called hundred-year flood zone, the U.S. Federal Emergency Management Agency (FEMA) produces FIRMs used to determine flood insurance premiums for individual dwellings. This program of voluntary citizen participation in cooperation with the government grew into a nationwide hazard mapping effort (Monmonier 1997, 105–12). By the beginning of the twenty-first century, an effort was underway to provide DFIRMs, a more useful digital form of flood insurance rate map.

A distinctly different hazard map addressed the plausible impact of an accident at a nuclear power plant. In 1980 the Nuclear Regulatory Commission required each of roughly 100 existing nuclear power facilities in the United States to prepare a hazard map for its emergency planning zone (EPZ), the area within a ten-mile radius of the plant, for use by area residents in evacuating during a nuclear emergency (U.S. Nuclear Regulatory Commission 1980). Strategies for designing and disseminating these maps varied widely. The EPZ was partitioned into a number of emergency response planning areas (ERPAs), useful if wind conditions called for some residents to leave while others stayed inside behind closed door and windows. The most efficacious distribution strategy was to publish the EPZ map in the local telephone directory, readily available in most homes and businesses, or to mail to each local address a

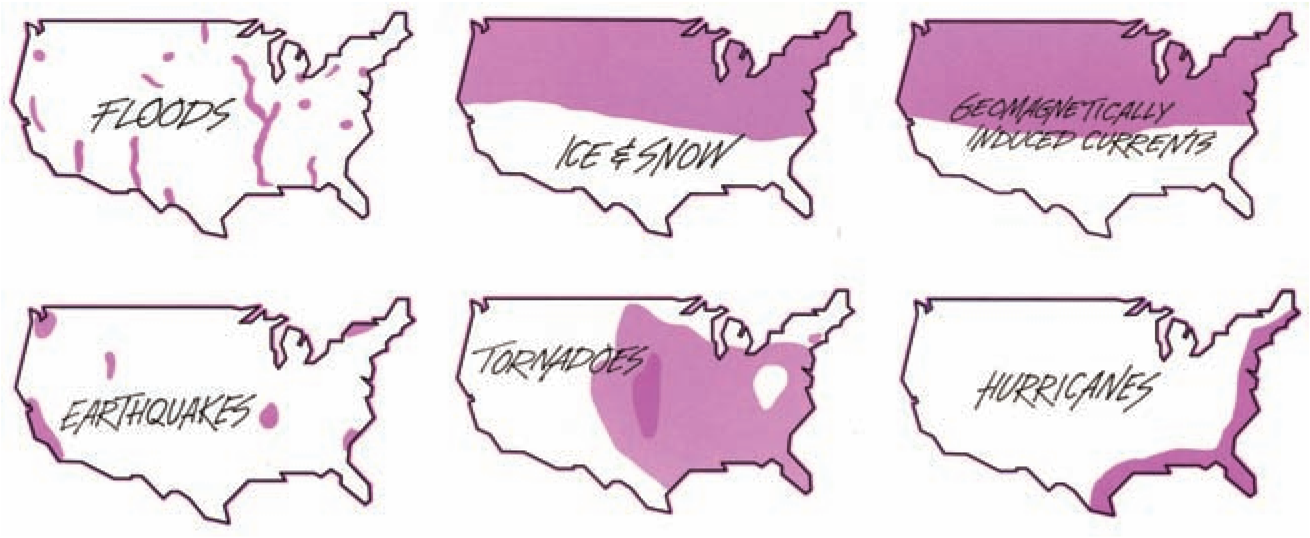
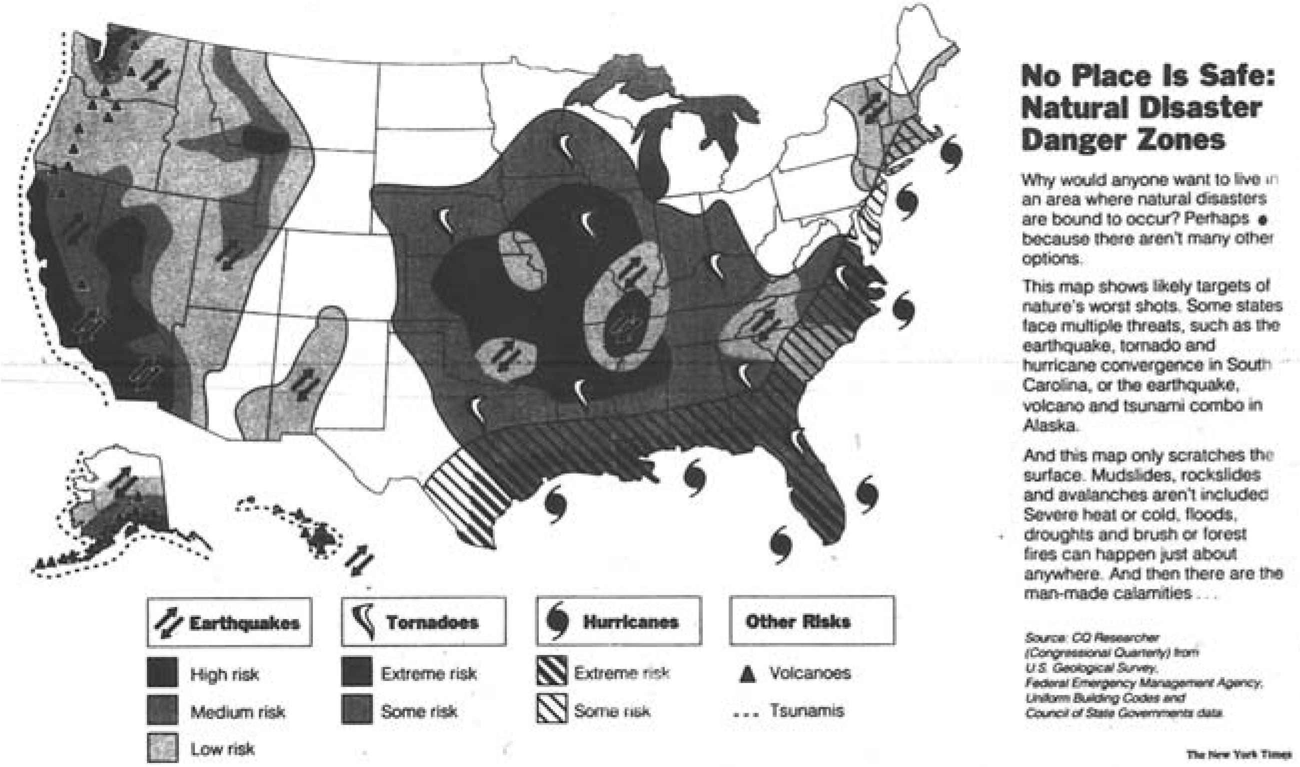


FIG. 365. U.S. HAZARD ZONES.
From Bob McGee, "Preparing for Disaster," *EPRI Journal* 17, no. 6 (1992): 22–33. Image courtesy of the Electric Power Research Institute, Palo Alto.



No Place Is Safe: Natural Disaster Danger Zones

Why would anyone want to live in an area where natural disasters are bound to occur? Perhaps because there aren't many other options.

This map shows likely targets of nature's worst shots. Some states face multiple threats, such as the earthquake, tornado and hurricane convergence in South Carolina, or the earthquake, volcano and tsunami combo in Alaska.

And this map only scratches the surface. Mudslides, rockslides and avalanches aren't included. Severe heat or cold, floods, droughts and brush or forest fires can happen just about anywhere. And then there are the man-made calamities . . .

Source: CQ Researcher (Congressional Quarterly) from U.S. Geological Survey, Federal Emergency Management Agency, Uniform Building Codes and Council of State Governments data.

The New York Times

FIG. 366. *NO PLACE IS SAFE: NATURAL DISASTER DANGER ZONES*. Key at the bottom and explanatory text to the right. From Isabel Wilkerson, "Big Disaster? Maybe It Is, But It's OUR Big Disaster," *New York Times*, 30 January 1994, E6.

free annual calendar that included a map showing EPZ and ERPA boundaries, evacuation routes, and one or more euphemistically labeled "reception centers."

Heightened awareness of natural and technological hazards in the last two decades of the twentieth century led to a multitude of hazard and risk maps and many new map types, almost all produced using electronic technology. Five federal agencies—the CDC, FEMA, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), and the Environmental Protection Agency (EPA)—were the principal producers. FEMA, a part of the Department of Homeland Security since 2003, produced maps in all four categories of hazards, while NOAA and the USGS focused on maps and geospatial data concerned with hydrometeorological and geological hazards, respectively.

NOAA, which is part of the Department of Commerce, includes the National Weather Service (formerly the U.S. Weather Bureau), which has used maps throughout the century to study weather and climate and identify imminent danger from severe weather, particularly tornados, hurricanes, blizzards, and drought. Other NOAA services include maintaining geostationary satellite surveillance of North America and adjoining oceans, managing environmental data at the National Geophysical Data Center (established in the early 1970s as the National Geophysical and Solar-Terrestrial Data Center), and archiving a searchable collection of environmental photography. NOAA's SLOSH (Sea, Lake, and Overland Surge from Hurricanes) simulations of the impact of storm surge, developed in the 1970s, were in use into the early decades of the twenty-first century, and the NOAA Coastal Services Center, established in Charleston, South Carolina, in 1994, has developed software to help communities assess vulnerability of critical infrastructure to wind and storm surge.

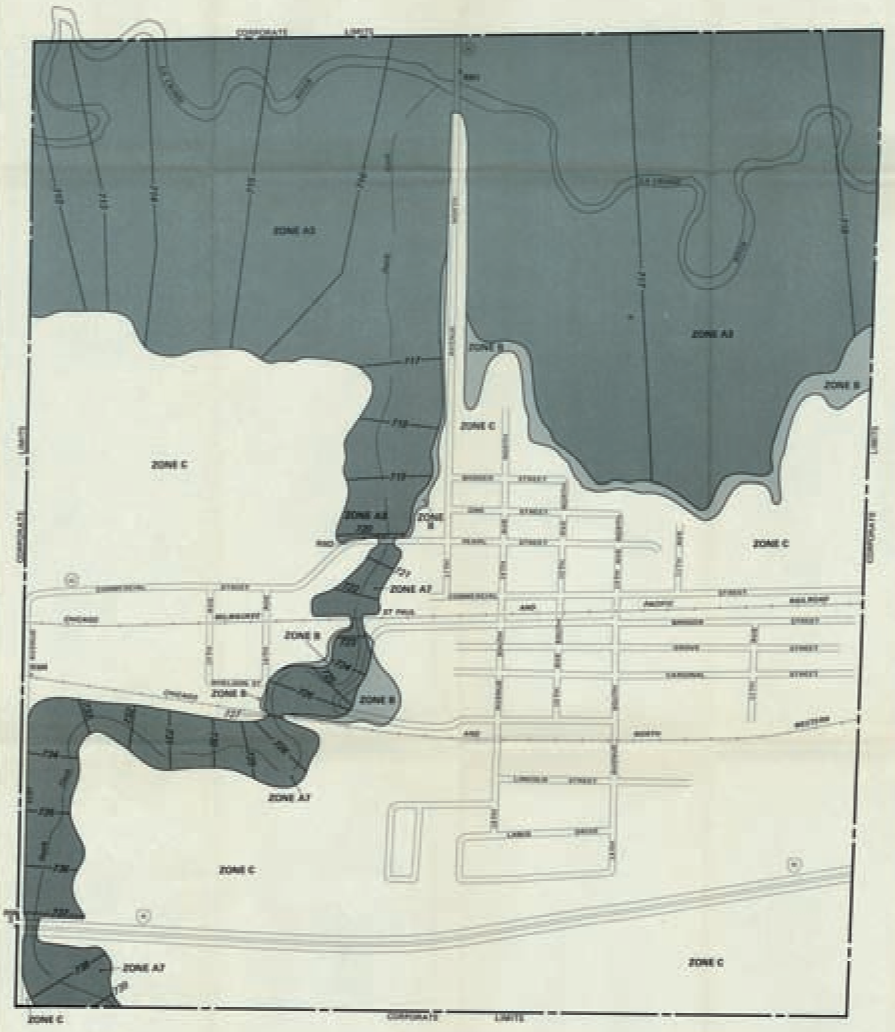
The USGS has produced a variety of cartographic products more specialized than its topographic and geologic maps to help engineers, architects, and emergency planners cope with land hazards. Its National Earthquake Information Center, established in Rockville,

(*Facing page*)

FIG. 367. FEDERAL FLOOD INSURANCE RATE MAP (FIRM), VILLAGE OF BANGOR, WISCONSIN. Size of the original: ca. 64 × 45 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

ELEVATION REFERENCE MARKS

REFERENCE MARKS	ELEVATION FEET (NGVD)	DESCRIPTION OF LOCATION
RM 1	723.00	Chiseled square on northeast corner of the 17th Avenue North bridge over La Crosse River.
RM 2	727.00	Railroad spike in wooden post of guardrail located at northeast corner of Pearl Street bridge over Dutch Creek.
RM 3	749.62	Nail set in wooden guardrail on west side of 21st Avenue, beneath the median area of Interstate Highway 90.
RM 4	746.08	Nail set in power pole at telephone pedestal located at northeast corner of intersection of 21st Avenue and Chicago and North Western Railroad.



KEY TO MAP

500-Year Flood Boundary	ZONE B
100-Year Flood Boundary	
Zone Designations* With Date of Identification e.g., 12/2/74	ZONE A1 / ZONE A3
100-Year Flood Boundary	
500-Year Flood Boundary	ZONE B
Base Flood Elevation Line With Elevation In Feet**	513
Base Flood Elevation in Feet Where Uniform Within Zone**	(EL 987)
Elevation Reference Mark	RM7×
River Mile	•M1.5

**Referenced to the National Geodetic Vertical Datum of 1929

*EXPLANATION OF ZONE DESIGNATIONS

ZONE	EXPLANATION
A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
AO	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined.
AH	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
A99	Areas of 100-year flood to be protected by flood protection system under construction; base flood elevations and flood hazard factors not determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (Medium shading)
C	Areas of minimal flooding. (No shading)
D	Areas of undetermined, but possible, flood hazards.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
V1-V30	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors determined.

NOTES TO USER

Certain areas not in the special flood hazard areas (zones A and V) may be protected by flood control structures.

This map is for flood insurance purposes only; it does not necessarily show all areas subject to flooding in the community or all planimetric features outside special flood hazard areas.

INITIAL IDENTIFICATION:
JANUARY 16, 1976

FLOOD HAZARD BOUNDARY MAP REVISIONS:
JULY 30, 1976

FLOOD INSURANCE RATE MAP EFFECTIVE:
JANUARY 2, 1981

FLOOD INSURANCE RATE MAP REVISIONS:

Refer to the FLOOD INSURANCE RATE MAP EFFECTIVE date shown on this map to determine when actuarial rates apply to structures in the zones where elevations or depths have been established.

To determine if flood insurance is available in this community, contact your insurance agent, or call the National Flood Insurance Program, at (800) 638-6620, or (800) 424-8872.

APPROXIMATE SCALE

400 0 400 FEET

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

VILLAGE OF
BANGOR,
WISCONSIN
LA CROSSE COUNTY

(ONLY PANEL PRINTED)

COMMUNITY-PANEL NUMBER
550218 0001 B

EFFECTIVE DATE:
JANUARY 2, 1981

federal emergency management agency
federal insurance administration

Maryland, in 1966 but relocated to Boulder and then to Golden, Colorado, in the early 1970s, had used data on earthquakes, faults, and tectonic plates to create a variety of specialized seismic risk maps, addressing tsunamis as well as earthquakes. Data collected by USGS stream gauging stations have served as a foundation for FEMA's flood mapping efforts and for real-time flood forecasting along rivers and streams. USGS data collection efforts have also been useful in assessing threats to the quality of ground and surface water and the impact of acid rain. The mapping of nationwide deposits of radioactive bedrock, which can contaminate the air inside structures, led civil jurisdictions throughout the country to impose regulations requiring radon testing before a house can be sold and launched a nationwide market for radon detectors.

The 1981 eruption of Mount St. Helens demonstrated the value of USGS efforts to map and monitor volcanic hazards. Maps released shortly before the eruption convinced authorities to close adjacent public lands in time to save countless lives. Except for a few recalcitrant holdouts who refused to evacuate, its mountainsides were barred to thousands of visitors during the explosive eruption. The lives saved were a praiseworthy achievement in the application of hazard and risk mapping to buttress effective risk communication. Even so, the lack of a warning covering areas east of the volcano, where significant ash fallout caught people unaware, was a serious oversight.

Monitoring and mapping biological hazards has been the responsibility of the CDC and its affiliated state and local health departments. Cartographic products depicting the West Nile virus, Lyme disease, and HIV played crucial roles in efforts to contain these threats. At the start of the twenty-first century, fears of a worldwide pandemic from the bird flu virus required fuller mapping in attempts to solve the mystery of the spotty progression of bird flu outbreaks around the globe. Mapping has also been useful in monitoring diseases that threaten plant and animal populations as well as in implementing regulatory measures like aerosol spraying and quarantine.

In the late 1980s, following passage of the Emergency Planning and Community Right-to-Know Act (EPCRA, also known as SARA [Superfund Amendments and Reauthorization Act], Title III) in 1986, the EPA launched a training program to educate local emergency response officials in the use of CAMEO (Computer-Aided Management of Emergency Operations), a suite of integrated software applications that included a chemical database; MARPLOT (Mapping Applications for Response, Planning, and Local Operational Tasks), a mapping system for relating chemical sites to a local geographic frame of reference; and ALOHA (Areal Locations of Hazardous Atmospheres), a chemical dispersion model useful in simulating the impacts of accidental releases and in coping with real emergencies. Local Emergency Planning Committees (LEPCs) encouraged collection and mapping of local geospatial data about pollution under the Superfund SARA Title III law. The EPA kept current a log of the locations and conditions of the most dangerous chemically contaminated Superfund sites, found in almost every state. While much of the mapping used in managing technological hazards originated at the EPA, other government agencies like the Occupational Safety and Health Administration (OSHA) and private enterprises like the Environmental Systems Research Institute (ESRI) also contributed.

Data acquisition for hazard and risk mapping increased apace with the growing sophistication of computer technology and the increasing facility for acquiring hazard data through remote sensing technologies, such as use of aircraft and satellites employing digital photography, lidar, interferometry, Global Positioning Systems (GPS), and thermal imagery. Key issues in data acquisition include a growing concern with data quality, documenting the source and reliability of the data, and keeping data current. In 1994 President Bill Clinton issued Executive Order 12906 authorizing the National Spatial Data Infrastructure (NSDI), a network of local, state, and federal databases. This wealth of data—some relevant, some not—created additional problems for emergency managers, including bureaucratic impediments to the timely acquisition of overhead imagery and local emergency management officials who lacked essential experience with the data and software they might be expected to use in coping with a disaster (U.S. National Research Council 2007). Additional problems on the agenda for the twenty-first century included the low-probability high-consequence threats posed by asteroids and space debris and the long-range but apparently inevitable consequences of climate change, including drought and sea level rise.

UTE JANIK DYMON AND
NANCY LEESON TEAR WINTER

SEE ALSO: Administrative Cartography; Emergency Planning; Environmental Protection; Geographic Information System (GIS): GIS as a Tool for Map Analysis and Spatial Modeling; Geologic Map; Geophysics and Cartography

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Heiskanen, Veikko Aleksanteri. Veikko (Weikko) Aleksanteri Heiskanen made significant contributions to the theories of isostasy and the global geoid. He was born in 1895 in Kangaslampi, Finland. Admitted to the University of Helsinki in 1914, he graduated three years later as a candidate in philosophy with the highest grades in astronomy, mathematics, physics, theoretical philosophy, and political economy and received his master of philosophy in 1919. In the winter of 1920–21 he continued his studies in astronomy at the observatory in Potsdam, Germany.

In 1921 Heiskanen joined the Finnish geodetic institute, Geodeettinen laitos, where he started his investigations in isostasy. The National Board of Survey of Finland, Maanmittaushallitus, had just decided to base the country's geodetic coordinates on the International ellipsoid (also called the Hayford ellipsoid), which was adopted as the international reference system at the 1924 Madrid congress of the International Union of Geodesy and Geophysics (IUGG). The only thing lacking was confirmation of the corresponding normal formula for gravity, which required measurements of gravity from around the world and the elimination of local irregularities caused by mountains and seas. Although it was known that the distribution of invisible masses beneath the earth's surface compensated for these irregularities, a mathematical formulation of this distribution was still speculative.

John Henry Pratt had assumed that mountains had risen from their bases like dough, so that a mountain's density was inversely related to its height. George Biddell Airy, on the other hand, had assumed that the continents and islands are resting hydrostatically on highly plastic or liquid material, with roots or projections penetrating the inner material of the earth, just as icebergs extend downward into the water. Heiskanen considered Airy's theory more reasonable and began to develop it further by systematically adjusting gravity anomalies and deviations of the vertical (plumb) line. Eventually he was able to show that Airy's theory was at least as practicable as that of Pratt as long as appropriate norms are chosen for the thickness of the earth's crust in different areas. Heiskanen used the results of his early research on isostasy as a basis for his doctoral dissertation, published in 1924. His research achieved international significance when the value he had calculated for the main term of the normal gravity formula was accepted at the Stockholm IUGG congress in 1930.

Heiskanen held the chair of professor of geodesy at the Helsinki University of Technology (Teknillinen korkeakoulu) from 1928 to 1949. For fourteen of those twenty-one years, he served as head of the Surveying Department. Despite the distraction of administrative duties, he continued his research in isostasy and physical geodesy, and together with his research assistants and other young scientists formed a research institute that the International Association of Geodesy officially recognized in 1936 as the International Isostatic Institute. Heiskanen returned to the Geodeettinen laitos in 1949, this time as its director.

In 1950, Ohio State University in Columbus appointed Heiskanen research professor and supervisor of the global gravimetric charting project. In 1951 he became scientific director of the university's newly established Institute of Geodesy, Photogrammetry and Cartography, and served as its exective director from 1953 to 1961, when the institute became the Department of Geodetic Science. In 1957, he completed a figure of the earth based on observations from fifty-nine countries and known as the Columbus Geoid.

Heiskanen was an active member of many scientific societes, including the American Academy of Arts and Sciences, the Pontificia Academia Scientiarum at the Vatican, and the Finnish Academy of Science and Letters (Suomalainen Tiedeakatemia), as well as the recipient of numerous awards and honorary doctorates. He died in 1971, in Helsinki, at the age of seventy-six.

JUHANI KAKKURI

SEE ALSO: Figure of the Earth; Geodesy: Geodetic Computations; Geophysics and Cartography

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Hermann Haack (Germany). See Justus Perthes

Hiking and Trail Map. See Wayfinding and Travel Maps: Hiking and Trail Map

Himalaya, Cartography of the.

The Himalaya is the highest and most massive mountain system on earth. Located at about 32°N latitude, it extends eastward, in the shape of an arc concave to the north, about 2,500 kilometers from the gorges of the Indus River (73°E) to the bend of Brahmaputra River (95°E) (Zurick et al. 2005, 3). Its approximate width varies from 280 kilometers in the northwest to 150 kilometers in the east. From the Indian lowland at its south to Tibet at its north, the system is divided into four mountain ranges: the Outer Himalaya Range (including Siwalik Range), the Lower Himalaya Range, the High Himalaya Range (with its highest peak, Mount Everest, at 8,848 meters), and, beyond a longitudinal valley zone in Tibet, the Trans-Himalaya Range.

