S

Salishchev, Konstantin Alekseyevich. K. A. Salishchev, perhaps the most prominent Russian cartographer of the Soviet period, was born on 20 November 1905, in Tula, Russia. After graduating in 1926 from what became the Moskovskiy institut inzhenerov geodezii, aerofotos"yëmki i kartografii (MIIGAiK), he began his scientific career in the expeditions in northeast Eurasia and was one of the discoverers of the Cherskogo Range, among the highest elevations in eastern Siberia. He received a Dr. Sci. Tech. degree from MIIGAiK in 1941 and later served as vice president (1964–68), president (1968–72), and past president (1972–76) of the International Cartographic Association (ICA) and as head of the Department of Geodesy and Cartography of the Lomonosov Moscow State University—Moskovskiy gosudarstvennyy universitet (MGU).

Salishchev's major creative endeavor was planning and editing the *Bol'shoy sovetskiy atlas mira* (1937–40), a massive undertaking that includes data on physical, social, economic, and political geography. He also participated actively in the creation of several other large Russian atlases, notably, the *Atlas istorii geograficheskikh otkrytiy i issledovaniy* (1959), the first two volumes of the *Morskoy atlas* (1950–53), the *Atlas mira* (1954), the *Fiziko geograficheskiy atlas mira* (1964), and the multivolume *Atlas okeanov* (1974–93).

In 1956, at the XVIII Congress of the International Geographical Union in Rio de Janeiro, Salishchev helped found the Commission on National Atlases, which he chaired for sixteen years. The commission promoted thematic cartography and the unification of atlas content as well as international cooperation among researchers worldwide. Under Salishchev's supervision, the commission prepared the scientific-methodical manuals *Atlas nationaux* (1960) and *Regional Atlases* (1964), which influenced atlas development in many countries, especially in the Third World. Salishchev also edited the monograph *Kompleksnyye regional'nyye atlasy* (1976), which synthesized the research experiences of many university geographers and cartographers. His research and writings contributed to scholarship in many areas, especially cartographic methodology, cartographic modeling, the theoretical development of geographic cartography, the use of spatial analysis in thematic mapping, and computer-assisted cartography. Salishchev produced numerous map series for Soviet secondary and higher education.

Salishchev's pedagogic activities started in 1931 on the geographical faculty of Leningrad University. In 1936 he joined the staff of the cartographic faculty at MIIGAiK, and in 1942 he began teaching courses to geographer-cartographers at MGU, where he worked until his death in 1988. He also held the post of prorector of the MGU and headed the Department of History of Geographical Sciences and, since 1950, the Department of Geodesy and Cartography, which became a large teaching and research center under his management.

Salishchev's textbooks on the fundamentals of cartology (the academic theoretical aspects of cartography), practical cartography, map design and compilation, and the history of cartography were kept current by frequent revision and informed several generations of geographers and cartographers in Russia and other countries. He sought to link cartography with earth science and the social sciences and to integrate it with geography and the natural sciences.

Salishchev's articles, reports, and textbooks have been translated into many languages, and he enjoyed considerable prestige within the world cartographic community. He was elected an honorary member of geographic and geodetic societies in Serbia, Columbia, Scotland, Poland, the United States, Bulgaria, Italy, Hungary, Georgia, and Azerbaijan, and he was awarded honorary doctorates by the universities of Warsaw and Berlin. For his multifaceted scientific and organizing activities, the ICA named him to an ICA Honorary Fellowship in 1974 and awarded him its Karl Mannerfelt Gold Medal for outstanding contributions to world cartography in 1980. Salishchev's numerous program reports at IGU and ICA meetings include "Modern Thematic Cartography and Problems of International Cooperation" at the XXI International Geographical Congress (IGC) in New Delhi (1968), "Contribution of Geographical Congresses and IGU to the Development of Cartography" at the XXII IGC in Montreal (1972), and "Methods of Map Use" (in collaboration with A. M. Berlyant) at the joint session of the XXIII IGC and the 8th Technical Conference of ICA in Moscow (1976). His activities and the scientific school he founded contributed to improved contacts between Russian scientists and the world cartographic community.

Salishchev's scientific achievements were highly acclaimed in the Soviet Union. In 1980 he was designated the State Prize Winner for his participation in the creation of the *Atlas okeanov*, and in 1967 and 1989 (posthumously) he won the D. N. Anuchin and M. V. Lomonosov Prizes. In 1963 he was awarded the highest state awards and orders, the Gold Medal of the Russkoye geograficheskoye obshchestvo, and in 1965 he was named Honored Scientist of Russia. Salishchev died in Moscow on 25 August 1988.