At the beginning of the twentieth century the cartographic picture of the Himalaya was still incomplete. For example, the fourth state of the map *Tibet and the Surrounding Regions, Compiled from the Latest Information* published separately by the Royal Geographical Society in 1906 labeled an area north of the Upper Brahmaputra as "unexplored." Maps illustrating subsequent exploration and travel accounts documented rapidly growing geographical knowledge of the region.

During the course of the twentieth century a number of medium-scale official map series included the Himalaya within the larger extent of their coverage. They included map series of the Survey of India, the Directorate of Overseas Surveys (Great Britain), the U.S. Army Map Service, and the Guojia cehui ju 国家测绘局 (State Bureau of Surveying and Mapping; SBSM) in China.

From the mid-1930s onward, though, cartography focused on the Himalaya came into its own. Medium-scale and large-scale single-sheet topographic maps of significant mountain areas were created by the Deutsche Alpenverein (DAV), the Österreichische Alpenverein (ÖAV), the Arbeitsgemeinschaft für vergleichende Hochgebirgsforschung, the team of Cartoconsult Austria, and the National Geographic Society (Washington, D.C.).

From its founding in 1862 the ÖAV had undertaken to prepare large-scale sheet maps in its cartographic department in Innsbruck. Later they did such mapping in cooperation with the DAV, founded in 1869 and based in Munich. After beginning with sheets of the eastern Alps, they also mapped non-European mountain areas later in the twentieth century (Arnberger 1970).

The Himalayan mountain peak of Nanga Parbat (India, later Pakistan) was covered on four 1:50,000 map sheets by the alpine clubs (1936). Fieldwork for that first large-scale map of the Himalaya was conducted by the Deutsche Himalaya-Expedition of 1934. Richard Finsterwalder was responsible for triangulation and terrestrial photogrammetry based on reference points of the Survey of India and for its analysis. Fritz Ebster depicted the relief with fifty-meter contour lines and rock drawing executed in his typical manner. The originals of 1936 were destroyed in 1944 during World War II, so a reproduction of the map was published in 1980.

The DAV and ÖAV continued their cartographic activities throughout the century. Two 1:50,000 sheets, *Langthang Himal–West* (Nepal-Tibet) and *Langthang Himal–East* (Nepal-Tibet) appeared in 1990. For those sheets, the results of methodologically different surveys by several working groups were compiled under the guidance of Robert Kostka. It was the first use of spaceborne stereo images (Skylab, 1973) in mountain cartography. Gerhart Moser executed the maps, representing relief by fifty-meter contours together with strong hill shading and rock drawing in his characteristic style.

The Arbeitsgemeinschaft für vergleichende Hochgebirgsforschung, located in Munich, was founded in 1965, following the end of the Forschungs-Unternehmen Nepal Himalaya, which had existed since 1960. An interdisciplinary group of scientists and researchers, the Arbeitsgemeinschaft sought to carry out its own scientific work in the field of high mountain research and to sponsor worthy research projects related to mountain regions of the earth. It published two periodicals, *Hochgebirgsforschung* and *Khumbu Himal*, with large-scale maps of the Nepal-Himalaya (Haffner et al. 2004).

Seven 1:50,000-scale sheet maps of the Himalaya published by the Arbeitsgemeinschaft were: (1) Kathmandu Valley (1977) (in the same year sixteen sheets of the Kathmandu Valley at 1:10,000 also appeared), (2) Khumbu Himal (1967), (3) Tamba Kosi-Likhu Khola (1968), (4) Rolwaling Himal (1974), (5) Shorong/Hinku (1974), (6) Lapchi Kang (1974), and (7) Dudh Kosi (1974). Until 1977 the preparation of those maps was the responsibility of Erwin Schneider, who organized and executed the fieldwork (triangulation, terrestrial photogrammetry, and aerial imagery), as well as the analysis. For the later map sheets after 1979 the scale 1:100,000 was chosen: (8) Helambu-Langtang (1987), (9) Annapurna (1993) (fig. 368), and (10) Jumla-Rara Lake (1997). Guidance of the compilation of base information and cartographic production then became the responsibility of Rüdiger Finsterwalder. Relief was represented on the maps by fifty-meter contour lines and hill shading; in areas with rock drawing the contour lines were omitted. Supplementary city maps of Kathmandu City at 1:10,000 (1979) and Patan City at 1:7,500 (1981) were also published.

Cartoconsult Austria arose in the 1980s out of research into the use of orthophotos for cartographic representation of high mountains, an interest of Wolfgang Pillewizer at the Technische Universität Wien. Led by Kostka, the Cartoconsult team in Graz sought to use remote sensing satellite images for different tasks in high mountain research (Kostka 1998). The spaceborne images made possible the production of combined image line maps (CIL-maps), a great achievement of twentieth-century mountain cartography. Cartoconsult used Global Positioning System (GPS) measurements in combining satellite imagery (Corona 1966, and Landsat 7, 1994) with results of fieldwork and collateral data. They produced four sheets of the Himalaya: Annapurna Sattrek (Nepal) at 1:250,000 (1991), Royal Chitwan National Park (Nepal) at 1:250,000 (1995), Kailash (Tibet) at 1:50,000 (2002) (fig. 369), and Mustang (Nepal) at 1:200,000 (2004). Relief depiction by cartographically revised satellite images was supplemented with 100-meter contour lines and naturalistic rock drawing by Heinz Krottendorfer.

Representations of Mount Everest (Sagarmatha, Chomolongma), of special interest as the highest peak in the Himalaya and in the world, exemplify the history of twentieth-century high-mountain cartography. The first reconnaissance and mapping of part of the area was by a British expedition in 1921. Topographic fieldwork by Henry T. Morshead and E. Oliver Wheeler resulted in a sketch map showing the Rongbuk glacier area north of Mount Everest.

The first ascent of Mount Everest by Sir Edmund Hillary and Tenzing Norgay on 29 May 1953 stimulated interest in large-scale topographic mapping of the region. The 1:25,000-scale map, *Mahalangur Himal: Chomolongma–Mount Everest*, edited by the DAV, ÖAV, and Deutsche Forschungsgemeinschaft, was published in 1957 (fig. 370). It was the first map to show the entire Mount Everest–Khumbu region at such large scale. The fieldwork (triangulation and terrestrial photogrammetry) during the International Himalaya Expedition 1955 and subsequent analysis was conducted by Schneider. Relief representation consisted of twenty-meter contours with rock drawing by Ebster.

FIG. 368. DETAIL FROM *ANNAPURNA 1:100,000*, 1993. The map was published by the Arbeitsgemeinschaft für vergleichende Hochgebirgsforschung, Munich, and shows a section of Annapurna (8,091 m), the first peak of more than 8,000 meters to be conquered. It was scaled by the French mountaineers Maurice Herzog and Louis Lachenal on 3 June 1950.

Size of the entire original: 79.3 × 85.3 cm; size of detail: ca. 22.7 × 19.5 cm. Permission courtesy of the Arbeitsgemeinschaft für vergleichende Hochgebirgsforschung, Munich.

Khumbu Himal (Nepal), edited by the Arbeitsgemeinschaft, was published at 1:50,000 (1965). That map representing the highest region in the world was executed in the then-current style of the alpine clubs (forty-meter contour lines, hill shading, and rock drawing by Ebster).

The founding of Sagarmatha National Park, on 19 July 1976, was another stimulus to mapping activity. Production of many large-scale trekking and topographic maps followed. The most interesting project was initiated by Bradford Washburn from the Boston Museum of Science

FIG. 369. DETAIL FROM *KAILASH 1:50 000*, 2002. The map was published by Cartoconsult Austria, Graz. Kailash (6,638 m) is the holiest mountain in the world for millions of Hindus and Buddhists. Size of the entire original: 49.6 × 39 cm; size of detail: ca. 14.6 × 25.4 cm. Permission courtesy of Prof. Dr. Robert Kostka.

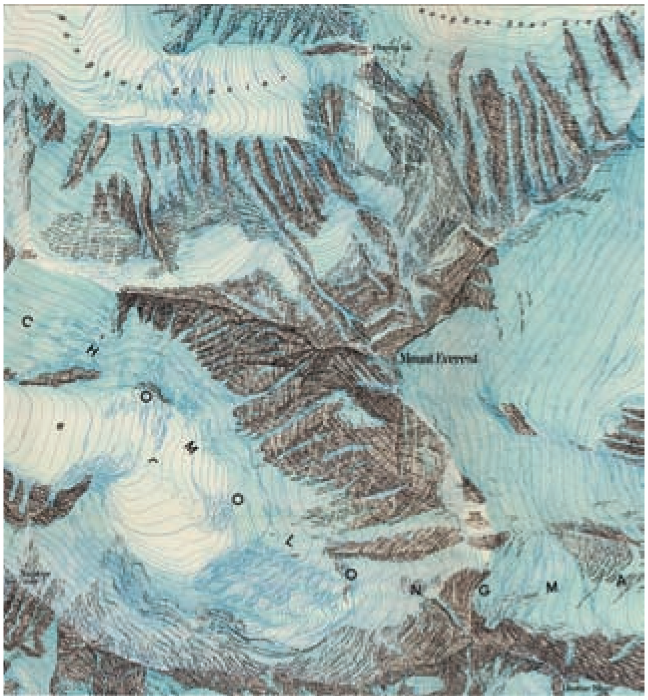

FIG. 370. DETAIL FROM *MAHALANGUR HIMAL: CHOMOLONGMA–MOUNT EVEREST*, 1:25,000, 1957. Size of the entire original: 77.3 × 97.6 cm; size of detail: ca. 27.8 × 25.8 cm. From Schneider 1957.

for the 1:50,000-scale sheet, *Mount Everest*, published by the National Geographic Society, Washington, D.C. in 1988 (Altherr and Gruen 1990). The map was prepared in the manner of the Swiss 1:50,000 topographic series. Leadership of the project, aerial imagery, and photogrammetric plotting was the responsibility of Swissair Photo & Vermessungen AG, Zurich. Data analysis was carried out in cooperation with the Eidgenössische Technische Hochschule (ETH) in Zurich. The Swiss Bundesamt für Landestopographie in Bern prepared the final cartographic product with forty-meter contour lines, hill shading, and rock drawing in the Swiss manner, the latter including thousands of details of Mount Everest's cliffs and glaciers. That map and the others discussed above witness the great achievements of high-mountain cartography of the Himalaya, as published in paper format during the twentieth century.

ROBERT KOSTKA

SEE ALSO: Alpine Cartography; Relief Depiction

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Zurick, David, et al. 2005. *Atlas of the Himalaya*. Kathmandu: International Centre for Integrated Mountain Development.

Hinks, Arthur R(obert). Born in London on 26 May 1873, Arthur Hinks graduated sixth in the Mathematical Tripos in 1895, and held Cambridge University posts at the Observatory, where he was Demonstrator in Practical Astronomy. His academic work demonstrated great skill and perseverance, which led to a Gold Medal from the Royal Astronomical Society in 1912 and election as a fellow of the Royal Society in 1913. Although his studies focused on astronomy, in 1903 he spent a month at the School of Military Engineering at Chatham, where he was introduced to map projections and field survey.

In 1908 Hinks became lecturer in surveying and cartography at Cambridge. Realizing that his future did not lay in the university, he became assistant to John Scott Keltie, secretary of the Royal Geographical Society (RGS), on the understanding that he would succeed Keltie. This coincided with the society's move to South Kensington and the outbreak of World War I. Hinks spent the last thirty years of his life as the secretary of the RGS. Despite the demands of administration, he was involved in discussions about the International Map of the World (IMW) and represented the society at the December 1913 international meeting at Paris, which established specifications for the IMW. According to Charles Frederick Close, the IMW and map production for military intelligence preoccupied Hinks, who turned over the RGS house to the Geographical Section, General Staff during the war (Close 1947, 116–17; Mill 1930, 199). Covering much of Central Europe, the resulting map sheets informed discussion of borders and frontiers at the Paris Peace Conference, and in recognition Hinks was appointed a commander of the British Empire (CBE) in 1920. During his time at the RGS Hinks took great interest in expeditions, especially polar ones, and revised the society's iconic book *Hints to Travellers*. For much of his period of office he wrote papers, reviews, and comments, some unattributed, for the *Geographical Journal*, of which he was editor. His punctilious approach was also applied to the Drawing Office, where new methods of mapmaking reached their apogee in the British Council map of *Europe and the Middle East* (1941).

At the RGS, Hinks found time to write and revise textbooks. *Map Projections* first appeared in 1912 and was being revised for a third edition when he died in 1945. *Maps and Survey* came out in 1913, confirming his academic conversion to cartography. For many years, it and its four new editions (1923, 1933, 1942, 1944) had few equals among English-language texts by nonmilitary authors. Hinks frequented major international congresses and regretted not being able to persuade British authorities to adopt air survey for mapping during the interwar period. Recognized by Hugh Robert Mill (1930, 207) for advancing "methods for securing higher efficiency in surveying by astronomical, wireless, and photographic means and in the devising of new projections to meet modern needs," he was awarded the Victoria Medal of the RGS (1938) and the Cullum Medal of the American Geographical Society (1943). Hinks died in Royston, Cambridgeshire, on 14 April 1945.

CHRISTOPHER BOARD

SEE ALSO: Academic Paradigms in Cartography: Europe; Education and Cartography: Cartographic Textbooks; International Map of the World; Royal Geographical Society (U.K.)

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Steers, J. A. 1982. "A. R. Hinks and the Royal Geographical Society." *Geographical Journal* 148:1–7.

Historians and Cartography. Since the profession of history was established in the late nineteenth century, most historians have regarded maps either as useful locators of events and places or as curious reflections of the state of geographic knowledge during a given period. Maps have seldom been central to historical research as sources of evidence or as a mode of representing historical understanding. This is mainly due to historians' training, which has traditionally emphasized the careful evaluation and contextualization of verbal sources and, to a lesser extent, numerical data. As art historian Barbara Maria Stafford (1996, 20–40) has argued, the privileging of texts, narrative, and literary methods has made history a logocentric profession whose practitioners distrust, or do not think to consider, more synoptic, visual ways of knowing, including the kinds of geographic information and spatial knowledge embodied in maps.

The rarity of maps in works of history is one of the signal differences between historical scholarship and the work of historical geographers and historians of cartography. Some intrinsically geographical histories, such as

Frederick Jackson Turner's *The Frontier in American History* (1920), contain not a single map. Individual historians and some genres of historical publication, however, have used maps for a variety of purposes, often to powerful effect. They are the focus of this essay. In distinguishing historians from historical geographers and others with both historical and geographical interests, my guide is scholars' self-identification. Samuel Eliot Morison summarized the key difference from the historian's point of view when he declared, "I am writing a history of voyages, not of maps" (1978, viii).

Morison and Irish historian David B. Quinn are two of a handful of prominent historians who used cartographic sources extensively in historical research. Maps drawn by European explorers were essential to their studies of the voyages of Sebastian Cabot, Jacques Cartier, Christopher Columbus, Ferdinand Magellan, Walter Ralegh, and others who probed the Atlantic and Pacific reaches of the Americas in the fifteenth and sixteenth centuries (Morison 1978; Quinn 1974). Morison's books on exploration also included aerial photographs of coastlines, some of which he shot from the cockpit of a small plane. As a sailor, Morison knew the significance of headlands and visual navigation. That may help explain his skillful use of historical maps, from portolan charts to globes, and his inclusion of quasi-bird's-eye view topographic maps to chart the coasting portions of many historic voyages. For his biography of the American revolutionary admiral John Paul Jones (1959), Morison had Harvard cartographer Erwin Raisz draw several maps and diagrammatic sketches of naval battles. Raisz also drew more elaborate maps for Morison's annotated edition of William Bradford's *Of Plymouth Plantation* (fig. 371).

Raisz's elegant hand lettering and his ability to render the texture of landscape were ideal for historical subjects. His excellent physiographic maps at the continental scale were used as base maps in a number of textbooks and historical monographs, either directly or imitated by other cartographers and graphic artists. One example is the Raiszian pen-and-ink topography in Scribner's *Atlas of American History* (Adams 1943), with cartography by LeRoy Appleton. Although American historians from Turner onward roundly rejected the literal notion of environmental determinism, the obstacles and opportunities posed by terrain remained fundamental to the saga of Euro-American migration and territorial expansion in the United States. In *Voyagers to the West* (1986), Bernard Bailyn's explanation of colonial migration in British North America was made vivid by topographic maps that guided the reader's eye up river valleys and through mountain gaps as if in the footsteps of early settlers. Not all historians have used thematic maps so effectively. The county-level maps of crop and timber production and bank loans in William Cronon's *Nature's Metropolis* (1991) reflect the limitations of early computer cartography. They are, however, vital to his argument that Chicago's hinterland drove much of the city's dramatic growth in the late nineteenth century.

FIG. 371. ERWIN RAISZ, *PLYMOUTH BAY, 1620–1650*. Antique type styles and Raisz's textured rendering of the morainic hills and sand bars evoke the historic landscape and echo the copperplate printing that produced his eighteenth-century source, *The Atlantic Neptune*.

Size of the original: 16.3 × 10.4 cm. From William Bradford, *Of Plymouth Plantation, 1620–1647*, new ed., ed. Samuel Eliot Morison (New York: Alfred A. Knopf, 1970), 91.

Maps have been particularly important in European studies of landscape history. In *The Making of the English Landscape* (1955), W. G. Hoskins determined much of the history of British towns and agricultural villages by comparing town plans and field patterns on large-scale British Ordnance Survey maps to archaeological evidence, aerial photography (which can reveal the ghostly imprint of immemorial land use), and his own field reconnaissance. Hoskins's fond regard for the

English countryside and small towns and his disgust for industrial landscapes echoed the sentiments of many people in postwar Britain. His comparative, highly visual and geographic method proved popular as well, as his approach was widely adopted by local historians and incorporated into school curricula.

One of the few historians to use maps analytically was Fernand Braudel, the most geographic thinker of the Annales school of social history in France. While many Annales historians shared his interest in the history of everyday life, the majority limited their forays into graphic representation to graphs of time series or simple locator maps. Braudel's method was exceptionally cartographic. In his history of the Mediterranean, Braudel drew upon the gifts of cartographer Jacques Bertin to depict his new conception of the region's context (fig. 372), a vision grounded in Braudel's understanding of physical geography, climate, vegetation, and the material influence of the ocean on its surrounding civilizations. In his later masterwork *Civilization and Capitalism* (1981–84), maps again provided key evidence for the regional differentiation of culture, commercial connections, and the changing spatial structures of European and world economies. No historian, and few geographers, have matched the variety or the originality of Braudel's cartographic arguments. Whether plotting overpopulation in relation to emigration circa 1745 or the reach of communications from Nuremberg in 1550, using his own or others' maps, Braudel demonstrated the evidentiary power of visualizing otherwise invisible social relationships.

FIG. 372. JACQUES BERTIN, *THE MEDITERRANEAN AND THE REST OF THE WORLD*. Fernand Braudel chose this unorthodox orientation to emphasize the barrier of the Sahara and his sense of the Mediterranean as a frontier and zone of connection between peninsular European regions.
Diameter of the original: 12.5 cm. From Fernand Braudel, *The Mediterranean and the Mediterranean World in the Age of Philip II*, abridged ed., trans. Siân Reynolds (New York: HarperCollins, 1992), 122. Copyright © Librairie Armand Colin 1966. English translation copyright © 1972 by Wm. Collins Sons Ltd. and Harper & Row Publishers, Inc. Reprinted by permission of HarperCollins Publishers.

Much more commonly, historians used maps as simple aids to exposition. What Jeremy Black (1997) and others call "historical cartography"—the mapping of historical themes and locations—became a standard feature of history textbooks and world and regional atlases with the advent of offset lithography in the late nineteenth century. Lithography held fine lines and lettering through large print runs, which facilitated the reproduction of detailed maps. In the first half of the twentieth century, historical cartography reflected the dominance of political and economic history. In American textbooks, common themes included the acquisition of western territory, state votes in presidential elections, and the location of major economic regions. European and world history texts typically included maps of the shifting boundaries of imperial civilizations, migration of language groups, regions of religious hegemony, and changing boundaries of nation-states due to war and political alliances. Military historians, familiar with the conventions of nineteenth-century topographic mapping, more often included maps at a variety of scales, from the regional scope of the theater of war to the local drama of famous engagements. Aside from the dynamic arrows marking troop movements and migration flows, textbook history maps were chiefly meant to locate places and political or cultural areas referred to in the text. They treated space as the static container of history, geography as a canvas dotted with places where things happened. It was important for readers to know where Constantinople was in relation to Jerusalem during the Crusades, but the places themselves were mainly points of reference.

Textbook maps became less cut and dried in the 1980s as history publishers exploited maps' visual appeal as a marketing strategy. The pedagogical potential of iteratively mapping historical demographic data inspired some of the first efforts to apply geographic information systems (GIS) to history. Social science historians were first to adopt GIS in the 1980s and 1990s, as they were familiar with statistical computer programs and accustomed to analyzing large data sets. Environmental historians have used GIS to analyze land use and other human impact upon physical environments. Archaeologists and historians of the ancient world and the early medieval period have also gravitated to GIS because of its ability to integrate physical and cultural evidence, which provides context for archeological sites and helps connect fragmentary evidence from other sources (Knowles 2002).

Historical GIS and digital history more broadly have been spurred by the rapid growth of digital depositories of historical maps, images, and texts. Projects such as the Greater Philadelphia Geohistory Network envision electronic linking of archival resources as a way to promote geographically informed local history. The Electronic Cultural Atlas Initiative, based at University of California, Berkeley, has fostered image-rich web-based historical publications, many of which use GIS mapping techniques to show change over time. Erik B. Steiner and other cartographers using Flash for animated and multimedia cartography began to influence how historians imagine past space and place, as in Steiner's collaboration with architectural historian Jim Tice in visualizing the built landscape of baroque Rome (fig. 373).

Historical geographer Alan R. H. Baker (2003) found a history of tension between the disciplines of history and geography. Scholars like to say that history is about time, geography about space. Tracing change through time leads to narrative, which is sequential, logical, and verbal; geographical comparison over space produces maps, which are synoptic, simultaneous, and visual. The two ways of knowing, and the methods to which they have given rise, nest uncomfortably for many scholars. For Braudel, "the dialectic of space and time (geography and history)" was "the original justification" for a particular kind of history in which maps and mapping were central (1972–73, 1:16). The intensely visual twenty-

This is one of the classic views of Rome repeated in numerous paintings, etchings and more recently in postcards: fishermen or boatmen in the foreground, Ponte and Castel S. Angelo (7) in the middle ground, and St. Peter's (3) in the distance with its dome rising above the center of the bridge, on which Bernini's angel statues stand out clearly. Except for Castel S. Angelo (7) and the distant Vatican buildings, most of what we see in this view has been demolished or has undergone radical transformation. The ancient bridge linking emperor Hadrian's tomb-turned-medieval-castle to the city was lengthened at both ends in the

FIG. 373. THE *INTERACTIVE NOLLI WEBSITE*. This screen capture links a georectified version of Giovanni Battista Nolli's 1748 map of Rome (lower right) with contemporary engravings by Giuseppe Vasi (left). As this example of the bridge and castle of St. Angelo shows, combining planimetric and pedestrian views of the city enhances one's perception of them both. Buildings on the map suddenly gain height and nearly become three-dimensional, while the engraved scene gains depth that conventional perspective obscures. Tying the visual documents together by location also enables one to connect lived experience, as depicted in Vasi's drawings, to the structure of urban space.
Image courtesy of the Architecture and InfoGraphics Lab, Department of Geography, University of Oregon, Eugene.

first century may bring another rapprochement between historical and geographical scholarship.

ANNE KELLY KNOWLES

SEE ALSO: Atlas: (1) Historical Atlas, (2) Historical-Boundaries Atlas; Education and Cartography: Teaching with Maps; Geographic Names: Place-Name Studies; Historical Geography and Cartography; Histories of Cartography

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Historic Preservation and Cartography.

Historic preservation maps delineate boundaries of a site or an area considered to have historical significance. Similar to special improvement district maps, they typically include administrative features like tax lots, physical elements like rivers and buildings, and transit ways like streets and highways. Occasionally they include topographical features like elevation or vegetation, and their boundaries, which generally surround contiguous areas, often encompass "noncontributing" resources such as relatively new structures or older properties that have lost their integrity. Because historic districts exclude buffer zones (acreage that does not directly contribute to the historical significance of a place), historic preservation maps are often larger in scale than a standard topographic map (fig. 374).

By the turn of the twentieth century, when industrialization's negative impacts were clearly apparent, historic preservation in general and its maps in particular were already in use to a large degree in England and to a lesser extent in the United States. In England, historic preservation maps emerged as national tools to preserve artistic and intellectual sites or irreplaceable landscapes such as country commons. In the United States, by contrast, historic preservation maps, which were made by local volunteers and held little or no regulatory power for much of the twentieth century, initially memorialized political sites like battlefields or economic successes like massive factories. When regulatory legislation was passed in the 1960s, maps not only became more standardized in content and symbolization but their meanings changed significantly as well.

As the failure of urban renewal programs was becoming apparent, historic preservation evolved into an urban planning strategy (Saito 2009; Wilson 2004). With the growth of the historic preservation movement, preservation maps became a critical tool for urban development. In this context, historic preservation maps were never just about protecting the past. Indeed, their role in shaping the future changed dramatically when city governments began to view the preservation movement, and its maps, as a political tactic for urban revitalization. Local planning offices embraced preservation ideology to spur economic investment and "high" cultural tourism as well as increase property tax revenue (Reichl 1997; Wilson 2004). This shift in the 1970s in *how* historic preservation happened—through more government-supported and proactive land use planning efforts—was accompanied by a shift in *what* was memorialized (Saito 2009). Historic preservation moved from primarily protecting individual, threatened buildings of political significance to recognizing various places of everyday life. In the early 1980s tax incentives for the restoration of these everyday historic places reinforced preservation as a critical theme of urban planning and expedited its emergence as an established fixture in U.S. cities, small towns, and rural areas (Kaufman 2004, 319–20).

Maps have played a fundamental role in the implementation of historic districts and historic properties or landmarks. The maps not only granted legitimacy to the interpretive quality of historic preservation but also, as a type of administrative cartography, provided a spatial framework for preferential taxation, civil engineering and public works, environmental protection, growth management, and zoning restrictions. Historical maps such as city atlases, rural plats, and especially Sanborn fire insurance maps have been crucial to initial data collection, documentation, and assessment of a place's historical significance as well as claims about particular preservation boundaries. As the century drew to a close,

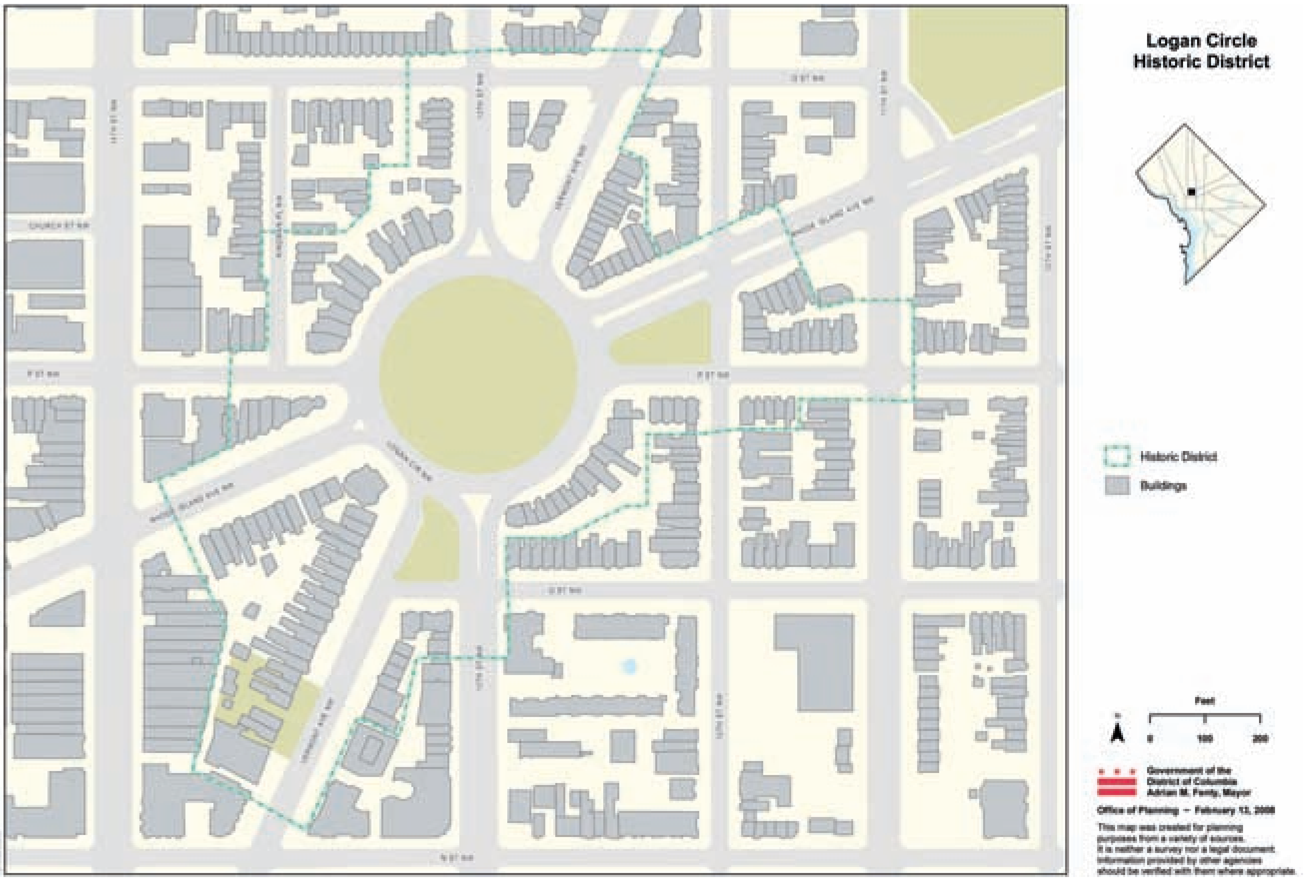

FIG. 374. GOVERNMENT OF THE DISTRICT OF COLUMBIA OFFICE OF PLANNING, *LOGAN CIRCLE HISTORIC DISTRICT*, 13 FEBRUARY 2008. It is common for historic preservation boundaries, which tightly follow select cultural or natural features of the landscape, to be highly irregular in shape and often include only one side of a street.
Image courtesy of the Historic Preservation Office, The District of Columbia, Washington, D.C.

new cartographic techniques, including GIS surveying, landscape modeling, cognitive and community mapping, and archeological methods provided vital and persuasive sources for the delineation of historic properties and districts as well as a justification for funding and a tool for regulating use (Stewart 2001).

Unavoidably, the historic preservation map also became a source of conflict, particularly in disputes about *where* boundaries are placed and *what* they mean. Discord over the inclusion and exclusion of certain properties (i.e., the selection of one historical resource over another) easily becomes a dispute over the implications of boundaries for property rights (i.e., the right to add a handicap-accessible ramp to a historic house or the right to modify a property in a cost-efficient manner that diverges from preservation codes) and property values. Although preservation maps are considered a form of restrictive cartography, debate arose over the degree to which preservation policies contribute to gentrification and constitute a form of racialized practice (Saito 2009). As entire cities fell within the bounds of historic districts in the twenty-first century the increased use of historic boundaries as tools of governance in North American and European cities raised further questions about the role of preservation cartography in land use planning.

KATIE J. WELLS

SEE ALSO: Administrative Cartography; Boundary Disputes; Community Mapping; Land Use Map; Landscape Architecture and Cartography; Planning, Urban and Regional; Urban Mapping

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Historical Atlas. See Atlas: Historical Atlas

Historical Geography and Cartography. Carl Ortwin Sauer claimed that the "most primitive and persistent trait" of geographers "is liking maps and thinking by means of them. We are empty handed without them in lecture room, in study, in the field," he went on. "Show me a geographer who does not need them constantly . . . and I shall have my doubts as to whether he has made the right choice of life" (Sauer 1956, 289). Although not all historical geographers are as wedded to maps as Sauer suggests, the most obvious difference between them and historians is the number and variety of maps that historical geographers include in their publications. The difference goes deeper, however, because for many historical geographers, cartography is an indispensible method, both descriptive and analytical. As British historical geographer H. C. Darby put it, mapping historical evidence is often necessary if one wishes to "set out [historical inquiry] upon a geographical basis" (Darby and Terrett 1971, ix). In other words, some historical geography would be impossible without cartography.

This is true in part because ready-made geographical evidence of the past is relatively scarce. Historical maps become increasingly rare and geographically inaccurate as one goes back in time. For many periods and places, the past survives only in verbal texts or in remnant features present in the physical landscape. When Darby set out to study the early medieval geography of England, he like many medieval historians turned to the Domesday Book, a manuscript text (ca. 1086) created for King William I that provides by far the most detailed and comprehensive record of land use and animal husbandry for the period. To "set out" the geography embedded in the text, Darby first had to restructure the material according to the geographic location of land holdings, then tabulate the agricultural information for each demesne, then produce maps showing the spatial distribution of each kind of information. Ultimately, this protracted exercise enabled Darby to estimate variations in agricultural productivity and specialization across much of England, in addition to the intensity of land use, the relative wealth of English regions, and other basic characteristics of the early medieval economy.

Like Darby, Sauer believed that the main purpose of geography was to identify and explain areal differentiation, particularly the multitude of cultural differences expressed in humanity's imprint upon the landscape. Of such studies there could be no end, Sauer thought, because the whole of human history waited to be explained in situ (Sauer 1925, 1941). Sauer's interest in early Mesoamerican agricultural societies led him to develop a slightly different method than Darby's. Because environmental conditions and archaeological remains provided evidence that helped fill gaps in the written record, particularly for periods before European contact, Sauer and his students incorporated extensive field observations in their reconstructions of past landscapes. For example, Robert C. West's monograph (1948) on the cultural geography of the Tarascan area of central Mexico begins with maps of the region's volcanic landscape, climatic zones, vegetation, and soils. Variations in the physical environment help explain regional economic specialization and the history of European colonization, which in turn influenced where the Tarascan language survived or most rapidly lost ground.

Urban historical geographers have produced some of the most detailed reconstructions of past landscapes, assisted by the comparative plenitude of urban plans, especially for European towns, and the survival of centuries-old street patterns in many urban centers. German historical geographer M. R. G. Conzen's study of the Northumbrian market town of Alnwick (1960) provided a model for how one could systematically document urban form and function as they changed over time. Conzen's highly cartographic approach had a lasting influence on scholars of urban morphology. In the United States, John William Reps's collections of bird's-eye views educated a generation of geographers, historians, and lay readers in the genres of American town plans, from the relentless grid (first platted for Savannah, Georgia, and Philadelphia, Pennsylvania) to the graceful curves of Frederick Law Olmsted's designs for residential suburbs.

Sauer argued early in the twentieth century that all human geographers should be interested to some degree in history because one could not explain any aspect of culture without understanding its origins and development over time. Historical geographers in the United States embraced the notion of mapping change over space and time in a number of ways. Fred Bowerman Kniffen, John Fraser Hart, and Terry G. Jordan, among many others, traced the westward movement of vernacular architectural styles and farming practices from culture hearths in Europe and the eastern seaboard. John C. Hudson rendered the less visible geography of migration to the farming frontier in maps that demonstrate the difference cartography makes to historical geography. Where other social science historians typically document migration in tables and charts, Hudson showed it as arcs of movement across space (fig. 375). In a glance, his maps sug-

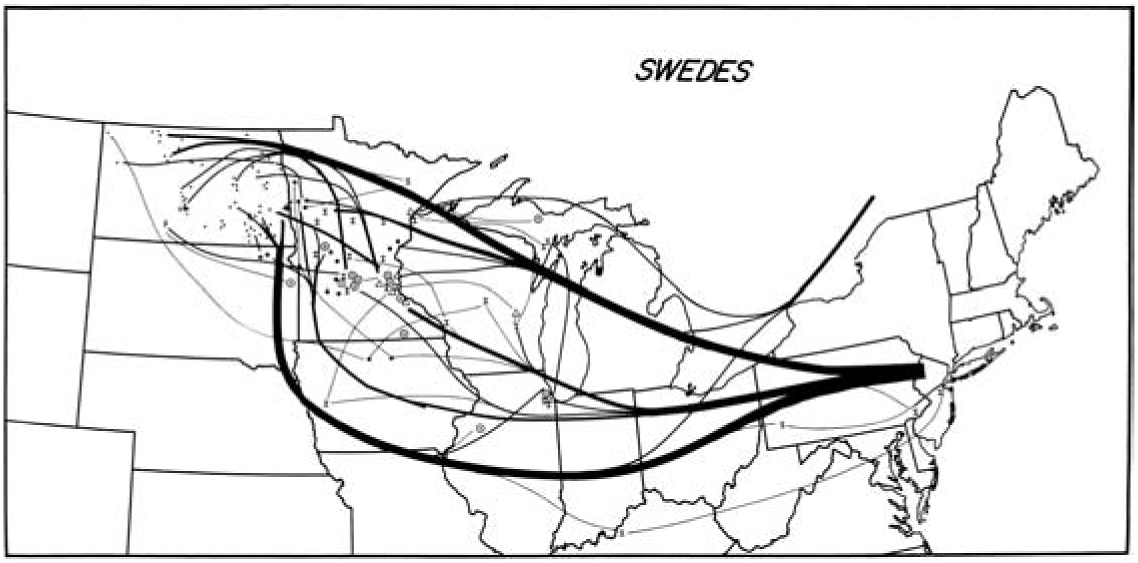

FIG. 375. JOHN C. HUDSON'S MIGRATION ROUTES OF SWEDISH AND SWEDISH AMERICAN PIONEERS IN NORTH DAKOTA, 1976. The map shows the direct movement of many newly arrived Swedish immigrants from New York City to North Dakota's farming frontier from 1875 to 1915. Smaller lines trace the migration of first- and second-generation Swedish Americans from established ethnic enclaves.
Size of the original: 7.2 × 14.8 cm. From John C. Hudson, "Migration to an American Frontier," *Annals of the Association of American Geographers* 66 (1976): 242–65, esp. 249 (fig. 8). Reproduced by permission of Taylor & Francis.

gest places of origin and destination, the networks connecting them, the volume of migration, and the distances migrants traveled. R. Cole Harris's critique of colonialism in British Columbia (2002) is most poignantly expressed in his maps of the minute, insupportable native reserves that representatives of the British state carved out of the vast province. D. W. Meinig (1986–2004) sometimes departed from tradition by graphically summarizing the processes of settlement, cultural encounter, landscape formation, and the exercise of imperial power in cartographic diagrams, which emphasize spatial relations rather than location or morphology (fig. 376).

Historical geographers based in Chicago have brought a distinct cartographic emphasis to U.S. history education, largely through the influence of the Newberry Library, which houses one of the country's leading map collections. The Newberry's Hermon Dunlap Smith Center for the History of Cartography began offering programs on the pedagogical uses of historical maps in the 1980s. One of the center's directors, David Buisseret, produced books that combine historical maps, aerial photographs, and sketch maps to teach students how to read history in the landscape. Along with historian Gerald A. Danzer, Buisseret compiled reproductions of historical maps on overhead transparencies with teaching notes as visual supplements to U.S. and world history courses. One of the first history textbooks to include a large number of thematic maps on social, cultural, and environmental topics was *America's History* (1987). The book's maps, over 110 altogether, were developed by historical geographer Michael P. Conzen, who later was cartographic editor for *The Encyclopedia of Chicago* (Grossman, Keating, and Reiff 2004), a Newberry project which, thanks to Conzen, is the most richly cartographic of all U.S. city encyclopedias (fig. 377).

Historical geographers' affinity for thematic mapping has been most emphatically demonstrated in historical atlases where maps fill the page and carry the weight of evidence and argument. Historian Charles Oscar Paullin and geographer John Kirtland Wright compiled hundreds of historical and thematic maps documenting the shifting configurations of territory, population, politics, economic activity, and culture in their monumental *Atlas of the Historical Geography of the United States* (1932). The three-volume *Historical Atlas of Canada* (1987–93) set the standard for cartographic complexity, though its most compelling plates are works of art that vividly render past landscapes. Historical atlases have sometimes been the impetus for generating the first thoroughgoing historical geography of a given region, as happened in the course of producing the state-funded Canadian atlas and the *Bateman New Zealand Historical Atlas = Ko Papatuanuku e Takoto Nei* (1997). The *Atlas of the Irish Rural Landscape* (1997) sparked national debate about the value of historical landscapes associated with Ireland's troubled colonial past. Some state historical

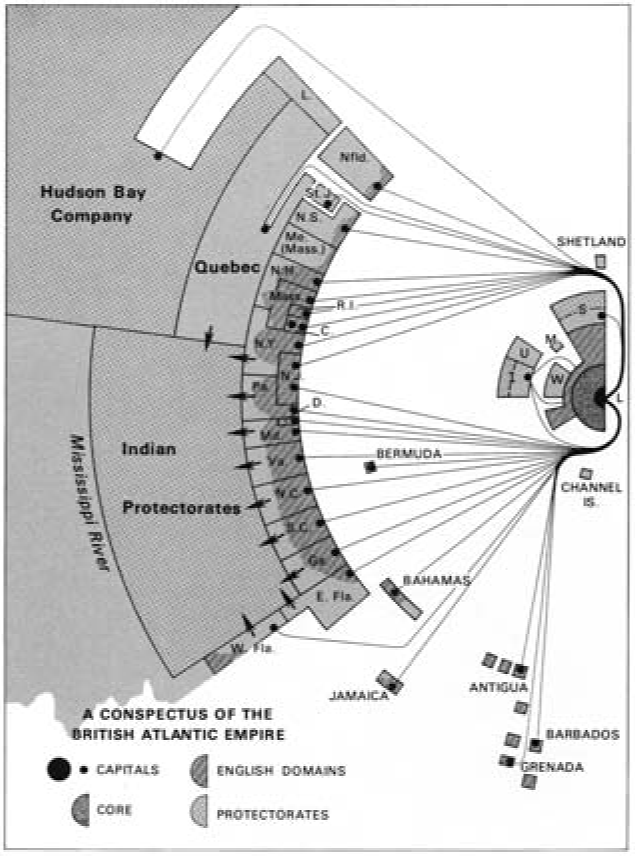

FIG. 376. D. W. Meinig, *A CONSPECTUS OF THE BRITISH ATLANTIC EMPIRE*, 1986. Meinig's "conspectus" discards geographic realism in the interest of highlighting the anchor-points of connection between the seat of empire in London and Britain's many colonies in North America and the Caribbean. The spatial diagram also suggests how shallow imperial territorial control was in the mid-eighteenth century.
Size of the original: 20.7 × 15.1 cm. From Meinig 1986, 1:376. Permission courtesy of Yale University Press, New Haven.

atlases, such as the *Historical Atlas of Maine* (forthcoming), have required a great deal of spade work to cover subjects that had never been studied geographically.

New interest in mapping as a method for historical inquiry has recently emerged in the form of historical GIS, the application of geographic information systems to historical research and teaching. One of the advantages of GIS is that its underlying database structure can hold, and map, enormous amounts of information, though converting historical data into digital form is a time-consuming and arduous process that often requires a team of researchers. The first historical GIS database program was published in 1985 by historian David W. Miller and computer scientist John Modell. Their digital mapping program, the "Great American History Machine," which was intended as a teaching tool, automated the mapping of demographic data from the federal census within state and county boundaries. More comprehensive national historical GIS projects were completed in a number of European countries, China, Taiwan, Russia, and the United States over the next twenty years. These infrastructure projects made mapping demographic data easier and more accurate where researchers reconstructed historically accurate administrative boundaries.

Since about 1995, historical geographers have been among the leaders in developing historical GIS as an interdisciplinary method (Gregory and Ell 2007), with studies as varied as the history of Chinese administration, the stewardship of land in colonial New England, and the geographies of the Holocaust during World War II (Knowles 2008). Historical maps play a prominent part in historical GIS, particularly as sources for evidence that no other documents contain. For example, British historical geographers used GIS to estimate the population density of England, Scotland, and Wales in the Middle Ages based on the settlement hierarchy encoded in the Gough Map, ca. 1360 (Lilley and Lloyd 2009). Historian Richard J. A. Talbert argued in the *Barrington Atlas of the Greek and Roman World* (2000) that cartography was the essential new method for ancient history. The digital descendant of that atlas, the Pleiades Project, carries the argument further by using GIS as a means for scholars around the world to share material and collaborate in studies of the ancient world.

While historical GIS invigorated geographical analysis in historical scholarship, the art of cartography also found new historical expression in spatial narrative at the beginning of the twenty-first century. Inspired partly by graphic novels and the deconstructionist movement of the late twentieth century, historical cartographers Michael J. Hermann and Margaret W. Pearce produced a series of large thematic maps that tell the stories of legendary historical journeys. Their multilingual, multiscale map of Samuel de Champlain's travels in Canada, 1603–16, gives voice to Native Americans as well as Champlain and his men at moments of peril, uncertainty, ambitious dreaming, and hopelessness (fig. 378). It reminds us that history and geography are inextricably connected where events take place that forever mark individual lives and the shape of human society.

ANNE KELLY KNOWLES

SEE ALSO: Atlas: Historical Atlas; Harley, J(ohn) B(rian); Historians and Cartography

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FIG. 377. MICHAEL P. CONZEN, *PROGRESS OF THE CHICAGO FIRE OF 1871*, 2004. This map brilliantly captures the movement of the fire from its beginnings on the South Side the night of October 8 to its leaps across the Chicago River and up the North Side the following two days. Color conveys the impression of sparks, smoke, and the burned-out core of downtown, all against the backdrop of city streets and landmarks.

Size of the original: 24.4 × 12 cm. From Grossman, Keating, and Reiff 2004, C2. Permission courtesy of the Newberry Library, Chicago.

FIG. 378. DETAIL FROM "*THEY WOULD NOT TAKE ME THERE*," BY MICHAEL J. HERMANN AND MARGARET W. PEARCE 2008. This excerpt captures two of the many placed events that express the desire and uncertainty of Champlain's journey. The full map contains scores of such moments. Size of the entire original: 99.1 × 149.9 cm; size of detail: 11.2 × 9.2 cm. From Michael J. Hermann and Margaret W. Pearce, "*They Would Not Take Me There*": *People, Places, and Stories from Champlain's Travels in Canada, 1603–1616* (Orono, Me.: Canadian-American Center, University of Maine, 2008). Permission courtesy of the Canadian-American Center, University of Maine, Orono.