A. M. BERLYANT

SEE ALSO: Academic Paradigms in Cartography: Europe; Atlas: National Atlas; *Bol'shoy sovetskiy atlas mira*; International Cartographic Association

BIBLIOGRAPHY:

Berlyant, A. M., ed. 2005. *Universitetskaya shkola geograficheskoy kartografii (k 100-letiyu Prof. K. A. Salishcheva)*. Moscow: Aspekt Press.

Konecny, Milan, Ferjan Ormeling, and Vladimir S. Tikunov. 2005. "Centenary of the Birth of Konstantin Alexeevich Salishchev (1905–1988)." *ICA News* 44:13–14.

Salishchev, Konstantin Alekseyevich. 1967. *Einführung in die Kartographie*. 2 vols. Gotha: VEB Hermann Haack, Geographisch-Kartographische Anstalt.

———. 1971a. "Contribution of Geographical Congresses and the International Geographical Union to the Development of Cartography." *IGU Bulletin* 22, no. 2:1–22.

———. 1971b. *Kartografiya: Izdaniye vtoroye, pererabotannoye i dopolnennoye*. 2d ed. Moscow: Izdatel'stvo Vysshaya Shkola.

———. 1990. *Kartovedeniye: Izdaniy tret'ye, dopolnennoye i pererabotannoye*. 3d ed. Moscow: Izdatel'stvo Moskovskogo Universiteta.

Scale. Since the real world is infinitely complex, it is essential that any representation of its surface simplify, generalize, abstract, or approximate what is being represented. It would be impossible, for example, to create a scale model of Mt. Everest that reproduced every aspect of that landform; impossible to draw a map that reproduced every detail of a city's built form; and impossible to create a digital database that recorded every detail of a university campus. Even Lewis Carroll's fantasy of a map as large as the area it was intended to represent (Carroll 1894, 169) would still disappoint. Leaving out detail is a common strategy for limiting the complexity of representations—but so too is the replacement of complex real forms with simple mathematical ones or the replacement of real detail with the output of some pattern-simulation process that produces artificial detail with all of the appearance of the real thing.

In cartography, the noun "scale" has come to stand as a single representative parameter of this complex process. Thus a comparatively detailed map, representing a small area on a large sheet of paper, will be termed large-scale, and a comparatively generalized map that represents the same area on a much smaller sheet of paper will be termed small-scale. Well before the twentieth century the term "scale" had become virtually synonymous in cartography with representative fraction, which is defined as the ratio of distance in the real world to distance in the representation. Maps and globes are examples of analog models, which represent aspects of the real world in the form of physical models, and all such models have an associated scaling parameter or representative fraction that is as applicable to a three-dimensional model of a building or a railway train as it is to a two-dimensional map.

As national mapping agencies such as the U.S. Geological Survey (USGS) addressed the task of providing consistent mapping of the land surface, the representative fraction became the parameter that defined entire series of maps. Thus the 1:24,000 series, which consists of over 57,000 maps covering the conterminous states, Hawaii, and U.S. territories, has an elaborate set of defining rules that govern content, positional accuracy, and level of detail, all of which differ sharply from those specified for other series, such as the 1:100,000 or 1:250,000 series. Figure 883 compares the contents and appearance of USGS maps at these three scales.

Within this simple conceptual framework lurk a number of issues and nuances that make scale one of the more problematic concepts in cartography. These have become progressively more important as cartography has moved from the paper-based, nationally administered approach characteristic of the first half of the century to the complex digital world of spatial data that began to emerge in the 1970s and as spatial data have become more important to a host of human activities ranging from science to day-to-day life.

Flattening the Earth

In addition to simplifying the earth's surface, maps and globes also change its shape. While the geoid, or the surface of equal gravitational potential, has numerous hills and dales, most globes are constructed on the assumption that the earth is a sphere, and all maps are constructed on the assumption that it is flat. Because the

FIG. 883. MADISON, WISCONSIN, SHOWN AT THREE DIFFERENT TOPOGRAPHIC MAP SCALES. The three examples, 1:24,000, 1:100,000, and 1:250,000, are centered on the Capitol building. Details shown at original size: 6.77 × 17.3 cm. Images courtesy of the Arthur H. Robinson Map Library, University of Wisconsin–Madison.

mathematical transformations inherent in this reshaping are nonlinear, it follows that no globe or map can have a representative fraction that is truly constant. The variation will be minute for maps of small areas, of course. But on a Mercator projection, for example, the representative fraction at latitude 80 will be approximately six times what it is at the equator. Tissot's indicatrix, a simple graphical device for illustrating the variation of the representative fraction over a map, consists of a series of small circles drawn to be a constant size on the earth's surface. On a map the indicatrix shows not only the spatial variation of scale as a function of both location and direction but also the resulting variation in relative area (except for an equivalent projection) and angular distortion (except for a conformal projection) (see fig. 973).