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Histories of Cartography. By 1900, distinct approaches to the study of early maps were pursued within each of four institutional settings: academic departments of geography and history; map collections in national libraries; government survey organizations; and communities of dealers and collectors of antiquarian maps. National traditions and linguistic limitations further divided the field (Cortesão 1969–71, 1:1–70; Skelton 1972, 73–99; Blakemore and Harley 1980, 14–75; Harley 1987). Map historians repeatedly interpreted this diversity as weakness. Some sought to promote communication through dedicated journals and the bibliographic control of primary sources and secondary literature (e.g., Eckert 1921–25, 1:24–48; Skelton 1972, 99–109; Simms 1991). Others argued that disciplinary unity could only be forged through a new intellectual identity, whether from the standpoint of cartographic practice (e.g., Shibanov 1973; Woodward 1974) or of cultural and social history (e.g., Blakemore and Harley 1980, 76–106). Such arguments necessarily defined a simplified and dualistic narrative—the unreformed past and present giving way to a reformed future—that obscured important structural distinctions within map history as a field of inquiry.

This article traces how the institutions supporting map history variously changed after 1900 in order to explore the shifting communities, concerns, and practices of scholars interested in early maps. Heuristically, Matthew H. Edney (2012) identified four configurations of institutions and concepts that can be called the traditional, the internal, the sociocultural, and the processual paradigms. Figure 379 summarizes their conceptual interrelationships and how other intellectual fields contributed. Significantly, the transitions between paradigms were neither unilinear nor absolute: the paradigms coexisted and continued to interact in complex ways. The twentieth-century field of map history has thus never comprised a single intellectual endeavor but rather multiple, overlapping histories of cartography.

The origins of the traditional paradigm of map history lie in the nineteenth-century idealization of "cartography" as the singular and universal science of observing, measuring, and graphically replicating the world at

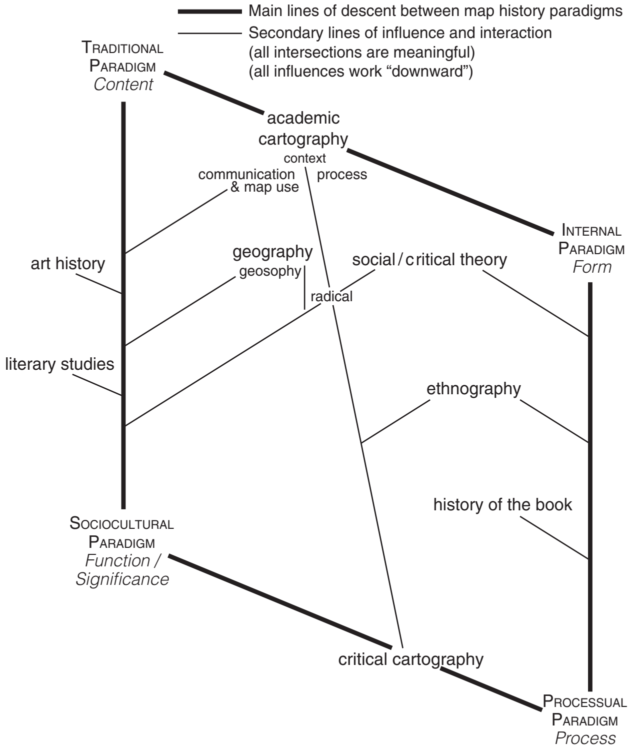


FIG. 379. TWENTIETH-CENTURY PARADIGMS OF MAP HISTORY. This schema depicts the intellectual descent and influence between the four primary groupings of map history studies and related disciplines. (A complete schema would include the influence in return of map history on other fields of knowledge.) Vertical scale (time) is only suggestive.

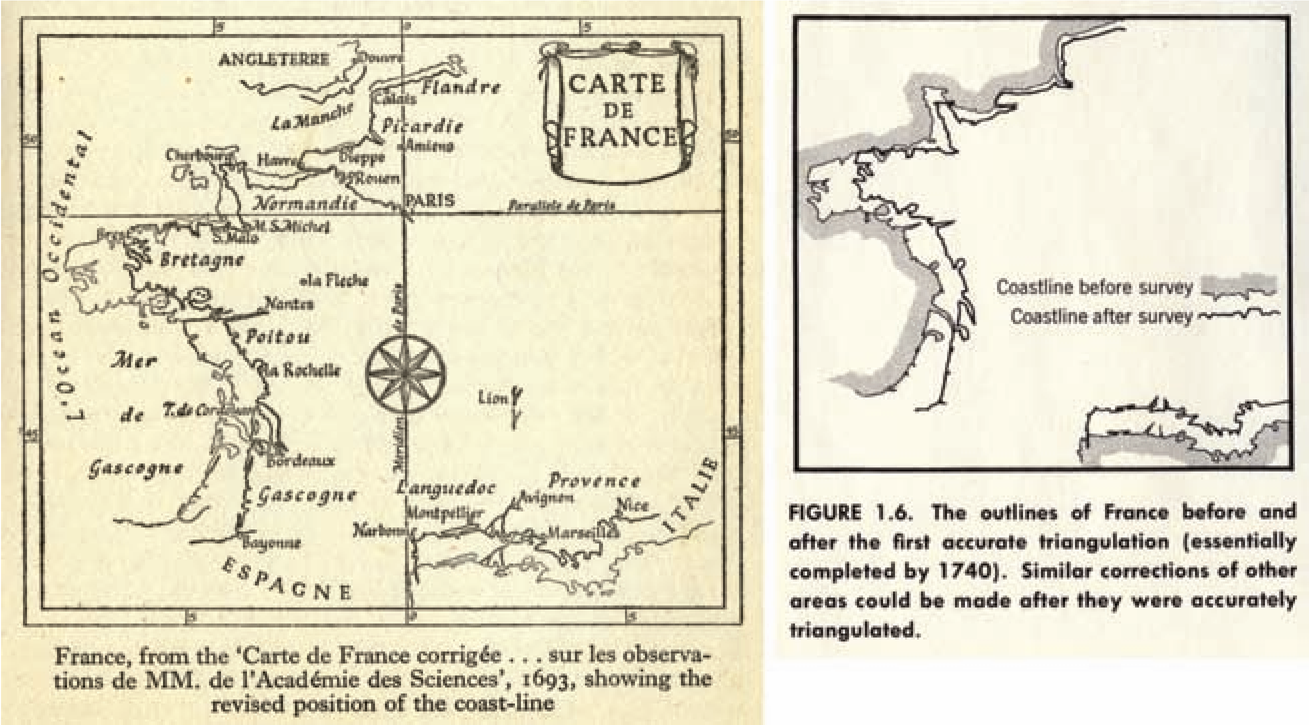
any and all scales. The cartographic ideal was sustained by a new "history of cartography" (a term coined in the 1870s) that traced this singular endeavor as it progressed from ancient Egypt, through Greece and Rome, to Renaissance and Baroque Europe. This progressive cartographic narrative resonated widely in the era of European global domination and imperialism because it succinctly and powerfully narrated the rise of Western civilization. After 1850, map history accordingly fostered a much larger community of scholars than had the previously sporadic study of old maps. By 1900, scholarly activity had grown sufficiently for academic map historians to meet in special sessions at international geographical and historical congresses. In 1935, antiquarian Leo Bagrow founded *Imago Mundi* specifically to foster the international community of map historians (Harley 1986). The post-1945 expansion of academia generated further international collaboration, such as the working groups within the international congresses that advocated the preparation of pan-European cartobibliographies, while economic growth stimulated new antiquarian journals such as R. V. Tooley's *Map Collectors' Circle* (1963–75) and *Map Collector* (1977–96).

Traditional map history was grounded in the "empiricist" idealization of cartography. This held that maps are properly grounded in the direct experience of the world, mediated only by the technical abilities of surveyors and mapmakers. This view gave rigor to the longstanding scholarly study of old maps as repositories of spatial facts. Map historians after 1850 worked to make the content of old maps understandable to historians of geography, exploration, landscape, and human settlement. In particular, they formalized and expanded the older practice of reprinting old maps in facsimile with works such as A. E. Nordenskiöld's *Facsimile-Atlas to the Early History of Cartography* (1889; reprinted in 1961, 1970, and 1973). They also embarked on a new project of conscientiously identifying old maps through catalogs of specific collections and, after 1900, through systematic cartobibliographies. Indeed, P. D. A. Harvey (1980, 7) characterized the narrative form of traditional map history as being essentially cartobibliographic, in which each essay comprised "a set of descriptions of one map after another."

The idealized narrative of cartographic progress depended upon a canon of maps that manifest the continual increase in quality and quantity of spatial data; maps lying beyond the normalized line of progress were excluded from study. Nonetheless, different groups of map historians used various criteria to refine the canon, producing a marked heterogeneity in the practices of traditional map history. Antiquarian concerns and the general historiographic interest in early modern discoveries limited the canon to European maps from the era 1450–1750. Within the canon, and driven as they were by national concerns and interests, academics, librarians, and antiquarians focused primarily on the development of knowledge of specific regions; their preeminent methodology was therefore regional cartobibliography. Map librarians further sought to establish bibliographic control over the collections in their care. Connoisseurs established collectible sets of antiquarian maps, such as those by a so-called master cartographer (e.g., Abraham Ortelius) or having a particular character (e.g., maps of Leo Belgicus). These disparate interests combined in the unfortunate idealization of discrete national schools—German, Italian, Dutch, French, and British—whose sequential periods of cartographic "leadership" gave traditional map history its basic narrative.

Professional survey histories constituted a separate stream of scholarship. Most were prepared by senior officers in governmental surveying agencies who wrote histories of their institutions' activities in part from genuine interest in the subject but also as part of constant efforts to maintain political patronage and funding. Such works include Charles Frederick Close's *The Early Years of the Ordnance Survey* (1926) and Georges Perrier's *Petite histoire de la géodésie* (1939). After 1890, professional map history intersected with studies by historical geographers of early topographical maps for the information they contained about preindustrial landscapes (Anonymous 1933). After 1960, J. B. Harley and other historical geographers such as J. H. Andrews, Richard A. Bartlett, and J. A. van der Linden undertook their own histories of private and official surveys in order to determine how best to use their products as evidentiary sources (Edney 2005a, 19–31).

Professional survey histories were slowly incorporated into the rest of the traditional paradigm. In *Die Reformation der Kartographie um 1700* (1905), C. Sandler argued that the French had placed cartography on a new and firmly scientific footing during the Enlightenment. While this concept was adopted more quickly in France than elsewhere (via Gallois 1909), it eventually became de rigueur that the Enlightenment formed the watershed between old/artistic and modern/scientific maps, as Bagrow maintained when he ended his antiquarian *Die Geschichte der Kartographie* (1951; English edition, 1964) in about 1750. Sandler's concept of cartographic reformation was eventually dogmatized in two widely read monographs that used professional histories to extend the history of scientific cartography from its ancient origins to modern topographical mapping. Lloyd A. Brown, in *The Story of Maps* (1949), and G. R. Crone, in *Maps and Their Makers* (1953), both enshrined Sandler's supposed eighteenth-century reformation as the defining moment for cartography as a truly modern science (fig. 380). Brown's text is notable as the only traditional history of cartography that treated the practices of mapmaking, including surveying and printing, in detail; it was also the primary source for John Noble Wilford's *The Mapmakers* (1981), a popular history of great men sacrificing their all to map the world. Brown's and Crone's commitment to the modern idealization of cartography was so stark as to risk self-parody. They crystallized map history into a strictly empiricist history of the progressive increase in the quality and quantity of



France, from the 'Carte de France corrigée . . . sur les observations de MM. de l'Académie des Sciences', 1693, showing the revised position of the coast-line

FIGURE 1.6. The outlines of France before and after the first accurate triangulation (essentially completed by 1740). Similar corrections of other areas could be made after they were accurately triangulated.

FIG. 380. THE ICON OF CARTOGRAPHY'S SUPPOSED CARTOGRAPHIC REFORMATION. C. Sandler in 1905 took Jean Picard and Philippe de La Hire's *Carte de France* (1693)—see the *History of Cartography*, vol. 4—to manifest the crucial moment when the French supposedly placed cartography on a firmly scientific footing. The map was widely adopted after 1945 as an icon of cartography's progressive nature, being redrawn—as here by G. R. Crone, *Maps and Their Makers: An Introduction to the History of Cartography* (New York: Hutchinson's University Library, 1953), 129 (left), and Arthur H. Robinson, *Elements of Cartography*, 2d ed. (New York: Wiley, 1960), 8 (right)—and reproduced in numerous histories.

Size of the originals: 8 × 9.5 cm (left, without caption); 6 × 6.5 cm (right, without caption).

spatial information, manifest in a normalized sequence of maps of ever larger scale and extent. This conviction was rehearsed in subsequent overviews of cartographic history, including Norman J. W. Thrower's *Maps & Man* (1972) and George Kish's *La Carte* (1980).

The internal paradigm of map history—cartographers' own view of the history of their profession—originated in the 1890s, when academic geographers first began to publish manuals of map design with introductory historical narratives (Ormeling 2007). Historical introductions proved a persistent feature of cartographic manuals, serving to demonstrate to new students that cartography is indeed a science (figs. 380 [right] and 381). This internal paradigm stemmed from more general academic desires to establish cartography as a coherent subdiscipline of geography or even as an autonomous discipline in its own right. The work of Max Eckert was crucial. His major disciplinary statement, *Die Kartenwissenschaft* (1921–25), was firmly grounded in historical analyses of each aspect of map design (such as lettering, relief depiction, and symbolization). Eckert's work was especially important for his pioneering attention to the history of thematic mapping.

The Cold War's demand for mapmakers prompted the rapid growth of cartography as an academic field. Academic cartographers followed Eckert's lead and deployed an internal history to define an identity and rationale for their field. In the United States, Arthur H. Robinson successfully delimited the academic field by arguing that small-scale map design, especially of thematic maps, had a different historical trajectory from large-scale base mapping and so was intellectually distinct (Robinson 1982). Robinson, many of his students, and other academic cartographers pursued detailed historical analyses of cartographic practices (Edney 2005b). Europeans did likewise. Eduard Imhof, for example, structured his landmark *Kartographische Geländedarstellung* (1965) around a historical treatment of relief representation.

Map historical projects were central to the work of the emergent professional cartographic societies. Within the International Cartographic Association, a standing commission (1972–) on the history of cartography began with a project to trace the history of cartography's multiple technological and conceptual developments; the result, edited by Helen Wallis and Robinson, was *Cartographical Innovations* (1987). Similarly, Erik Arnberger's ambitious disciplinary compendium, Die Kartographie und ihre Randgebiete (1975–), included the two-volume *Lexikon zur Geschichte der Kartographie* (1986), edited by Ingrid Kretschmer, Johannes Dörflinger, and Franz Wawrik.

Internal map history had a markedly new flavor. From their standpoint as academic cartographers, internal historians were interested primarily in the creation, look, and form of maps. They extended the historical canon to include modern thematic and commercial maps. While their sense of progress was as presentist as that of the traditional historians, internal historians such as Mark Monmonier, with his *Technological Transition in Cartography* (1985), replaced the single eighteenth-century reformation with multiple reforms engendered by new concepts and technologies, from printing through thematic mapping to digital computers (see also Freitag 1972; Robinson 1982, 12–15). They promoted the careful analysis of archival sources in addition to studying the maps themselves, especially when elucidating the practices of early map publishing and the contexts in which maps were produced.

Traditional map historians adapted in part to the new internal history. They began, for example, to draw on academic cartography's quantitative techniques to develop competent cartometric assessments of the accuracy of early map content (Blakemore and Harley 1980, 54–75). Some traditional map historians were individually motivated by more professional concerns, as was the case with François de Dainville's history of early map signs, *Le langage des géographes* (1964), and P. D. A. Harvey's comparative study, *The History of Topographical Maps* (1980).

Despite these accommodations, the development of the internal paradigm posed significant problems for the field as a whole. Institutionally, internal map history had significantly enlarged the community of map historians by adding new scholars, even as it made very few converts among the traditionalists. The inevitable conflicts—e.g., the debate in the 1970s over the appropriate subject of map history: map form or map content—served only to make the community of map historians seem still more diverse and fragmented. It was specifically to unite the community that Eila M. J. Campbell, then editor of *Imago Mundi*, hosted a miniconference on map history within the 1964 International Geographical Congress in London; its success spawned the biennial series of International Conferences in the History of Cartography (1965–). In 1974, Campbell sought to codify the core community with the first *International Directory of Current Research in the History of Cartography and*

(*Facing page*)

FIG. 381. *MODERN MAPS: AGE OF NATIONAL SURVEYS, 1700–PRESENT*, 1938. Erwin Raisz prepared several such graphic timelines for the lengthy historical introduction to his manual, *General Cartography*. This particular timeline traced the narrative of cartographic progress through the supposed national schools from an art to a science.

Size of the original: 17.2 × 25 cm. From Erwin Raisz, *General Cartography* (New York: McGraw-Hill, 1938), 52–53.

TIMECHARTS OF HISTORICAL CARTOGRAPHY

4. MODERN MAPS

Age of National Surveys, 1700–present

EVENTS

1700

10

20

30 Octant, Hadley

Chronometer, J. Harrison

40 V. Bering, North Pacific '28–'41

La Condamine, measuring the arc in Peru '36–'43 – Earth as an ellipsoid

50 Tobias Mayer, longitudes by Tables of the Moon '53

60

70 J. Bruce in Abyssinia

J. Cook in S. Pacific and Antarctic

80

Ramsden, theodolite

90 Metric system,

Mackenzie in Canada

1800 Humboldt in America

Mungo Park on the Niger

10

Karl Ritter, Erdkunde,

20 LITHOGRAPHY used for maps

30

40 Ross in Antarctica

WAX ENGRAVING – S.E. Morse in New York

50 D. Livingstone on the Zambezi

60

HELIOGRAVURE PHOTOZINCOGRAPHY

70

Stanley on the Congo

Richthofen in China

80 El. Reclus, La Géographie Univ. '75–'94

Fr. Ratzel, Anthropogeographie

90 Ed. Suess, Das Antlitz d. Erde '83–1901

Nordenskiöld, Facsimile Atlas '89, Periplus '97

1900

10 PHOTOGRAMMETRY

WORLD WAR

20 Echo sounding

AIRPLANE

30 PHOTOGRAPHY

Stereogrammetry

ITALY – SPAIN LATIN AMERICA

Sam. Fritz, Amazon R. 1691–1707

L. Feuillée, Chile – Peru coast '07–'11

J. Petroschi, Jesuit map of Paraguay '32

J. Escandon, surveys in Mexico

G. Nolli, ROME 1:3000 (superb)

P.M. Vinchio in Casale, maps, globes

A. Dury, Sardinia – Genoa (fantastic mountains)

LA CRUZ Cano y Olmedilla South America 1:5000000

G.A. RIZZI-ZANNONI, 1736–1814 Supreme engr. Medit. Sea, Naples atl.

Ant. Zatta, Venice, Atl. Novissimo

TOMÁS LÓPEZ de Vargas, 1730–1802 survey of Spain, maps of America

NAPOLEON'S SURVEYS OF EUROPE –

Spanish Admiralty, Atlas of Amer. coast 1802. Langara, Valdes atl.

A.v. Humboldt, Atlas de Nouvelle Espagne

J.B. Pentland, surveys in Bolivia

R.H. Schomburgk " " the Guianas

NEW GRANADA, A. CODAZZI, '49–'55

BOLIVIA, Castelnau

PORTUGAL, 1:100000 1856 on

MEXICO, G. Cubas, '58 '74 '86

ARGENTINE, M. de Moussy '65

PERU, PAZ SOLDAN '65

NAPLES, 1:250,000, 25 sheets '71–'74

ITALY, 1:100000, 277 sh. '75 on

SPAIN, 1:50000, 1080 sh. '75 on (Iberia)

CUBA, Atlas, E. Pichardo '75

PERU, 1:500000 under Raimondi '71 on

ARGENTINE, Geogr. Inst. Atl. '86–'98

M. Fiorini, Sfere terrestri e celesti

ECUADOR, Th. Wolf '97

MEXICO, 1:100,000, '97–1910 unfinished

CHILE–ARGENTINE boundary

CARTE GÉOLOGIQUE INTERNATIONALE DE EUROPE – Beirich '96 – Hauchecorne 1900 – Beyshlag '04 – 1913

CUBA, U.S. ARMY 1:?? '06–'08

INTERNATIONAL MAP OF THE WORLD, 1:1,000,000 – proposed by A. Penck in 1891 – Committee London 1909, – about 300 sheets (20 published in 1925)

Mexico, Atlas, '21

TOURING CLUB ATLAS, Milan, '27

R. Almagià, Studies in cartography

FRANCE

LONGITUDE MEASUREMENTS OF THE ACADEMY

J.D. Cassini, La Hire, Nolin, Claude Delisle, Pene, etc.

J.B.L. Franquelin, maps of Amer. Nouv. France 1700

Guill. DELISLE 1675–1726
- reduction of Mediterr. to 42°
- maps of Amer. 1700, '03, '18
- California as peninsula
- Secant conic projection
- Ferro meridian (Royal order since 1734)

Mr. C***, Atlas Historique, 7 vol.

J.B.B. D'ANVILLE 1697–1782
- Atl. Général '27–'80
- Africa '49, Asia '51, S. Am. '48 clearing maps from false detail
- History of geography

TRIANGULATION OF FRANCE '34–'44

C.F. CASSINI, Carte Géométrique de la France 1:86400 1756–1789

Ph. BUACHE 1700–'73 succ. of Delisle
- Contour lines, English Channel '37
- Geogr. physique '53

J.N. Bellin '03–'72
- Atl. Maritime '51
- Antilles '58, St. Domingue '68

R.J. Julien, Atlas of France '51 '58 '62

Rigobert Bonne '27–'94
- Atlases – America '80
- Projection

Gilles, Didier ROBERT de Vaugondy
- ATL. UNIVERSELLE '57 on
- Globes, atlases

C.F. Delamarche 1740–1817, maps, atlases

Jos. Roux, Charts, harbor views

G.L. Le Rouge, Atlas Amer. Septentrional '78

J. Lattré, maps, atlases

N. Desmarest, Atlas Encyclopédique '87 on

Dupain-Triel, Contour line map of France '91

NAPOLEON'S SURVEYS OF EUROPE –

Bacler d'Albe, Italy 1:256,000

Le Sage, Atlas Historique '07

C. de la France de l'État Major 1:80000 '18–'80

C. Malte-Brun, Geographies and atlases

A.H. Brué, maps, atlases '16–'32

Pierre + Al. Émile LAPIE
- N. America 1806
- Turkey 1:800,000
- Greece

FRANCE 1:100,000, 587 sh.

HISTORY OF MAPS
- de Santarem, mappemondes '38 to '52
- J. Lelewel, Géog. du moyen âge '50–'57
- E.F. Jomard, Monum. de la géog. '42–'62
- L. VIVIEN de St. Martin, Hist. de géog. '73; Atlas '77 on

A.H. Dufour, maps, atlases.

Avezac du Castera-Macaya, medieval maps

F. Schrader, Atlas Univ. '83 on (Vivien de St. Martin)

ALGIERS, 50000 since '86

P. Vidal de la Blache, Atlas Général '94 on.

FRANCE 1:50000, colored, 846 sheets

Carte Bathymétrique des Océans, Monaco since '03

INDOCHINE 1904 on

Service Géogr. de l'Armée, topographic maps of Africa, Madagascar, Levante, China and Indochina

Atlas des Colonies Fr. under G. Grandidier '34

Atl. = atlas. ms. = manuscript Am. or Amer. = America N. = North sh. = sheets m/i = miles per inch

NETHERLANDS GERMANY – AUSTRIA

Homann house in Nuremberg

Seutter " " Augsburg

prolific mapmakers: Dutch style

HESSEN-KASSEL 1:540000 Schleuen

WÜRTTEMBERG, triangulation 1710 by Johann Mayer

LATE DUTCH MAPMAKERS
R.+J. Ottens, Covens + Mortier, J. Loots, P. van der Aa, G.L. Valk, C. Allard, F. de Wit, J. v. Keulen, Isaac Tirion, P. Schenk etc.

First contourlines on maps – Merwede River bottom by Cruquius 1728/'30

J.G. Doppelmayr, Atl. Coelestis '42

T.C. Lotter, Augsburg, maps

BRANDENBURG 1:50000, 270 sh. v. Schmettau '67–'87 ms.

Projections
- J.H. LAMBERT
- Leonhard Euler

SILESIA, SAXONY, MORAVIA, 1:100000 [illegible] '80s ms.

Tobias Mayer, Mappa critica, '50

HANNOVER, 1:21333, 165 sh. '64–'86

MECKLENBURG, 1:50000, '80–'88, Schmettau

J.W.A. Jaeger, Gr. Atlas d'Allemagne '89

J.G. Lehmann, system of hachuring '99

Tranchot – Moreau etc. 1:100,000

Projections, Mollweide '05, Albers '05

Karl Ritter, Physical map of Europe '06

Weimar Inst. Germany 1:177000, 204 sh. '07

Justus Perthes, Gotha, maps since 1786

A.v. Humboldt, Isotherm map '17

C.F. Gauss, projections '22

ATLASES F.A. Schrambl, Vienna 1786–1800
STIELER 1817–on, H. Berghaus, Phys. Atlas since '38
H+R. Kiepert '60–on, Andree 1881–on, Debes
Dietrich Reimer, Berlin, L. Ravenstein, Frankfurt
R. Spruner historical atlases

WALLMAPS, Emil Sydow

ALTITUDE TINTS
- v. Hauslab '42
- E. Sydow '42

WÜRTTEMBERG 1:50000 '21–'44

BAVARIA, 1:50000 '12–'68

PRUSSIA, 1:100000 '40 on.

Petermanns Mitteilungen '55 on.

AUSTRIA-HUNGARY 1:75000, 765 sh.

CENTRAL EUROPE 1:200,000, 192 sh.

GERMANY 1:100,000, 675 sh.

K. Kretschmer, Atl. discovery of Amer.

Vogel: Karte d. Deutschen Reiches

K. Peucker, Plastic colorshading, Vienna

Konrad Miller, studies of early maps

Max Eckert, projections

Joseph Fisher S.J. studies of Ptolemy

F.C. Wieder, Monumenta Cartogr. Leyden '25 on

GR. BRITAIN

English Pilot, 1685 – 1792

Herman Moll (from Amsterdam) fl. '98–'32

John Senex d.'40, maps, geographies, atlases, globes

Henry Popple, America in 20 sheets '33

LONDON MAPMAKERS and PUBLISHERS
John + Thomas Bowles, Emmanuel + Thomas Bowen fl. '10–'90, Thomas Kitchin '38–'84, John Rocque fl. '34–'62, Thomas JEFFERYS fl. '31–'71 succ. by Sayer + Bennet = Wm. Faden, Whittle + Laurie fl. '98–1818, John CARY (1680–1836) + Aaron Arrowsmith fl. '90–'33 (successors up to 1878) Imray, charts
A. Dalrymple charts

John Mitchell, N. Am. '55

SCOTLAND, Watson surv.

J. Rocque, d.'62 Atl. of [illegible] '62

J.F.W. Desbarres, Atlantic Neptune '74–'81, N. Am. Pilot '79

J. Rennell, Bengal Atlas '81

TRIANGULATION of Engl.

ORDNANCE SURVEY '91

HYDROGRAPHIC OFFICE '95

SURVEY OF INDIA 1800

Wm. Smith, Geological maps '15

IRELAND survey 6"/m

A.K. Johnston, Edinburgh since '30

ROYAL GEOGRAPHICAL SOC. '30

Ch. + A. Black, London since '40

6"/m Ordnance S. maps '46 on.

John Bartholomew, Edinburgh

Edw. Stanford, London

Ordnance Survey 1"/m 696 sh. since '72

E.G. Ravenstein, E. Equatorial Africa '83

Bartholomew J.G. Physical atlases

George Philip + Son, Liverpool

R.G.S. maps of explorations in Geogr. J.

The Times Atlas, 1900 on.

Geogr. Section of General Staff maps of Balkans, Near East, Sudan, Asia 1:4000000, Africa 1:2000000 etc.

OTHERS

J.J. Scheuchzer, Switzerl.

RUSSIA, Coast survey of Peter the Great

J. Chr. Müller, Bohemia '20

Kirilov, Atlas of Russia '34

de Marsigli, The Danube

Russian Acad. Atl. '45

Lewis Evans, Middle British Colonies, Philadelphia '55

TYROL, Anich + Huber '60– (Bauernkarte) 1:104000

Kanter, Poland '70 Königsberg

de Lacy, Hungary

BELGIUM, de Ferraris '71–'78 275 sh. 1:86,400 triangulated

DENMARK, Acad. survey

SWITZERL. J.H. Weiss '96–'02

Schmettau, [illegible]

La Perouse, North Pacific '85

NETHERLANDS, Krayenhoff

SWEDEN, Hermelin '97–'18

TURKEY in Arabic, 22 sh.

EGYPT, 47 sh. Napoleon

HUNGARY, Görög [illegible]

" de Lipszky 12 sh. '06

Takahashi Inō, Japan, surveys

GREECE [illegible] Fr. Military

John Melish, U.S.A.

RUSSIA 1:420,000 [illegible]

H.S. TANNER in Philadelphia

A. de KRUSENSTERN Atlas of the Pacific, St. Petersburg '24

SWEDEN, 1:500000, altitude tints

Sam. Aug. Mitchell, U.S.A.

GREECE, 1:200000 20 sh. '52–'80

SWITZERLD. Dufour map oblique hachuring '42–'65

RUSSIA, 1:126000 [illegible]

CAUCASIA, 1:210000 [illegible]

HOLLAND, 1:50000, 776 sh. [illegible]

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BALKANS, 1:200000, 36 (Russian) 1:200000 (Austrian)

SWEDEN, 1:100000, 534 sh.

JAPAN, 1:200000 '87 on

CHINA

Kordt, Facsimile Atlas of Russia 1899–1931

FINLAND, Atlas '99 + 1910

1:1000000, '03 on

Kümmerly + Frey, Berne

NATIONAL ATLASES
- CANADA, Atlas '06 + '15
- SIBERIA " '14
- NORWAY " '22
- EGYPT " '28
- CZECHOSLOVAKIA '28

Prepared by Erwin Raisz of the Inst. of Geogr. Exploration, Harvard University *in Carto-Bibliography*. This mimeographed typescript identified 206 scholars; the professionally printed ninth edition (1998) listed 630. A few research institutions dedicated to map history were also established, notably the Hermon Dunlap Smith Center at the Newberry Library in Chicago (1970) and the Explokart project at the University of Utrecht (1981). Yet while university-level courses in map history proliferated in conjunction with academic cartography (Ruggles 1989), map history could not sustain a presence elsewhere in academia.

The difficulty of reconciling traditional and internal approaches prompted efforts to create a single disciplinary identity for map history (Edney 2005a, 1–2, 33–83; 2005b, 19–22). David Woodward (1974) proposed a disciplinary framework grounded in the internal paradigm; while suggestive, it was quickly criticized for apparently excluding traditional concerns (Woodward 2001, 37n15). Harley instead began to work with academic cartography's fundamental concept of cartography as a communication system (whether informational or linguistic). Yet several factors greatly complicated the development of an overarching intellectual framework. First, the target was moving. Contextual studies of past mapping processes inevitably led internal historians to consider not only how but also *why* maps were made, thereby introducing an external aspect into otherwise internal studies. Such studies highlighted many maps excluded from the historical canon that could not be adequately handled by established approaches. Second, the rhetorical deployment of communication models prompted many map scholars to reconsider the empiricist commitment to maps as statements of spatial fact. Because smaller-scale maps, at least, were clearly open to manipulation, some began to wonder whether it was ever possible to exclude personal or cultural bias from mapmaking. At the same time, interest in the idea and practice of communication brought the map user into scholarly focus and opened up new intellectual territories unknown to traditional and internal map historians. Finally, academia's "postmodern" turn led scholars across the humanities to question the nature of representation. Because maps have long been held up as exemplifying unproblematic representation, such critical scholarship soon exposed and rejected the modern cartographic ideal as simply that, an ideal.

The combined result was the development from the late 1980s of a new sociocultural paradigm of map history; its evolution is readily traced through the history of Harley and Woodward's *The History of Cartography* (1987–). Grounded in the understanding that, as social and cultural documents, maps are as complex and as worthy of study as any work of art or literature, the sociocultural paradigm substantially broadened and enlivened the study of map history even as it posed a significant challenge to academic cartography's own precepts. Sociocultural map historians were interested in the function and significance of maps: why were maps made and what did they mean to their contemporaries? Harley and like-minded colleagues opened up new and exciting philosophies, methodologies, research questions, and topics (such as previously ignored map genres). Despite such apparent fragmentation, the new approaches clustered around three dominant, interrelated themes (Edney 2012).

The origins of the first sociocultural theme lie in M. J. Blakemore and Harley's (1980) advocacy of the art historical methodology of iconography as the best methodology to elucidate the cultural meanings embedded in maps, triggering a wave of new studies of maps as cultural texts. Such textual analysis also appropriated semiotics (as defined by Roland Barthes) and literary analysis more generally. Textual analyses, notably of maps as foci of religious beliefs or nationalistic sentiments and as constructions of places and regions, were accessible to some traditional map historians, who now shifted their interest to elucidating map meaning. Textual analyses also meshed well with the concerns of literary and art historians, who began to study maps in concert with other graphic and linguistic texts. Key texts include Paul Carter's *The Road to Botany Bay* (1987) and Richard Helgerson's *Forms of Nationhood* (1992). By the mid-1990s, such studies almost completely dominated the content of *Imago Mundi*.

In the second theme, ethnographically minded studies of the spatial practices of nonmodern peoples (whether ancient, medieval, traditional, or indigenous) opened up to serious investigation cartographies that had previously been marginalized as unscientific and fanciful. Such work, exemplified by the early volumes of Harley and Woodward's *History of Cartography*, revealed the cultural determinants that underpin cartographic practices and pointed to the need to integrate non-European cultures into the general narratives of map history. Analyses of the performative and oral character of indigenous mapping seriously undermined the modern ideal of cartography as a process of observation and measurement. In breaking down the conceptual divide between maps and nongraphic strategies for representing space, their authors urged a greater intellectual flexibility in studying modern cartographies. Historical studies of indigenous cartographies have tended to focus on encounters, especially with Native Americans, as in Rainer Vollmar's *Indianische Karten Nordamerikas* (1981) or G. Malcolm Lewis's *Cartographic Encounters* (1998).

The crucial question of why maps are made led, in the third sociocultural theme, to contextual analyses of the social settings of mapmaking. Such studies had roots in both professional-traditional and internal map histories but, in the 1980s, they evinced a more profound concern for issues of economic and political inequality. A particular focus was the role of official cartography—both topographic and thematic—in modern state formation and imperialism. These studies accounted for perhaps the majority of new monographs in map history, starting with Josef W. Konvitz's *Cartography in France, 1660–1848* (1987) and R. J. P. Kain and Elizabeth Baigent's *The Cadastral Map in the Service of the State* (1992). This scholarly theme understandably encouraged some social scientists to pursue map studies, beginning with Thongchai Winichakul's *Siam Mapped* (1994); reciprocally, map historians drew upon the work of social theorists, most notably Michel Foucault. For a few commentators, this sociological critique extended an older, humanistic critique of cartography. Humanists such as Theodore Roszak in *Where the Wasteland Ends* (1972) or Yi-Fu Tuan in *Space and Place* (1977) held nonmodern maps to be representative of the individual's experience of space and community, whereas modern maps were by comparison sterile and culturally impoverished. Commentators such as David Harvey in *The Condition of Postmodernity* (1989) or James S. Duncan and David Ley in *Place/Culture/Representation* (1993) now accepted the idealization of modern cartography at face value and dogmatically bludgeoned modern mapmaking as an inherently iniquitous practice (Edney 2012).

Almost universally, sociocultural historians abandoned the broad diachronic view of traditional and internal map history for focused, synchronic studies. However, Denis Wood (1977) advocated an ethnogenetic structure, using a tendentious history of relief depiction to argue that cartography had as a practice developed in a manner directly akin to the cognitive development of individuals; Harvey (1980) used Wood's structure as an organizational framework. Subsequently, Wood (1994) identified in Harvey's *Medieval Maps* (1991) an overtly evolutionary model in which the proliferation and termination of mapping traditions were expressions of otherwise undetermined processes of diversification and extinction (fig. 382). However, without establishing precise mechanisms, Wood's models remain descriptive in character.

The sociocultural paradigm dramatically increased the institutional presence of map history in academia, extending it across the humanities and social sciences, especially in Anglophone countries. Yet parallel changes in the other long-standing institutions of map history meant that the new map historians could find little support for their interests in the old disciplinary core. In the 1980s, the excitement of new digital technologies turned academic and official cartographers away from the historical justification of their intellectual autonomy to embrace a forward-looking vision of digital revolution and innovation. As academic cartographers turned away from their established agenda, internal map history trailed off significantly; Harley and Woodward's (1989) apology for internal map history fell on deaf ears. Subsequently, digital technologies and general reforms in library managerial practices increasingly forced map librarians to emphasize information management and curtail historical scholarship, significantly weakening the traditional paradigm. Conversely, map dealers and collectors underwent a renaissance in scholarly activity with the collapse of the traditional antiquarian canon. Trade in archetypal antiquarian maps was

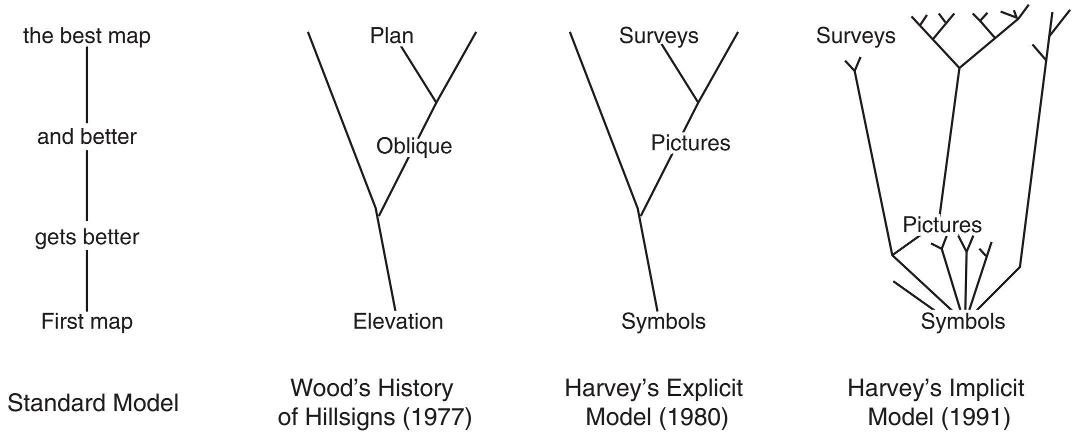

FIG. 382. DENIS WOOD'S EVOLUTIONARY MODELS FOR CARTOGRAPHIC HISTORY. The standard model of linear progression; Wood's own developmental schema of hill signs; P. D. A. Harvey's adaptation of Wood's model; and the evolutionary model identified by Wood as being implicit in Harvey's *Medieval Maps* (London: British Library, 1991).
After Wood 1994, 55 (fig. 1).

supplemented by a vibrant trade in the products of modern cartography, from nineteenth-century atlases to twentieth-century road maps, whose histories required clarification and understanding. Map societies flourished. The field's institutional reconfiguration was manifested in shifting patterns of conferences and courses. Dedicated international conferences were increasingly supplemented after 1990 by focused seminars and by dedicated panels within large disciplinary conferences. Courses on map history all but dried up in cartography programs but proliferated in other disciplines. (Unfortunately, there remain only impressionistic data for these trends.)

The sociocultural paradigm was thus as fragmented as the paradigms it sought to replace, a fragmentation that permitted the modern cartographic ideal to persist and undermine critical scholarship. One solution, hinted at occasionally through the 1990s—as in the concept of cartographic mode that underpins the last three volumes of *The History of Cartography* (Edney 1993) or in Christian Jacob's cross-cultural analysis of the map concept in his *L'empire des cartes* (1992)—entails paying careful attention to the various processes whereby maps have been produced, circulated, and consumed. Such a processual paradigm, open to textual analysis even as it resurrects some of the internal paradigm's concerns with practices, may provide a truly comprehensive framework for map history (Edney 2012).

MATTHEW H. EDNEY

SEE ALSO: Academic Paradigms in Cartography; Almagià, Roberto; *Imago Mundi*; Bagrow, Leo (Lev Semenovich Bagrov); Harley, J(ohn) B(rian); History of Cartography Project; Social Theory and Cartography; Vinland Map; Woodward, David

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History of Cartography Project.

The History of Cartography is the centerpiece of the inclusive and culturally minded approaches to the history of cartography that flourished after 1980. The manner in which its structure has changed and its volumes have grown (tables 21 and 22) exemplifies the frequently difficult, often controversial, and sometimes painful character of the field's intellectual evolution.

Its origin lies in J. B. Harley and David Woodward's concern for the fragmented state and intellectual impov-

Table 21. Stages in the growth of *The History of Cartography*. Read each column vertically for the organization of the series' volumes at each stage. [E] indicates encyclopedic volumes; an underscore indicates volume published by the year indicated.

	1977–81	1982[1]	1983	1987	1993	2001
Nonmodern	1	1				
Prehistoric, Classical, and Medieval Europe			1	1̲	1̲	1̲
Traditional Asia			2			
Islamic and South				2.1	2̲.̲1̲	2̲.̲1̲
East & Southeast				2.2	2.2	2̲.̲2̲
Indigenous			*where?*[2]	*where?*	2.3	2̲.̲3̲
Renaissance Europe	2	2	3	3	3	3
Enlightenment Europe	3	3	4	4	4	4 [E]
Nineteenth Century	4	4	5	5	5	5 [E]
Twentieth Century		5	6	6	6	6 [E]

[1] Harley and Woodward 1983.

[2] The issue of how to treat indigenous traditional cartographies continued to be discussed by Harley and Woodward (Woodward 2001, 25).

erishment of the history of cartography as a field of inquiry. In 1977 they decided to edit a "general history" of the practices and institutions of mapmaking in four volumes, totaling one million words and to be completed by 1992. The project would unify the scattered literature, "provide an authoritative reference work, which is at present entirely lacking in the subject," and "serve as a rallying point for scholars from which a more coordinated research effort can be attempted" ([Woodward] 1982, 113; also Harley and Woodward 1983; Woodward 2001, 23–24; Edney 2005, 51–56).

With the first receipt of funding from the U.S. National Endowment for the Humanities in 1981, Woodward established the History of Cartography Project (as it would become known) at the University of Wisconsin–Madison. Here, graduate assistants, led since 1981 by managing editor Jude Leimer, have processed and edited every contribution, carefully checking every fact and reference, and have seen each volume through publication by the University of Chicago Press.

The *History*'s ethos was necessarily broadly inclusive. Harley and Woodward pushed their authors to consider all forms of maps and to consider how those maps related to broader cultural and social issues, although without prescribing specific theoretical approaches (Woodward 2001, 31–48). Some authors could not break free of traditional approaches to map history; their work was dropped and new authors sought. Furthermore, Harley and Woodward soon realized the need to add further volumes for the twentieth century and for traditional Asian societies; pragmatic concerns subsequently led to the Asian volume's division into two separately published books. The issue of indigenous cartographies—should they be considered in concert with the Europeans who collected and preserved indigenous maps?—was solved only after Harley's death in 1991, when Woodward decided to pursue, with G. Malcolm Lewis as coeditor, a separate book for indigenous mappings. Not only did the *History* grow in the number of volumes, those volumes also inexorably grew as authors explored new historical vistas.

Volume one appeared in 1987 to profound effect. Richard J. A. Talbert (2008) argued that the volume created, almost de novo, the now flourishing study of Greek and Roman cartography; the volume also significantly reinvigorated the study of medieval mapping. The publication of the three books of volume two in the 1990s further reinforced the validity of examining mapping as a sociocultural activity. Together, the volumes publicized the field across the humanities and social sciences, attracting new scholars to the field, many of whom would contribute to later volumes.

But by 1999 the *History* threatened to become a victim of its own success: the later volumes would have to be of monstrous and unpublishable size to cover modern European mapping in the same degree of detail as the first two volumes. Woodward therefore capped the last four volumes at one million words each. He recruited colleagues to share the editorial load: Matthew H. Edney, Mary Sponberg Pedley, and D. Graham Burnett for volume four (Burnett stepped down for professional reasons in 2005), and Mark Monmonier would be lead coeditor with Woodward for volume six. (A parallel project encouraged the exploration of themes in the history of twentieth-century cartography: Monmonier and Woodward 2002). Woodward's recruitment of collabo-

TABLE 22. Final publication sequence of *The History of Cartography*. Note that all the volumes are significantly larger than the 250,000 words originally allocated for each of the original four or five volumes.

Year	Vol.	Words	Editors, Title, and Prizes
1987	1	475,000	J. B. Harley and David Woodward, eds., *Cartography in Prehistoric, Ancient, and Medieval Europe and the Mediterranean*. • The Association of American Publishers Best Scholarly Book in the Humanities for 1987.
1992	2.1	460,000	J. B. Harley and David Woodward, eds., *Cartography in the Traditional Islamic and South Asian Societies*. • The Association of American Publishers R. R. Hawkins Award for Best Scholarly Book for 1992
1994	2.2	760,000	J. B. Harley and David Woodward, eds., *Cartography in the Traditional East and Southeast Asian Societies*.
1998	2.3	500,000	David Woodward and G. Malcolm Lewis, eds., *Cartography in the Traditional African, American, Arctic, Australian, and Pacific Societies*. • American Historical Association, James Henry Breasted Prize, presented at the 2000 Annual Meeting.
2007	3	1.5 million	David Woodward, ed., *Cartography in the European Renaissance*.
	6	1 million	Mark Monmonier, ed., *Cartography in the Twentieth Century*.
	4	1 million	Matthew H. Edney and Mary Sponberg Pedley, eds., *Cartography in the European Enlightenment*.
	5	1 million	Roger J. P. Kain, ed. *Cartography in the Nineteenth Century*.
total		~ 6.5 million	

rators fortuitously provided a mechanism for continuity after his death in 2004. Edney became project director in 2005, with a permanent project manager, Beth Freundlich, in Madison, and worked with the other editors to set editorial policy. The editorial group was completed when Roger J. P. Kain became editor of volume five in 2008.