By the end of the twentieth century, computer graphics technology had advanced sufficiently to support the display and manipulation of representations of three-dimensional objects. The first virtual globes appeared in the early 1990s, on machines that cost several hundred thousand dollars, but by 2000 the same capabilities were available on standard personal computers. One of the first publicly available virtual globes was EarthViewer, subsequently redesigned and rebranded as Google Earth. In such systems the user is able to view the earth as if seen from space (in effect a perspective orthographic projection), zoom to submeter detail, add layers of two- and three-dimensional information from the Internet, and pan across the earth's surface in simulation of a flight (a "magic carpet ride" in the terms of former U.S. vice president Al Gore). Increasingly, such systems allow the earth's surface to be explored without the distorting effects of projections and to be viewed and analyzed as if working with a globe rather than a flat map.

Scale in Science

While the term "scale" may have a fairly well-defined meaning in cartography, its meaning in science generally is far more complex. As a noun, "scale" can have the sense of spatial scope or extent, and a large-scale study could be one that covers a large area of the earth's surface. But it can also have the sense of spatial resolution, much as it does to a cartographer, except that a scientist is likely to use the term in precisely the opposite sense of a cartographer, since in the broader community a small-scale study is one that examines a small area in great detail.

If extent and resolution are both measured on linear scales, then their ratio is dimensionless. The remarkable consistency of this ratio across a range of technologies—from the computer screen to paper maps to the human retina—has important implications for the design of visual interfaces to geographic data (Goodchild 2004). While the ratio of extent to resolution is typically on the order of 1000, resolution can be allowed to degrade substantially in the visual periphery, allowing services such as Google Earth to maintain high-quality displays even under rapid movement of the viewpoint, such as occurs in flight simulations. Such economies are essential if services are to be fed sufficient data over Internet connections with limited capacity.

"Scale" is one of the more pervasive terms in science, with a wide range of meanings (Quattrochi and Goodchild 1997; Sheppard and McMaster 2004). In studies focusing on the earth's surface, such as might be conducted in the environmental sciences, it can refer to the extent of the study or the resolution of the study's data, but it can also refer to conceptualizations of the dynamic processes that operate in the real world and are the focus of the study. For example, it is common to differentiate in atmospheric science between macro-, meso-, and microprocesses, each determining the changing conditions of the atmosphere at relevant scales. Macroscale processes are defined at spatial resolutions of roughly 100 kilometers or coarser, and include the fronts and cells of high or low pressure that influence daily weather patterns. Mesoscale processes include the winds that develop downslope in evening hours, coastal fog, and other phenomena that are observable at spatial resolutions of roughly 1 to 100 kilometers. Finally, microscale processes influence the atmosphere at resolutions finer than roughly 1 kilometer, and include boundary layer effects such as ground frost and urban heating. Clearly one's ability to study a process that operates at a given scale is determined by the availability of data at that scale or finer.

"Scale" is often used in science as a verb, and there has been much interest, particularly in the 1980s and 1990s, in what are known as scaling laws, or the predictable behavior of systems across scales. A phenomenon is said to be self-similar if any part can be enlarged to resemble the whole; such phenomena are said to possess fractional dimensionality, or to be fractals. Many geographic phenomena are fractals, and some of the earliest fractal studies concerned the lengths of features such as shorelines (Mandelbrot 1983).

Fractals have interested cartographers for a number of reasons. If a feature is fractal, then it is possible to predict how much more detail will be revealed if it is remapped at a finer resolution. Fractals provide an interesting approach to data compression: if a coastline is fractal, then something resembling the real thing can be regenerated from a generalized version. Fractals have also been proposed as a generic form of geographic data that can be used to test new tools (Goodchild and Mark 1987).

While the representative fraction, discussed above, directly determines the physical size of the map representation, it also determines the map's contents and positional accuracy. For example, the U.S. National Map Accuracy Standards make the following stipulation regarding horizontal positional accuracy: "For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1⁄30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1⁄50 inch. These limits of accuracy shall apply to positions of well-defined points only" (U.S. Geological Survey 1999).

The question of how to interpret "larger than" and "smaller than" has already been addressed—one assumes that in cases such as this the interpretation is the cartographic one, in other words "larger than" implies "finer than" and "smaller than" implies "coarser than."