The editors concluded in 2001 that the last three volumes must adopt an encyclopedic structure. No other format can manage the ever-increasing array of cartographic activities after 1650, provide space for interpretative accounts, and still keep within publishable limits. The structure for each volume was based in the concept of cartographic modes. Contributors are thus encouraged to think explicitly about the conjoined processes of map production and consumption. These last three volumes will have a more subtle effect than did the first two. After all, the field has largely internalized the intellectual changes of the 1980s. Yet the last volumes continue to push scholars to think about maps and their history in new ways and to explore previously unaddressed issues. In this respect, the completed *History* will indeed serve as a "rallying point" not for one kind of history but for an open and inclusive understanding of the important place maps possess in past cultures and societies.

MATTHEW H. EDNEY

SEE ALSO: Harley, J(ohn) B(rian); Histories of Cartography; Modes of Cartographic Practice; Woodward, David

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H. M. Gousha Company (U.S.). The H. M. Gousha Company was one of three firms (with Rand McNally and the General Drafting Company) that dominated the

FIG. 383. COVER ART AND MAP DETAIL SHOWING COORDINATION OF COLOR SCHEMES WITH CLIENT CORPORATE BRANDING, *1931 ROAD MAP OKLAHOMA: SHELL.* Size of cover: 12.6 × 28.9 cm; size of map detail: 11.5 × 28.7 cm. Image courtesy of the Newberry Library, Chicago, H. M. Gousha Collection. Map © Rand McNally; R.L. 11-S-001.

production of road maps for free promotional distribution in North America in the mid-twentieth century. American oil companies had begun offering road maps to their customers in the mid-1910s, but the widespread use of maps as marketing tools was not really feasible until improvements in highway surfaces and universal route marking made it possible for inexpensive promotional maps to function adequately as navigational tools. Harry M. Gousha played a major role in the development of the free "gas" maps that became icons of American automobile culture. As manager of Rand McNally's Auto Trails department from 1920 to 1926, he encouraged the bulk sales of special editions of its popular Auto Trails maps to several oil companies, and he imported this business model to the company bearing his name established in Chicago in 1926. By 1928 Gousha had secured the contracts of three former clients of Rand McNally (Gulf, Standard Oil of Indiana, and Conoco), and by 1935 the firm had published some 235 map titles for free distribution by thirty-two clients, mostly oil companies, a number exceeded only by Rand McNally (Brink 1926; H. M. Gousha Collection).

Gousha maps typified the North American road map style, which was ideally suited to the large print runs, annual revision, and customization that promotional cartography required. Highways were differentiated by color and width according to their status as local, state, or federal highways; their traffic capacity and importance; and their surface quality. Political boundaries and hydrography provided geographical frames of reference, but topographical complexities received little attention. Still, the maps were not unattractive. Heavy use of color in cover art enlivened the spare cartographic style and allowed Gousha to appeal to the specific promotional agendas, even while the basic cartography changed little from client to client (fig. 383). Occasionally the company developed special product lines for major clients, most notably the *Touraide*, developed for Conoco in 1936 (Edwards 1936). These were spiral-bound booklets consisting of sectional maps, illustrated travel information, and hotel and attraction listings that were prepared to order for individual Conoco customers and provided as alternatives to similar (and often bulkier) information they might otherwise obtain from automobile clubs (Continental Oil Co. 1952).

For most of its existence, H. M. Gousha was not a diversified map publisher like Rand McNally, and consequently it suffered when the oil company business declined in the 1970s. In 1947 the company moved to San Jose, California, and in 1961 it was acquired by the Los Angeles–based Times Mirror Company, which moved the road map compilation and printing operations to Comfort, Texas, in 1966. Times Mirror diversified Gousha's product lines, adding road atlases, a series of street maps (prepared for the American Automobile Association and later offered under its own Chek-Chart brand), and some general atlases and wall maps. These enabled Gousha to survive until 1996 (after 1987 as a subsidiary of Simon & Schuster), when, ironically, it was purchased by its old rival Rand McNally.

JAMES R. AKERMAN

SEE ALSO: Marketing of Maps, Mass; Rand McNally & Company (U.S.); Road Mapping: Canada and the United States; Wayfinding and Travel Maps: (1) Indexed Street Map, (2) Road Atlas

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Edwards, Clarence. 1936. "Conoco's 'Touraides' Do Effective Sales Job." *Advertiser* 7 (November): 40, 55.

H. M. Gousha Collection, Newberry Library, Chicago.

Holdich, Thomas Hungerford. Sir Thomas Hungerford Holdich was born in Dingley, Northamptonshire, England, in 1843. He was the eldest son of a clergyman and was educated at Godolphin Grammar School, Hammersmith, and Addiscombe College, the school established to train future officers for the East India Company, before going to the Royal Military Academy at Woolwich. He was commissioned into the Royal Engineers in 1862 and, after further training, was sent to India in 1865 where he joined the Bhutan expedition of 1865–66 as temporary assistant surveyor. This led to a permanent appointment to the Survey of India, in which he served until his retirement in 1898 (Mason 1930).

Holdich worked as a surveyor on many military operations from Abyssinia in 1867–68, to the Afridi Tirah expedition of 1897–98, but it was as a boundary surveyor that he had his greatest impact. In 1884 he was appointed to the Pamir Boundary Commission, which surveyed and monumented the narrow strip of Chinese and Afghan territory that separated the Russian-controlled khanates of Central Asia from the Indian Princely States to the south. From 1891 until 1898 he was superintendent of frontier surveys, working on the Asmar and Pamirs delimitations and the Perso-Baluch delimitation. Holdich was deeply interested in both the theory and practice of boundary making, providing a good firsthand account of his work and its underlying principles in *The Indian Borderland, 1880–1900* (1901).

Following his retirement from the Survey of India, Holdich served on a tribunal appointed to fix the boundary between Chile and Argentina in Patagonia. The boundary treaty of 1881 had become difficult to interpret due to a lack of coincidence between the continental divide and the highest peaks of the Andes. Holdich was able to arrive at a satisfactory solution, going on to carry out the demarcation on the ground. An account of the work is published in *The Countries of the King's Award* (1904). His most influential book was *Political Frontiers and Boundary Making* (1916). Written at a time when the post–World War I settlement was already being actively discussed, Holdich's book was the first to combine the theory and practice of boundary making between states. His advocacy of strong natural boundaries was an important contribution to the debate.

Holdich had long been concerned with the problem of mapping in Africa and wrote important papers on the subject. He had a major impact on the reform of survey instruction in Britain and the empire during his later years with the Survey of India and after he retired. This influence included the reform of teaching practices at the Royal Geographical Society, which was the main provider of instruction for those intending to serve in Britain's colonies (Collier and Inkpen 2003).

Holdich also made a wider contribution to geography through his work for the Royal Geographical Society. He served on a number of committees, was a vice-president for many years, and president from 1916 to 1918. Holdich died at Merrow, Surrey, in 1929.

PETER COLLIER

SEE ALSO: Boundary Disputes; Geodetic Surveying: (1) Latin America, (2) Africa

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Mason, Kenneth. 1930. "Colonel Sir Thomas Hungerford Holdich, K.C.M.G., K.C.I.E., C.B." *Geographical Journal* 75:209–15.

Holographic Map. Derived from the Greek *holos* (whole or complete) and *gramma* (message or something written), *hologram* originally referred to an image that depicts an object in its totality, that is, in all three dimensions. In the middle of the twentieth century the term was applied to a photographic film or plate produced using a split laser beam that allows the viewer to see a three-dimensional image when viewed in coherent (laser) or ordinary light. Hungarian-British Nobel laureate Dennis Gabor developed this method in 1948 while trying to improve the resolution of electron microscopes.

In 1978 Geoffrey Dutton, a researcher at Harvard University's Laboratory for Computer Graphics and Spatial Analysis, was the first person to use holography for visualizing geographic data. At the century's end, his spatio-temporal hologram was still one of the few examples of an animated four-dimensional holographic map. An enhanced version of Dutton's innovation described change in population density for the United States between 1790 and 1980 using a succession of county-level population maps recorded on a rotating cylinder sixteen inches in diameter (Dutton 1978).

In 1982 I. Prikryl described a procedure for using multiple high-resolution color images of a three-dimensional surface captured from a variety of directions to make a synthetic hologram that can be viewed in white light. Although Prikryl claimed (1982, 2882) that his method could be used for making "holographic land maps," he apparently never produced any.

In 1998 Manfred F. Buchroithner and Robert Schenkel of the Technische Universität Dresden generated the first arguably realistic holographic map by combining a white-light hologram with a (horizontal) holographic stereogram (Buchroithner and Schenkel 1999). Their prototype holo-relief image, which covered an area with elevations between 508 and 2,996 meters, was derived from stereo photographs of a solid terrain model. Digitally generated labels enhanced the map's photorealistic laminar relief. Toggling these annotations on and off and varying the viewing angle yielded an animated holographic map.

In the late 1990s and early 2000s firms and research institutes in the United States and Europe began to specialize in three-dimensional holographic maps or map-like products. Although the Spatial Imaging Group of the Media Lab at the Massachusetts Institute of Technology, the worldwide leader in holographic visualization, never focused on the representation of geographic objects, in 2005 a spin-off company, Zebra Imaging, in Austin, Texas, generated three-dimensional holographic maps that could be illuminated under battlefield conditions or during an environmental disaster using a portable light or even sunlight. Rendered in green monochrome or true color, these maps could show underground features like gas mains or sewers, and annotations could be added using dry-erase markers or grease pencils. Proposed uses included rescue and evasion, evacuation and recovery, military defense, and homeland security (Coupé 2005).

Since 2007 thousands of three-dimensional holographic maps have been deployed to assist U.S. military personnel (fig. 384). When produced for urban terrain at scales between 1:1,000 and 1:50,000, the minimal relief offered no clear benefit. But a user assessment indicated that this type of map was most valuable at scales between 1:100 and 1:1,000 and was often superior to conventional paper maps for many purposes, such as determining line of sight and the relative heights of buildings (Holzbach 2008). NATO countries also began to deploy holographic maps (Dalkiran, Özağaç, and Büyükbayrak 2012).

MANFRED F. BUCHROITHNER

FIG. 384. TACTICAL DIGITAL HOLOGRAM (TDH). The U.S. Army Deputy Chief of Staff for Intelligence initiated the Tactical Battlefield Visualization (TBV) program in 2006. The program has provided TDHs, which are highly accurate 3-D battlefield representations, to combat units in Iraq and Afghanistan. Image © Zebra Imaging, Austin.

SEE ALSO: Electronic Cartography: Display Hardware; Oblique and Perspective Views; Terrain Analysis and Cartography

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Hölzel, Eduard. See Verlag Ed. Hölzel

Hotine, Martin. A dominant force in the development of geodesy and photogrammetry during the middle years of the twentieth century, Martin Hotine was passionate and outspoken in all he did and was accorded enormous respect by all who met him. Above all, he was committed to getting things done and, in this, he was immensely successful.

Born in Putney, a suburb of London, on 17 June 1898, Hotine came into surveying though entry into the Royal Engineers and a position, in 1925, as research officer for the Air Survey Committee, set up to coordinate the developments in new techniques for making use of aerial photographs. He was very active in this position and developed the radial line technique. During his next posting, within the Geographical Section, General Staff (GSGS) at the War Office, he published a definitive textbook on aerial survey (Hotine 1931).

In 1931, Hotine experienced his first taste of geodetic work, when he was sent to close a gap in the triangulation of the 30th Arc of the Meridian in Tanganyika from Urundi in the north to Northern Rhodesia in the south, a distance of some 300 miles. With two noncommissioned officers, he carried this out entirely on foot, first walking south to choose the hills needed for the triangulation and then returning north to make the observations.

Hotine's experience in Tanganyika stood him in good stead on his next assignment. Between 1934 and 1939 he worked for the Ordnance Survey on the retriangulation of Great Britain. He insisted on the highest standards of work and, to this end, developed, as a stable observing platform, the famous Ordnance Survey pillar (Hotine 1937), which came to be built on every prominent mountain in the country and which, though a man-made lump of concrete, strangely became a much-loved feature of the landscape and a reassuringly certain position for any hill walkers lost in the mist.

The outbreak of World War II in 1939 put a stop to the retriangulation, and Hotine returned to military service. In 1941, as director of Military Survey, he took command of the GSGS, which assessed and commissioned military mapping requirements. During this time he developed close relations with the U.S. Army Map Service and championed the free exchange of geodetic and cartographic material between the two organizations.

At the same time, discussions were beginning within the British government on how to tackle postwar problems. Hotine took the opportunity to set out his view that the geodetic surveying and topographic mapping necessary for the colonies after the war might best be carried out by the Ordnance Survey using military personnel. However, as the war progressed, he found the Ordnance Survey too slow to respond to changing military requirements and developed the idea of a central specialist unit within the Colonial Office that would provide a quicker response to urgent priorities. In this, he found himself as a colonel arguing against the ideas of the major general (Malcolm MacLeod) running the Ordnance Survey. His correspondence with MacLeod is extraordinary in its uninhibited outspokenness, and it is clear that MacLeod must have had huge respect for his subordinate insofar as he never showed any sign of offense. By 1944, Hotine had convinced his colleagues that a specialist unit was the way forward. Funds for the next ten years were made available, and in 1946 the Directorate of Colonial (Geodetic and Topographical) Surveys came into being with Hotine as its first director (Macdonald 1996).

The Directorate must be considered Hotine's finest achievement. During its thirty-eight-year history, it mapped in detail over 2,000,000 square miles of the earth's surface—about a third the area of the United States. Hotine expected hard work from everybody—wives were initially prevented from going overseas as their presence would make it difficult for husbands to "avoid gravitating towards a semi-permanent base camp" rather than spending all their time in the bush (quoted in Macdonald 1996, 81). He knew from experience that without aerial photography the Directorate could not meet its commitments. Constraints on budgets meant that simple methods had to be used—slotted-template assemblies and multiplex machines. The first 1:50,000 maps to be produced, known as Preliminary Plots, were criticized by users as lacking detail, but Hotine had insisted that the principal points of all the photographs be printed on the map. He then patiently explained to his critics how simple it was, using radial line techniques, to plot any additional detail from the aerial photographs. As time went on, more detailed colored maps were produced, including the attractive photomaps of island territories and elegantly shaded maps of the Antarctic.

On retirement in 1963, Hotine was welcomed by his old colleagues in the United States and took up a research post, first with the U.S. Geological Survey and later with the U.S. Environmental Science Center, where he worked on his primary interest, three-dimensional geodesy (Hotine 1969). His premature death on 12 November 1968 in Woking, England, deprived cartography of a charming genius.

ALASTAIR MACDONALD

SEE ALSO: Directorate of Overseas Surveys (U.K.); Geodesy: Geodetic Computations; Mathematics and Cartography; Photogrammetric Mapping: (1) Analytical Photogrammetry and Control Surveying, (2) Instrumental Photogrammetry and Stereocompilation

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Hydrographic Chart. See Coastal Mapping; Hydrographic Techniques; Marine Chart; Marine Charting: Overview of Marine Charting

Hydrographic Techniques.

- EARLY TWENTIETH-CENTURY HYDROGRAPHIC TECHNIQUES
- AERIAL IMAGERY IN HYDROGRAPHIC MAPPING AND COASTAL CHARTING
- SOUNDING
- SATELLITES IN HYDROGRAPHIC AND OCEANOGRAPHIC MAPPING
- GLOBAL POSITION SYSTEMS IN HYDROGRAPHIC MAPPING

Early Twentieth-Century Hydrographic Techniques. The compilation and publication of coastal charts involves a number of processes that at first glance seem unrelated. In the nineteenth century national nautical charting organizations such as the British Admiralty, the U.S. Coast and Geodetic Survey (USC&GS), the Service hydrographique de la Marine, and the Deutsche Seewarte had adopted a process that assured adequate nautical charts for many of the harbors and coastlines of the world. The process included a horizontal control network, that is, a triangulation network tied to either a local horizontal datum (a point with latitude and longitude determined by precise astronomic methods) or a national interlocking geodetic network; coastal topography, including the delineation of shoreline by classical methods such as plane table mapping and chain and compass surveys; and depth observations positioned relative to the horizontal control network. Because depth observations were referred to the stand of tide, tide staffs and gauges had to be established in the survey area in order to reduce depth soundings to a common vertical tidal datum for a given working area. In addition, magnetic observations were made to determine the magnetic declination.

Although all of the above steps supported the compilation of nautical charts, the measurement and recording of depth with coincidental determination of position were the two most significant aspects of nautical surveying. At the beginning of the twentieth century, the primary tools of nautical surveying were the sextant, for determining position; the three-arm protractor (sometimes called the station pointer), for plotting position; the lead line for determining depth; and a timekeeping mechanism, record book, and survey sheet. For near-shore and harbor surveys a small boat or survey launch was used, while for surveys in less restricted waters a small ship was used. In general, the survey team was organized with a hydrographer-in-charge, left and right anglemen, a leadsman, a coxswain, a recorder, and a launch engineer. The leadsman would acquire depths by casting the lead ahead of the vessel and reading depths as the lead line came up vertical next to the vessel. The anglemen would measure left and right angles from onshore objects with positions determined by geodetic or topographic techniques. (So that an unambiguous position could be determined, a common center object was typically surrounded by a selection of easily identified objects to its left and right.) The hydrographer-in-charge used a three-arm protractor to plot the positions determined by the measured angles on a survey sheet constructed specifically for the area being surveyed. The hydrographer-in-charge would also call out courses for the coxswain to steer in order to keep the survey boat on a predetermined line, generally perpendicular to the trend of the shoreline. Hydrography was a well-choreographed process that called for careful teamwork by crew members. Tens of thousands of soundings would be acquired by this methodology over the course of a single large survey.

Except for minor variations, these procedures were well established by the end of nineteenth century, but the winds of change were blowing. To "look" between the discrete point soundings acquired with the lead line, hydrographers devised a variety of wire sweep methods, beginning with the French floating sweep, first used in the Gulf of Tonkin in 1882. The early French system consisted of a drifting wire suspended by buoys at a predetermined depth that would either sweep an area clear or catch on rocks or other obstructions rising from the bottom. The U.S. Lake Survey modified this method into a sweep or wire drag towed between two boats (fig. 385). The USC&GS further improved the system to sweep shipping channels over five kilometers wide. Such a system was particularly useful in Alaskan waters, which contained many submerged pinnacle rocks. Although wire systems were still used by some surveying organizations at the beginning of the twenty-first century, the development of high-resolution side-scan sonar systems in the last decades of the twentieth century made them obsolete.

The 1912 *Titanic* disaster stimulated new hydrographic techniques for detecting underwater obstacles. In Germany, Alexander Behm was awarded a patent in 1913 for what he termed the Echolot, an acoustic device for sensing underwater obstacles and measuring depth. In the United States, Reginald Aubrey Fessenden of the Submarine Signal Company, which since 1901 had op-

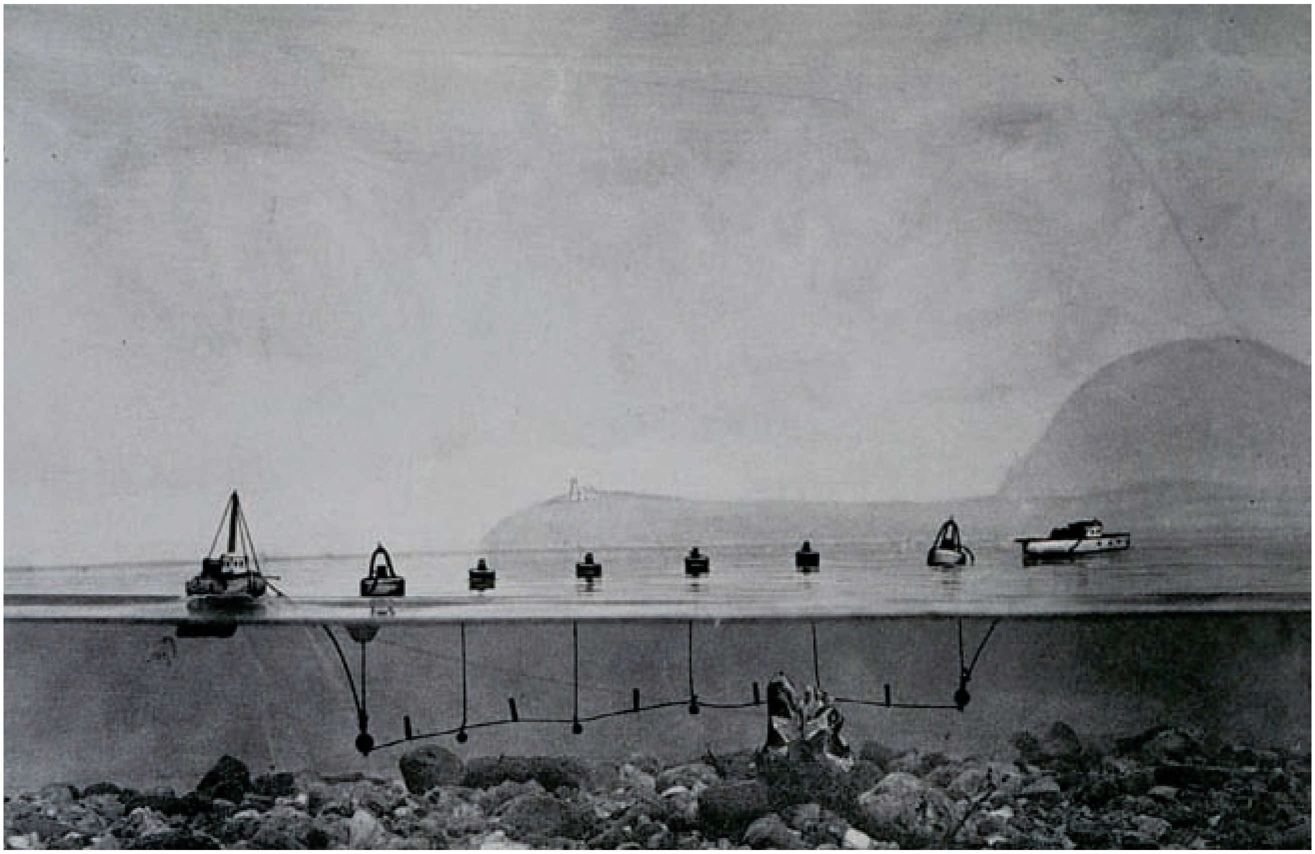

FIG. 385. A WIRE SWEEP, CA. 1920. This method employed a submerged wire suspended between two vessels and supported by buoys and weights. A wire that encounters an obstruction like a pinnacle rock became taut and formed a V in the chain of buoys.

Image courtesy of the National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

erated an acoustic underwater signaling system to help guide ships into port, led the development of acoustic systems. In 1914 he succeeded in reflecting sound waves from an iceberg and also obtained an echo from the seafloor, thereby demonstrating the feasibility of using acoustic means for avoiding obstacles as well as measuring depth.

Although World War I interrupted these promising developments in hydrography, engineers who devised active and passive acoustic echo-ranging devices for antisubmarine warfare built on the work of Behm and Fessenden. Following the war, the French were the first to develop new echo-sounding instrumentation and techniques. Their many notable advances included a profile of soundings across the Mediterranean from Marseilles, France, to Philippeville, Algeria. The 1942 edition of the USC&GS *Hydrographic Manual* suggested that this survey, commissioned to assist in routing an undersea cable, was the first practical application of echo sounding (Adams 1942, 440).

By 1922, the United States had developed the Hayes Sonic Depth Finder, named for U.S. Navy physicist Harvey C. Hayes. This instrument was installed on the USS *Stewart*, which produced a continuous line of soundings from Boston to Gibraltar, through the Mediterranean Sea, and on to the Philippine Islands. The Atlantic profile obtained by the *Stewart* was published in the first issue of the *Hydrographic Review* and made an immediate impression. Geoffrey Basil Spicer-Simson, secretary-general of the International Hydrographic Bureau, commented (1923, 71): "It is scarcely necessary to draw attention to the enormous importance of this method of sounding," and noted that a vessel does not have to stop or reduce speed to use this method, and soundings could be taken at very short intervals, even in the deepest water. Hydrography would never be the same.

Early methods required a human operator to listen for both the transmitted signal and its echo, which introduced human error into the sounding process. In 1925 USC&GS physicist Herbert Grove Dorsey devised a visual method whereby a light was illuminated on a circular scale next to the observed depth. The French developed the Marti recording system, which involved coating the recording paper with lamp black by exposing it to an open flame and adjusting separation and exposure until a thin film of soot was deposited. A mechanical stylus would etch the bottom profile on the coated paper. This system was not used for long because of the difficulty in preventing the paper from igniting (Anonymous 1926, 94). By the late 1930s paper recording systems that used chemically treated and electrosensitive papers were providing hydrographers with a continuous profile of the seafloor and a physical record for later checking.

Most early depth-finding instruments were used primarily for navigation, and their accuracy did not meet the needs of the marine surveyor. Sufficiently accurate shallow-water systems were generally not available until the mid- to late 1930s. Before then, hydrographers had relied on various improvements to existing leadline and pressure tube sounding systems. The Service hydrographique de la Marine developed a device called the fishlead that could be continuously raised a short distance off the seafloor and dropped while a boat was proceeding at four knots. This technique would allow the generation of a nearly continuous profile at depths up to thirty meters. Maurice Rollet de l'Isle, head of the Service hydrographique de la Marine, commented, "It is no exaggeration to say that this invention constitutes one of the most remarkable forward steps for the exploration of the bottom since the time of [Charles-François] Beautemps-Beaupré [named *ingénieur hydrographe* in 1785 and head of the French hydrographic service in 1814]" (Rollet de l'Isle 1926, 187–88). Two years later the USC&GS had perfected pressure-tube sounding (Patton 1928, 208), a method devised in 1870 by William Thomson, Baron Kelvin, who recognized that pressure at depth could force water into a hollow tube filled with air. Although there were other designs, the USC&GS method measured the amount of water trapped at the bottom of the tube, an indication of the pressure at the seabed, which in turn was used to derive the depth. By 1930, acoustic sounding had made both the fishlead and the pressure tube obsolete.

Acoustics also provided the first accurate all-weather marine surveying system. In 1924 the USC&GS began developing an accurate navigation system for hydrographic surveying that incorporated both acoustic methods and radio. Named radio acoustic ranging (RAR), this system involved placing hydrophones (underwater microphones) at accurately determined locations, exploding dynamite charges dropped into the water from the survey vessel, and observing the resultant sound wave at the hydrophones. Reception of the sound wave at each hydrophone triggered a radio signal back to the surveying vessel. The time interval between initial explosion and the reception of the returning radio wave at the survey vessel was used to determine the distance between the ship and the hydrophone at a number of hydrophone locations. The vessel's position was then determined by finding the intersection of circles with corresponding radii centered at these locations. This system led to a fuller understanding of how sound traveled underwater as well as improved telemetering oceanographic instruments and the development of marine seismological studies. RAR was used to carry hydrographic surveys far offshore in order to determine bottom configuration, which provided navigators with valuable undersea signposts insofar as mariners equipped with depth-sounding

FIG. 386. DETAIL FROM U.S. COAST AND GEODETIC SURVEY CHART, *SAN DIEGO TO SANTA ROSA ISLAND*, 1939. This prototype chart (5101A) was based on data acquired through RAR (radio acoustic ranging) surveys. Its bathymetry was sufficiently accurate to serve as a navigational tool. No other charts like this were ever produced.
Image courtesy of the National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

instruments were then able to navigate by comparing the depth profile observed on their ship with the trend of contours on an offshore chart. The value of filling nautical charts with depth data for bathymetric navigation was recognized as early as 1924 (Möckel 1939, 120).

The USC&GS led the way in filling nautical charts with depth data by using RAR to extend its surveys out past the edge of the continental shelf to at least the 1,000-fathom curve. By the late 1930s much of the continental shelf and slope of the United States had been surveyed. In 1939 a prototype chart was produced that was a detailed contour chart of the Channel Islands area of Southern California (fig. 386). The data acquired in the far offshore surveys were used for scientific purposes for years to come, but the concept of bottom-contour navigation never became a primary means of deep-sea navigation. World War II was on the horizon and resources of charting agencies were increasingly shifted to the war effort. New technologies were developed during the war years, notably electronic navigation systems such as Loran (long-range navigation). In addition, the use of radar had become widespread. Hydrographic survey organizations incorporated these new technologies into the design of their nautical charts, adapted the new electronic navigation techniques to hydrographic surveying, and abandoned RAR as well as most far-offshore surveys for nautical charting purposes. A new era was on the horizon.

ALBERT E. THEBERGE

SEE ALSO: Coastal Mapping

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Aerial Imagery in Hydrographic Mapping and Coastal Charting. The early twentieth century witnessed two significant developments in depth measurement and aerial imaging: acoustic echo sounding and aerial photography. In 1922 depths were first measured acoustically aboard the USS *Stewart* (Bates 2005, 21). At about the same time there was recognition of the value of aerial photography for hydrographic charting (Rollet de l'Isle 1923). Both these technologies were developed much further during the century and had a significant effect on the cartography used for hydrographic mapping and coastal charting. In the latter part of the century the hydrographic mapping of shallow waters was further expedited by the introduction of airborne laser sensing and geophysical techniques. The introduction of digital data gathering and processing, and ultimately the ability to display digital information graphically on a computer monitor, was crucial in the development of hydrographic and coastal charting.

Following World War I several national hydrographic offices began to use aerial photography to assist in the mapping of the coast. In 1926 the Second International Hydrographic Conference agreed, in a formal resolution, to examine the use of the technology (Spicer-Simson 1927). At that time aerial photography was used primarily to identify offshore shoals and irregularities of the coastline. But as photogrammetry was developed for general mapping of terrestrial areas, the hydrographic community adopted it for mapping the coastal fringe, including the measurement of depth in relatively shallow clear water. The U.S. Coast and Geodetic Survey was a leader in these developments. The emergence of color photography greatly aided this procedure (fig. 387).

FIG. 387. COLOR AERIAL PHOTOGRAPH OF CENTRAL BISCAYNE BAY, FLORIDA, 1992.
From A. Y. Cantillo et al., *Biscayne Bay: Environmental History and Annotated Bibliography* (Silver Spring: NOAA, 2000), 119. Image courtesy of the Center for Coastal Monitoring and Assessment, National Oceanic and Atmospheric Association.

In 1969 the Syracuse University Research Corporation reported that it was possible to measure nearshore bathymetric measurements using an airborne pulsed laser (Hickman and Hogg 1969). Further development of the technology was quickly taken up by Australia, Canada, Sweden, and the United States. Generically the system is known as lidar (light detection and ranging), but specific implementations are known by a variety of commercial names, such as LADS (Laser Airborne Depth Sounder) in Australia, Larsen in Canada, ABS (Airborne Bathymetric System) in Sweden, and SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) in the United States. Most significant among the numerous ongoing developments following the technology's introduction in the 1970s has been the collection of a complete swath of depth measurements by scanning across the track of the aircraft with laser beams. Although turbidity is a constraint, in clear water the system can measure depth precisely in waters deeper than fifty meters (fig. 388). Modern systems with high pulse repetition rates can provide nearly complete seafloor measurement under each swath. This in turn has fostered the development of very accurate digital terrain models. Lidar systems have now been used for production surveys on a global basis from the Canadian Arctic to the Australian Great Barrier Reef.

The obstacle presented by the air-sea interface has always limited the ability of electromagnetic signals from an airborne platform to reach the seafloor. One attempt to overcome this difficulty used an acoustic transducer towed below a low flying helicopter. This method was used in the Canadian Arctic to survey areas of open water between the ice-covered sea (Eaton 1963). Although successful, it was abandoned as being overly dangerous. Another method used with some success in the ice covered waters of the Canadian Arctic is TIBS (Through Ice

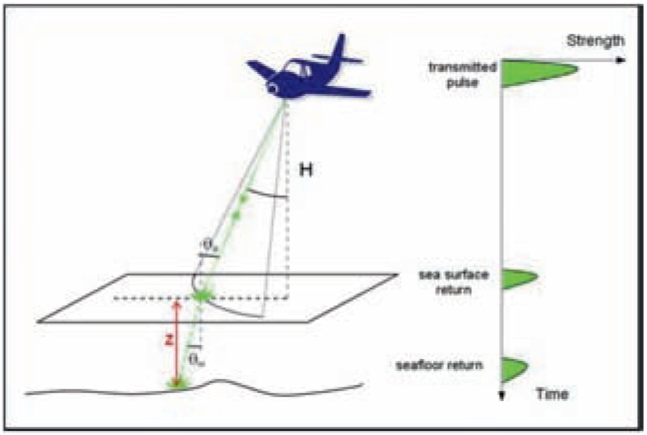

FIG. 388. LIDAR WORKING PRINCIPLE. Lidar uses a laser beam in two wavelengths (red and green lights) to determine the depth of water from an aircraft. Particularly useful in clearer waters.
From International Hydrographic Organization, *Manual on Hydrography*, Publication C-13 (Monaco: International Hydrographic Bureau, 2011), 183 (fig. 3.44). Permission courtesy of the International Hydrographic Bureau, Monaco.

Bathymetry System). In this system a large antenna suspended in the air beneath a low-flying aircraft is used to estimate depth from the magnetic field in the material beneath the water. Systems using radar images have been used to measure depth in shallow turbid water (Calkoen, Hesselmans, and Wensink 1998).

Satellite systems also carry a variety of sensors. Because of the great height of the platform above the water, satellite systems generally have a lower measurement resolution than those carried by aircraft. Even so, satellite systems such as the French SPOT (Système Probatoire d'Observation de la Terre) have been found valuable for mapping remote areas, including coral atolls.

Aerial imagery has provided the cartographer with a new dimension for mapping the seas, but limited by water clarity, it has not provided a substitute for acoustic measurement from a sea-borne platform. Even so, the processing of data to produce maps and charts is much the same. The availability of digital data and computer processing has permitted the rapid production of graphics. Previously these were limited to a paper medium, but with the development of the electronic or digital chart the information can be displayed dynamically on a computer monitor.

ADAM J. KERR

SEE ALSO: Coastal Mapping; Marine Charting; Photogrammetric Mapping: Aerial Photogrammetry and Cartography

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Sounding. In the nineteenth and first half of the twentieth centuries, both marine charting and safe sailing relied on "sounding" the depth of water with a lead line. A rope line was marked in fathoms (six feet) and attached to a tapered cylindrical lead weight with a cavity at the bottom. Tallow pressed into the cavity captured a specimen that indicated whether the seabed was sand, shingle, or mud. In poorly charted waters safe navigation required the lead line to be swung forward quickly while the vessel was under way so that soundings could be taken when the line became vertical. The expression "swinging the lead," describing a seaman working leisurely at the bow but meaning "to shirk one's duty," was still used in the twenty-first century. Surprisingly perhaps, naval hydrographers were still using lead line sounding in the early 1960s (Ritchie 1967).

Captain Henry Boyle Townshend Somerville of the Royal Navy's hydrographic survey vessel HMS *Research*, adapted the lead line for depths to twenty fathoms using steam winches and 500-pound mechanical devices that rolled along the seabed. In 1878 Francis Robert Lucas developed a hand-powered winch sounder (fig. 389) loaded with thin wire for sounding in deeper waters, with similar devices sounding up to 5,000 fathoms (Wharton 1920). These nineteenth-century sounding devices were still commonly used in the late 1930s on the Royal Navy's hydrographic vessels (Ritchie 1967).

Early in the twentieth century hydrographic technology recognized the potential of a more efficient and reliable sounding method that came to be known as sonar (sound navigation and ranging). An early form of sonar developed between 1916 and 1922 was called ASDIC, after the Anti-Submarine Detection Investigation Committee of the British Naval Staff. Depth of water was calculated from the time sound waves took to reach to the seabed and bounce back. France simultaneously developed similar techniques. This early echo sounder was not deployed on British naval vessels until 1921. Before World War II the system was improved by incorporating an electromagnetic hammer that hit a diaphragm plate on the ship's hull; an operator who listened for the re-

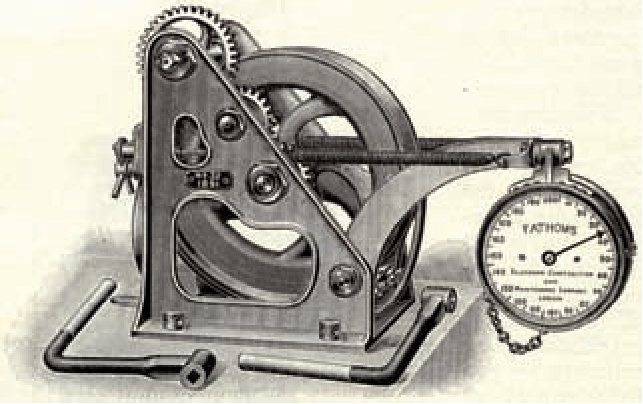

FIG. 389. LUCAS SOUNDING MACHINE, CA. 1891. This mechanical hand winch was developed to sound deeper waters with a thin wire and lead weight. Gauges indicated the depth, and later versions used steam driven winches to assist raising the wire.
Size of the original: 5.7 × 9.3 cm. From Otto Krümmel, *Handbuch der Ozeanographie*, vol. 1, 2d rev. ed. (Stuttgart: J. Engelhorn, 1907), 78 (fig. 13).

turning pulse then dialed in the time delay and read off the depth (Morris 1995, 31–32). In 1929 echo sounders were equipped with paper tracers to record the depth. It was not until the early 1930s that the British Admiralty, in collaboration with Hughes Ltd., developed an improved echo sounder. The British technology was passed on to the United States prior to World War II. In 1947 the British Navy still relied on ASDIC to survey the seafloor between sounding lines.

Early echo sounders used a narrow beamed acoustic pulse emitted from an electrically driven ceramic transducer at frequencies between 12 and 200 kilohertz. (A transducer is a device that transmits and receives pulsed frequency signals.) Because an accurate estimate of depth depends not only on travel time to the seafloor and back but also on the speed of sound in water (roughly 1,500 meters/second), which varies with salinity (conductivity), temperature, and depth (pressure), density variations related to temperature differences or estuaries required frequent calibration. By the mid-1970s digitally integrated systems had substantially improved accuracy and efficiency by using sound velocity profiles calculated from data obtained from a conductivity, temperature, and depth sensor lowered through the water column (Ingham 1975).

Side-scan sonar is an adaptation of a sideways-looking echo sounder. The fan-shaped swath of acoustic pulses emitted from the sounder helped identify wrecks and seabed features such as sand waves. It used frequencies typically between 100 and 500 kilohertz and was limited to a range of around 200 meters. The use of side-scan sonar during echo sounding surveys to identify wrecks became standard practice in the 1970s.

Mapping of the deep ocean seabed by lead line or narrow-beam echo sounder was inadequate for geologists and geophysicists studying the deep abyssal plains and rift zones associated with plate tectonics. For this reason, the British Institute of Oceanographic Sciences developed a deep-ocean high-power side-scan sonar designed to be towed by the research vessel and known as GLORIA (Geological Long Range Inclined ASDIC). GLORIA had a sounding swath of twenty-seven kilometers to one side of the sonar.

For the faster, more efficient surveying of sheltered waters such as harbors and estuaries, early swath-sounding systems used multiple transducers (up to fifty) separated on beams suspended from either side of the vessel. This practice was often referred to as channel sweep sounding. For more exposed coastal waters, researchers in Sweden developed a method of multiple-craft surveying whereby a mother ship and smaller launches ran a parallel course so that the vessels' echo sounders collectively formed a wide swath.

In the 1950s the United States began to develop multibeam echo sounders (MBES), that is, swath-sounding systems in which multiple transducers in a tight array could be electronically steered in a fan-shaped swath across the seabed. The U.S. Navy used these systems operationally in the 1970s for high-resolution seabed mapping to support submarine navigation, and commercial applications followed in the late 1970s. MBES allowed a high density of soundings and 100 percent coverage of the seabed, thereby meeting International Hydrographic Organization (IHO) standards for ports, harbors, and areas of limited depth clearance for vessels (IHO 2008). Subsequent developments included swath systems using two perpendicular transducer arrays with phased beam shaping. The very high density of the resulting soundings required highly efficient computers, as did the related software for spatial filtering and three- and four-dimensional visualization.

In the final decades of the twentieth century, very high-resolution seabed mapping was possible with towed multibeam echo sounders combined with side-scan sonar, typically with swaths 200 meters wide and the device flown 30 meters above the seabed, which yielded depth estimates accurate to within 25 centimeters. The DSL-120A sonar, developed by the Woods Hole Oceanographic Institution, was effective at depths as great as 6,000 meters.

Autonomous underwater vehicles (AUV) with multibeam echo sounders, side-scan sonar, and inertial navigation systems were developed in late 1950s. A mother ship was needed to launch and recover the AUV. This approach combined the clearest soundings possible in deep water with the benefits of flying closer to the seabed.

Because the heave, pitch, and roll of a survey vessel produces errors in soundings, engineers attempted to minimize these errors with motion sensors based on the gyroscopes and accelerometers in inertial navigation systems used in aircraft and submarines. Motion systems introduced later in the 1990s used a satellite navigation method known as Real-Time Kinematic Differential GPS, which enhanced the accuracy of instantaneous GPS estimates of the sensor's position in three dimensions.

In the 1980s the U.S. Landsat and the French SPOT (Système Probatoire d'Observation de la Terre) satellites demonstrated the effectiveness of shallow-water mapping from space but were limited to a depth of about twenty-five meters in clear water. Even so, bathymetric remote sensing has been useful in rapidly mapping habitats in remote tropical coral waters.

Airborne lidar (light detection and ranging), developed in the mid-1960s, has proved much more successful in mapping clear coastal waters to a depth limit of around 70 meters. Systems flown on light aircraft or helicopter at altitudes of 500 meters or less fire two types of pulsed laser beams, one green and the other near-infrared (see fig. 388). Water depth can be measured because the green laser beam is reflected from the seabed while the near-infrared beam is reflected from the water surface—subtracting one surface from the other yields the water depth. Although turbidity undermines bathymetric lidar's effectiveness, it has been able to measure depths as great as 60 meters. Accuracies around 30 centimeters meet IHO standards, except for construction surveys (Jong et al. 2002; Lekkerkerk et al. 2006).

In marine charting an accurate determination of the sounding's geographical position (latitude and longitude or grid coordinates) was no less important than the estimated water depth. Through the first half of the century, the latitude and longitude of shore control were determined by star observations, and the vessel's position was tied to shore points using horizontal sextants and plotted on a chart using a station pointer (Ingham 1975; UKHO 1969a). In the second half, sailors relied on the electronic methods of hyperbolic radio navigation, a short-range microwave positioning system called a trisponder, and eventually satellite navigation systems such a Doppler Transit and Navstar GPS (Global Positioning System) (fig. 390).

Sounding of the depth of water requires correction for tidal variations. The vertical reference level used for charting is the chart datum, which is usually the lowest astronomical tide or mean lower low tide. In coastal surveys prior to self-recording tide gauges it was the role of a tide gauge observer to write down the hourly tide level from a tidal staff.

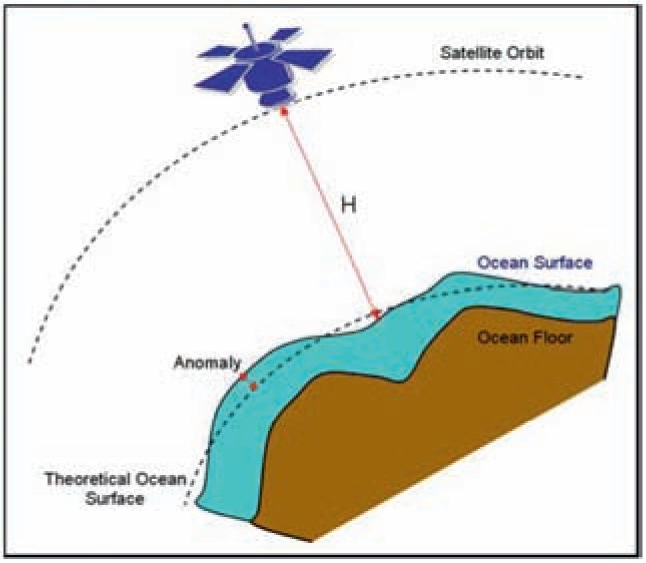

FIG. 390. SATELLITE-DERIVED BATHYMETRY. Satellite radar altimetry has provided global coverage of sea levels using the TOPEX/Poseidon followed by Jason satellites. This information helps correct depth soundings in the oceans where tidal data are needed.
From IHO 2011, 186 (fig. 3.46). Permission courtesy of the International Hydrographic Bureau, Monaco.

Because it was not always possible to have the complete confidence required when soundings were used to chart harbors and channels, even with side-scan sonar, wire sweeping was used to ensure that no dangerous rocks or remains of wrecks were overlooked (see fig. 385). Survey vessels ran parallel with a taught wire held at depth by weights and trawl otter boards. An alternative strategy employed a horizontal bar, such as a length of rail of the type used in railway construction, that was suspended below the vessel at the required depth to identify or clear any objects (UKHO 1969b; Ingham 1975) .

Although seabed sounding has had a wide-ranging role in safe navigation, chart production, and seabed geomorphology, hydrographic sounding developments were closely related to naval operations, particularly during World Wars I and II. Many nations used a dedicated naval survey fleet to update existing charts surveyed only by lead line, and multibeam swath systems were common by the 1970s. This work also included high-resolution mapping for submarine navigation. International organizations that helped develop methods and standards for hydrographic sounding surveys include the IHO and the International Federation of Hydrographic Societies. In Britain the Maritime and Coastguard Agency has taken over some of the work for the civil and commercial requirements from the Admiralty Hydrographic Office, but at the dawn of the twenty-first century less than half of British waters had been surveyed to IHO Order 1 standards (IHO 2008). Other national establishments active in seabed sounding were the Service hydrographique et océanographique de la Marine in France and the National Ocean Service in the United States.

In the late twentieth century legal responsibility for soundings on charts published by national agencies was of growing concern to shipping lines, lawyers, and government hydrographers (Guy 1989). National hydrographers could be held legally responsible when charts with erroneous soundings or missing hazards causing damage or loss of a vessel.

Soundings attained an even wider significance after the United Nations Conference on the Law of the Sea (UNCLOS) defined Exclusive Economic Zones related to submarine features such as the foot of the continental slope. By century's end dedicated hydrographic survey vessels were mapping seabed features with great significance to geographical boundaries and economic resources such as minerals and fisheries.

The transition in sounding methods had a visual impact as well, particularly in the use of colors and isobaths to present a more vertically detailed representation of the seafloor. By contrast, many early twentieth-century charts show tracks of lead line soundings. More efficient sounding and chart production methods allowed soundings spaced at even intervals, which improved visual interpretation and chart aesthetics. In addition, early twentieth-century charts had a distinctive artistic style associated with the cartographer's hand-drawn linework and other embellishments.

The most important twentieth-century development in the display of hydrographic soundings and chart information is the electronic chart, which made navigation easier and promoted safety by integrating real-time GPS navigation with an instantaneous, interactive display of the ship's position and intended course as well as submerged hazards, visible landmarks, and the boundaries of restricted areas. Chart updates important for military operations and commercial shipping could be distributed by CD-ROM or downloaded while at sea using satellite telecommunications.

DAVID J. DIXON

SEE ALSO: Coastal Mapping; International Hydrographic Organization (Monaco); Lidar; Marine Charting: Overview of Marine Charting; Tidal Measurement

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Satellites in Hydrographic and Oceanographic Mapping. Looking back at the final third of the twentieth century, the well-known oceanographer Walter H. Munk (2002, 2) observed, "Satellites have revolutionized oceanography. This is not so much because of the instrument packages (remarkable as they are) but the ability to sample adequately, and to sample globally (two different things)." By century's end satellites were providing a plethora of oceanographic observations from a variety of platforms and sensors using visible light, various wavelengths of the electromagnetic spectrum in both active and passive modes, and the earth's gravity field. From the standpoint of cartography, the vast majority of these observations were of transient surface phenomena used in forecast maps, real-time data depictions, or hindcasting. Transient parameters mapped by satellite included sea-surface temperature, plankton blooms, large ocean currents, wind, waves, swell, global tides, ice cover, and ocean-atmosphere interaction features such as tropical storms. Various types of satellite sensors have mapped permanent features on human timescales such as global bathymetry, many shallow zones of the world ocean, the geoid, and sea level.

The concept of observing oceanographic phenomena from space dates virtually from the beginning of earth-observing satellites. A vision of what was to come emerged in 1964, when the Advanced Missions, Manned Space Science Program of the National Aeronautics and Space Administration (NASA) sponsored a conference, hosted by the Woods Hole Oceanographic Institution, to discuss "The Feasibility of Conducting Oceanographic Explorations from Aircraft, Manned Orbital and Lunar Laboratories." Whether by design or by the sheer momentum of an emerging technology, unmanned satellite oceanography received a large share of attention at this conference. Numerous prominent scientists, science administrators, and engineers exchanged ideas as to how satellites could ultimately be used to observe the ocean, what sort of data sets could be obtained from satellite observations, what kind of sensors could be deployed, and what resolution was required for adequate delineation of various oceanographic parameters. It was well understood at this meeting that satellites held the key to regional and worldwide observation of various parameters on a timescale of minutes to years.

The overall vision of satellite usage encompassed two main missions: direct or derived observation of oceanic phenomena from a suite of active and passive sensors and communications with fixed and mobile oceanic sensing platforms, including ships, buoys, and floats that transmitted data to a satellite, which in turn transmitted to a shore processing facility. Although a subset of positioning applications of modern space-based navigation systems, a third major component of satellite oceanography realized between 1990 and 2010 is the ability to position a vehicle somewhere over or on the ocean with twenty-four-hour all-weather precise-positioning capability.

Participants at the 1964 conference suggested multispectral imaging, including visible light as a potential sensing technology, to determine such varied parameters as sea surface temperature, ice cover, chlorophyll content of the ocean, and depth measurement in shallow clear waters. But because the various forms of electromagnetic radiation are rapidly attenuated by passing through water, it was also understood that systems of this nature are constrained to observations of the upper few meters of the ocean for visible light and perhaps a few millimeters, at best, for infrared, ultraviolet, and microwave emissions.

An active method, measuring distance to the ocean surface by satellite radar altimetry, was suggested as a means to determine sea level, make tidal observations, determine the configuration of the geoid, and observe wave heights, which could be used to derive winds. Oceanographer Albert Oshiver of the U.S. Coast and Geodetic Survey noted, “If, therefore, a system for measuring the height of the satellite over the ocean with sufficient accuracy can be developed, both geodesy and oceanography could be served by determining geoid profiles and at the same time measuring the magnitude of tidal effects and their progress with time over the ocean surface” (1965, 218). He also surmised that derived gravimetric data could be used to determine local geologic features. Over the intervening years it also became apparent that such data could be used to derive bathymetry throughout the world ocean and observe long-term changes in sea level.

Another conference participant, U.S. Navy Captain Paul M. Wolff, of the U.S. Fleet Numerical Weather Facility, predicted, “Satellites will in the future find their principal use in communication, including the interrogation of automatic stations. . . . The satellites are expected to assist mainly in interrogation, communication, and improvement of navigation (for current drift use)” (1965, 150).

Wolff perceived that satellites would be the key element of a worldwide communication network consisting of ships, moored buoys, and drifting sensors such as the 3,000 Argo floats that transmit their oceanographic data to a satellite typically every ten days (Roemmich et al. 2003). By the early twenty-first century thousands of moored, drifting, and powered oceanic sensors were transmitting data and receiving instructions through a variety of satellite communication systems.

By the mid-1970s, many of the predictions voiced at Woods Hole were borne out. Numerous environmental satellites were launched for a variety of reasons; serendipitously, many of their systems could be used for multiple purposes including oceanographic studies. Various early TIROS (Television Infrared Observation Satellites), including ESSA (Environmental Science Services Administration) and NOAA (National Oceanic and Atmospheric Administration) satellites, and the seven Nimbus satellites carried sensors that led directly to many of the systems in use decades later. The Nimbus satellites, beginning with Nimbus 1 in 1964, were the ancestors of many of the operational ocean and land observational satellites monitoring the planet at century’s end. They hosted a variety of increasingly accurate and higher-resolution radiometers, provided proof of the concept of communicating with and positioning remote observational systems including instrumented animals and drifting instrument packages through the Interrogation, Recording, and Location System (IRLS, mounted on Nimbus 3 and Nimbus 4 launched in 1969 and 1970) and the Tropical Wind Energy Conversion and Reference Level (TWERLE) system (Nimbus 6, launched in 1975), and pioneered observing and monitoring changes in ocean color through the Coastal Zone Color Scanner (CZCS) mounted on Nimbus 7. With the launch of NOAA-2 in 1972, the one-kilometer-resolution Very High Resolution Radiometer (VHRR) made possible global sea surface temperature observations. Besides the obvious benefit to science from derived sea surface temperatures, ship routing tests (1975) were run based on satellite analysis of the axis of the Gulf Stream and VHRR sea surface temperature data became available to commercial fishermen for the purpose of locating ocean fronts that tend to be productive fishing areas.

Although phytoplankton blooms in the Baltic Sea were observed by Landsat 1 as early as 1973 (Horstmann and Hardtke 1981), global phytoplankton productivity was observed as the result of ocean color observations made by the CZCS, which evolved into the SeaWiFS (Sea-viewing Wide Field-of-view Sensor) ocean color sensor. The SeaWiFS sensor was mounted on a commercial satellite, a partnership between the commercial satellite and satellite oceanography communities. This system was superseded by the NASA MODIS (Moderate Resolution Imaging Spectroradiometer) sensor on the Earth Observing System satellites Terra and Aqua. Visible light images of the ocean surface have also been used to discover and delineate shallow reef structures in clear waters such as the northwest Hawaiian Islands. Although the aquamarine hue of these shallow clear waters made these structures relatively easy to find, using such data for reasonably accurate determination of depths was less successful. In general, photobathymetry from space has not met hydrographic charting standards.

As with the growth of products and applications derived from various electromagnetic spectrum sensors, the value of satellite altimetry has progressed significantly since the first suggestions for its use. The first satellite altimetry mission was flown on the S-193 Skylab in 1973, followed by the 1975 GEOS-3 (Geodetic and Earth Orbiting Satellite) and 1978 Seasat missions. Seasat failed only three months into its mission, but because of its then astounding ten-centimeter accuracy (distance from sensor to ocean surface) and six-kilometer sampling interval, it produced a data set that became a landmark for marine geodesy and geophysics. Although short-lived, the Seasat mission proved the efficacy of using altimetry to define the marine geoid, improve understanding of the marine gravity field, and, perhaps most surprisingly, infer global bathymetry. Techniques for inferring bathymetry from satellite altimetry data were pioneered by geophysicist William "Bill" F. Haxby (McAdoo 2006). Seasat was followed up by the U.S. Navy Geodetic Satellite (Geosat) launched in 1985 and originally classified, the European Space Agency's European Remote Sensing satellites (ERS-1 and ERS-2, launched in 1991 and 1995), and the TOPEX/Poseidon mission, launched in 1992 as a joint effort of the Centre national d'études spatiales (CNES) and NASA's Jet Propulsion Laboratory. Geosat and the ERS satellites proved invaluable to investigators such as Walter H. F. Smith and David T. Sandwell for producing bathymetric maps of the world ocean, which revealed unknown seafloor features and helped solve many problems in global tectonics (Smith and Sandwell 1997). The TOPEX/Poseidon mission, because of exact repeat orbits on a ten-day cycle, was the first to observe and determine global tides as well as to map short-term and long-term global ocean surface circulation; it also helped refine estimates of global sea level rise. The TOPEX/Poseidon collaboration resulted in what Munk spoke of as "the most successful ocean experiment of all times" (Munk 2002, 2).

According to Mary Louise Cleave, associate administrator for NASA's Science Mission Directorate, "TOPEX/Poseidon revolutionized the study of Earth's oceans, providing the first continuous, global coverage of ocean surface topography and allowing us to see important week-to-week oceanic variations." What's more, "Its data made a huge difference in our understanding of the oceans and their affect on global climatic conditions" ("NASA's TOPEX/Poseidon Oceanography Mission Ends," NASA press release, 5 January 2006). By 2010 data sets from satellites such as the Gravity Recovery and Climate Experiment (GRACE) and the European Space Agency's Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) satellites were further refining the view of the earth's gravity field and its relationship to both the geoid and the dynamic ocean. If the past is the key to future directions for satellite remote sensing, two things are certain—higher-resolution sensing systems will be developed and major discoveries remain to be made (Theberge 2010). Between 1960 and 2010, satellites not only revolutionized the ability to visualize and monitor earth's atmosphere and land surface, but also revolutionized our view of the world ocean.

ALBERT E. THEBERGE

SEE ALSO: Coastal Mapping; Marine Charting: Overview of Marine Charting; Remote Sensing: Satellite Systems for Cartographic Applications

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Global Positioning Systems in Hydrographic Mapping. Charting is inseparably intertwined with positioning and position fixing. The positional accuracy of surveying is the determining factor for resolution of detail in maps and their fitness for use. When using maps for navigation, positioning is a prerequisite for identifying the location and associated features surrounding the vessel. The particular challenge at sea is kinematic positioning on a moving craft, which is notoriously less accurate than stationary positioning.

Advances in positioning techniques are therefore an essential factor for progress in charting. For most of the twentieth century, positioning at sea relied on astronomical methods (accuracy about 1.5 nautical miles), and from the 1950s forward also on radio navigation (accuracy about 200 meters). In 1995 the Global Positioning System (GPS) was declared fully operational. For the first time, one could determine the geographical position of a vessel on the open water continuously, in real time, regardless of distance from shore, at a horizontal accuracy of better than 100 meters. After the artificial GPS signal degradation (Selective Availability) was turned off in 2000, positioning to 10-meter accuracy was possible. Differential GPS (DGPS) methods, developed in the late 1980s, improved positioning accuracy to 1 to 2 meters, and phase evaluation methods for GPS signals under development promise centimeter accuracies both in stationary and kinematic mode, allowing real-time tidal correction of soundings.

Since the 1990s, GPS technology, rapid advances in computing power, and progress in marine technology have had a large impact on maritime navigation and on expanding marine uses such as deep sea mining and offshore wind farms. This created a huge demand for charts matching GPS positioning accuracies and a need for marine governance requiring the Hydrographic Offices to resurvey their waters at GPS accuracy. GPS positioning linked with hydrographic surveying techniques, such as multibeam sonar sounding in deep water and airborne lidar bathymetry in shallow water, have greatly enhanced surveying efficiency at this higher accuracy.

There are two basic types of hydrographic maps compiled from data obtained by GPS and other highly accurate positioning techniques: nautical charts primarily used in marine navigation and scientific maps used not only in oceanography but also as the basis for compiling nautical charts. Additionally, there are maps displaying hydrographic surface parameters such as sea temperature, waves, and sea ice, which are derived from satellite imagery independent of GPS positioning.

Bathymetric charts are the most prominent type of marine scientific chart. Depicting seafloor morphology at high resolution, these charts have benefited from the high positional accuracy offered by GPS and from the continuous availability of GPS signals allowing real-time positioning. In their simplest form, bathymetric charts contain the results of hydrographic surveys at the largest scale appropriate for a given area. Throughout the century, bathymetric charts were produced by national agencies and used as sources for compiling nautical charts. On a smaller scale, the long-term General Bathymetric Chart of the Oceans (GEBCO) international project aimed at evaluating all available survey data for a comprehensive, detailed depiction of the seafloor for the world's oceans. The project was jointly coordinated by the Intergovernmental Oceanographic Commission (IOC) and the International Hydrographic Organization (IHO). GEBCO charts are digitally available as the *GEBCO Digital Atlas*.

The content of nautical charts is designed to meet the needs of safe navigation, depicting aids to navigation, regulated zones, and many other marine features, but seafloor topography is shown only as detailed as necessary. Since 1921, chart content and symbology have followed the standards and specifications of the IHO (2012). Nautical charts are mandatory for seagoing vessels according to the International Convention on Safety of Life at Sea (SOLAS).

Electronic charts became a necessity in marine navigation to capitalize on the benefits of GPS positioning. Electronic charting had arisen from improvements in computer technology. The first fully functioning electronic chart was introduced in 1983 (Rogoff 1985; Rogoff, Winkler, and Ackley 1983). It was based on a vector digital chart and included many advanced capabilities such as a radar image overlay. In 1996 the Electronic Chart Display and Information System (ECDIS) was internationally approved as a digital navigation information system based on worldwide standards that satisfies the carriage requirement for nautical charts, integrating the functions of charts with navigation sensors (fig. 391) such as GPS and radar (Hecht et al. 2011). At the end of the century, integration was expanding to melding spatial data infrastructure and broadband satellite communication with maritime information from ashore and onboard sensors into what is termed e-navigation. Marine charting is currently evolving into GIS databases accommodating the purposes of science, marine administration, and navigation based on a universal data standard (IHO 2010).

HORST HECHT

SEE ALSO: Coastal Mapping; Global Positioning System (GPS); Marine Charting

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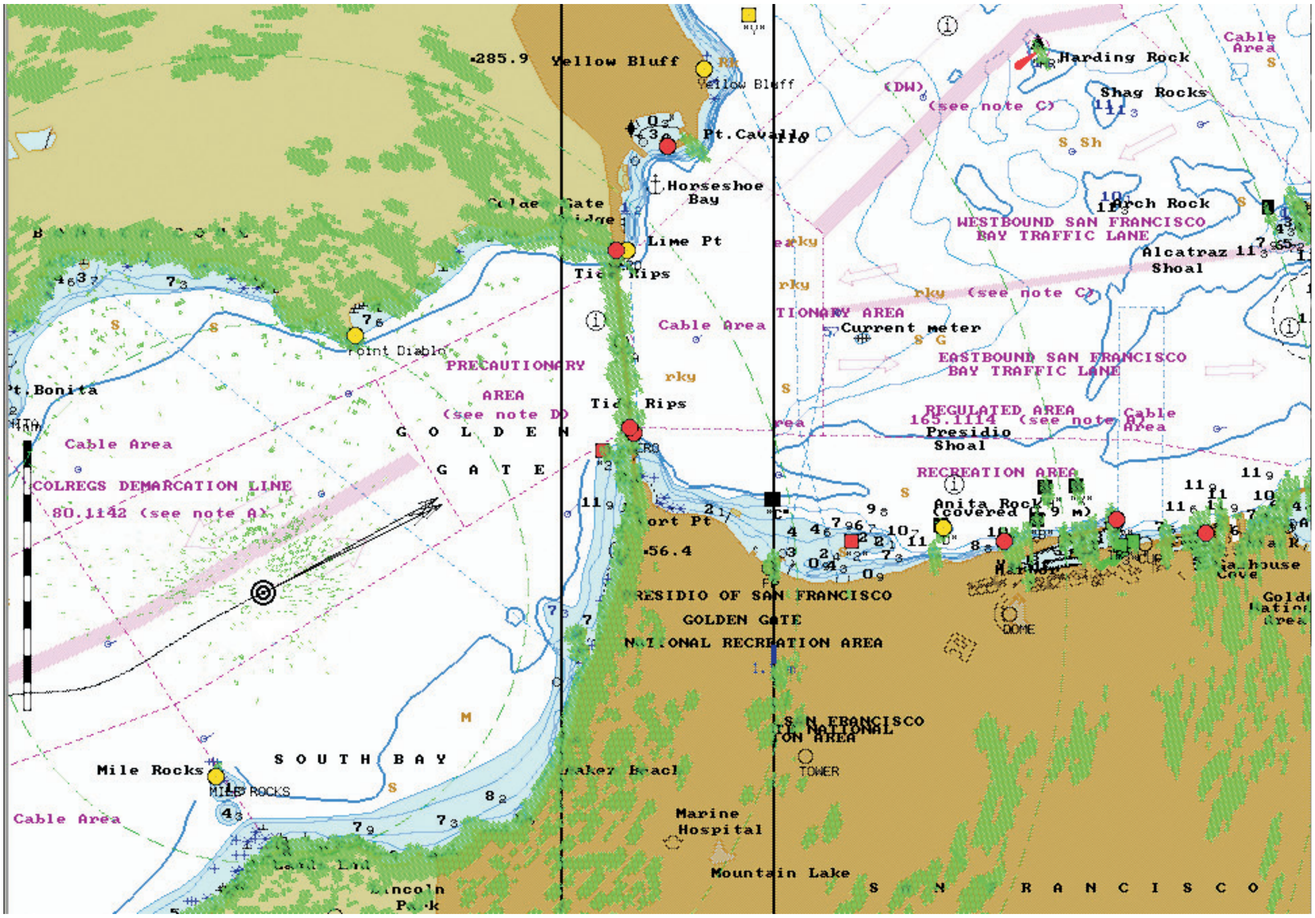

FIG. 391. ELECTRONIC CHART WITH RADAR OVERLAY, SAN FRANCISCO, 1:30,000 (RADAR RANGE: SIX NAUTICAL MILES). The coastline, some targets, and other relevant features (Golden Gate Bridge) are shown (Hecht et al. 2011, 197 [fig. 12.4]).

Image courtesy of TRANSAS Ltd.

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Hydrography. See Hydrographic Techniques; Marine Charting

Hypermapping. What could be considered the first hypermap application was the Aspen Movie Map Project, devised and undertaken by the MIT Architecture Machine Group in 1978 (Negroponte 1995, 66–67). This two-videodisc system was developed to demonstrate the possibilities of providing information using multimedia resources. The videodiscs, controlled by computers, allowed the user to “drive” down corridors or streets in Aspen, Colorado. Every street and turn was filmed in both directions. Software that integrated the straight street segments on one videodisc with the curves on the other provided an artificial seamless driving experience. Users entered buildings, saw archival photographs, and undertook guided tours, leaving a trail like Ariadne’s thread (see fig. 401).

Another hypermap product was the Domesday videodisc, the innovative multimedia “picture” of Britain in the 1980s jointly produced by the BBC, Acorn Computers, and Royal Philips Electronics. Launched in 1986, this double-videodisc Laservision system contained national information on one disc and community informa-

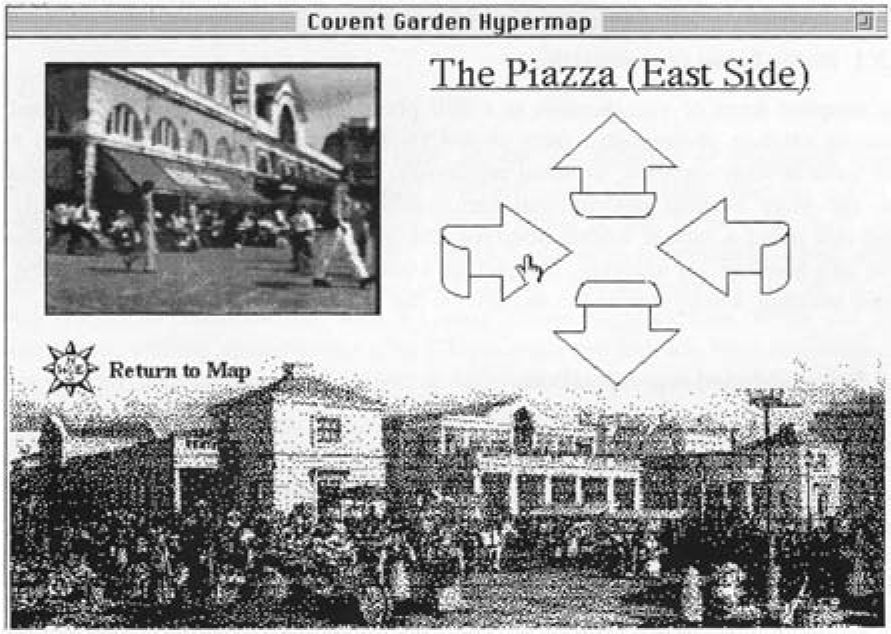

FIG. 392. THE COVENT GARDEN AREA PROTOTYPE INTERFACE. Users move around the package by clicking the directional arrows.

Size of the original: ca. 8.4 × 11.8 cm. From Parsons 1995, 207 (fig. 16.4). Reproduced by permission of Taylor & Francis Books U.K.

tion on the second (see fig. 402). Early interactive mapping using videodiscs was the forerunner of later, more developed products.

Robert Laurini and Françoise Milleret-Raffort (1990) introduced the term "hypermap" to describe a unique way of using multimedia with geographic information systems (GIS). The hypermap is an interactive digitized multimedia map that allows users to zoom and find locations using a hyperlinked gazetteer. Geographic access is provided through a coordinate-based interface whereby a user can retrieve all information relating to a place by clicking on the point or region on a map.

M. J. Kraak and Rico van Driel (1997) explained the various forms of hyperpublishing and the underlying concepts. Their core concept was that hypertext related to text only. If images and sound were added, it became a hyperdocument. The addition of user interactive control made it a hypermedia system, while the provision of a geographic reference system created a hypermap.

During the late 1980s and early 1990s, interest focused on the production of electronic atlases, mainly due to the wide availability of Apple's HyperCard software developed for the Macintosh computer and released in 1987. HyperCard cartographic products included the *Glasgow Online* digital atlas, which operated around a hypermedia spatial interface, *La Francophonie nord-américaine á la carte*, and *Mines et minéraux á la carte*. The dynamic structure of *La Francophonie nord-américaine á la carte* provided access via eight navigation buttons: instructions, impression, stop, region, localization, origin, brief description, and flag icon of the local French community. Also of note is HYPERSNIGE, developed by A. Camara and A. L. Gomes in 1991, which included Portugal's national, regional, and subregional maps and information, and Ed Parsons's Covent Garden area prototype. Parsons's project presented users with a through-the-window view of the market in 3-D perspective (Parsons 1995). Users navigated around the package using conventional cursor controls and mouse clicks (fig. 392).

WILLIAM CARTWRIGHT

SEE ALSO: Interactive Map

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