Content is similarly determined by representative fraction, and the specifications for a national map series can run to many hundreds of pages. Detailed specifications include rules for determining features to include and to exclude, for typefaces and colors, for the generalization of features, and for the classification of land cover and land use.

Decoupling of Representative Fraction and Spatial Resolution

During the twentieth century many new technologies emerged that fundamentally changed the mapping process. Aerial photography, for example, was first developed for military applications and after World War II became a powerful source of intelligence as well as the basis of a new approach to topographic mapping based on measurement from images. Subsequently, digital technology was adopted, first as a way of improving the efficiency of map compilation and later as an end-to-end solution to the creation and use of geographic data. By the end of the century digital technology was present at some stage in virtually all aspects of map production and use. Entire new disciplines emerged, including geographic information science (GIScience), which can be defined as the study of the fundamental issues that arise from and are exploited by the use of geographic information technologies.

Photography brought a new dimension to geographic data by making it possible to enlarge, reduce, and generally rescale paper maps. The representative fraction is a perfectly satisfactory way of characterizing a map provided the medium on which it is printed remains fixed. Small stretching and shrinking of maps, due, for example, to changes in humidity and folding, have the potential to change the representative fraction slightly. But photography and xerography have the potential to change the representative fraction dramatically, as do projection devices. How, for example, should one define the representative fraction of a photographic plate, if its image could easily be enlarged and if its spatial resolution was as fine as the grain of the photographic emulsion? In the new era of aerial photography it was clear that the representative fraction could no longer serve as the primary means of characterizing a map.

Digital technology essentially replaces analog representations, or physical models, by models that encode relevant information in a binary alphabet. Much of the research conducted in GIScience since the mid 1960s can be characterized as searching for appropriate coding schemes and addresses the question "How can I capture important and useful aspects of this immensely complex planet in the binary alphabet and limited capacity of a digital computer?" The rewards are enormous, of course, in the form of technologies that store, process, and share bags of bits irrespective of their meaning and thus enjoy enormous economies of scale. Compared to paper, digital media offer numerous advantages, including reliable storage, negligible costs of copying and shipping, and powerful computational systems for analysis and modeling.

The medium on which digital data are stored, whether magnetic or optical, clearly bears no simple relationship to the paper and globes of earlier technologies. The representative fraction cannot be defined for digital media because there is no distance on these media that can be compared to distance in the real world. Instead, digital databases can be visualized at any representative fraction, whether by drawing on computer screens or on paper. Moreover, it is common for the same data to be displayed at many representative fractions, for example, by simultaneously being displayed on a laptop and projected on a screen. It is impossible for the designers of software to anticipate their dimensions. Although a graphic scale bar can be useful at times, any representative fraction shown on a computer-displayed map is misleading at best.

Two strategies emerged in response to these technological changes. Because the representative fraction had such universal significance to cartography, efforts were made to preserve it through the adoption of specific conventions. For example, it became standard practice to define the representative fraction of an aerial photograph from the dimensions of the camera's focal plane, by comparing distance on the focal plane with distance in the real world—and to maintain this fraction when the plate was later enlarged. But because the photographic plates used in aerial photography were very fine grain, the detail visible in a photograph at 1:35,000 bore little relationship to the detail visible on a map compiled at 1:35,000. In effect, representative fraction defined in this way was no longer an effective surrogate for spatial resolution, as it had been for paper maps.

By convention as well, a digital data set derived from a map could be said to inherit the map's representative fraction, since the latter was an effective surrogate for content, spatial resolution, and positional accuracy. Thus many digital data sets are described with representative fractions, despite the fact that the fraction cannot be defined for digital media. Moreover, this convention will not work for data that were "born digital." For example, a digital orthophoto is a digital image that has been rectified to appear as if every point has been observed from a point vertically above. A form of digital orthophoto that became available in the United States in the 1990s is known as a DOQQ (digital orthophoto quarterquad), and is defined as having one-meter spatial resolution and six-meter positional accuracy. Thus, an analyst who compares a DOQQ's spatial resolution to that typical of paper maps might infer an equivalent representative fraction of 1:2,000, while a colleague who calculates (as the USGS does) an equivalent scale based on positional accuracy and the National Map Accuracy Standards would infer a representative fraction of roughly 1:12,000.

In essence, the introduction of new technologies rendered obsolete the traditional role of the representative fraction as a surrogate for several indicators of quality. In the new world that is dominated by digital data each indicator is to some extent decoupled, though strong correlations remain. The need emerged for different measures of content, spatial resolution, and positional accuracy, and the task of describing scale became far more complex—but at the same time more flexible and precise.

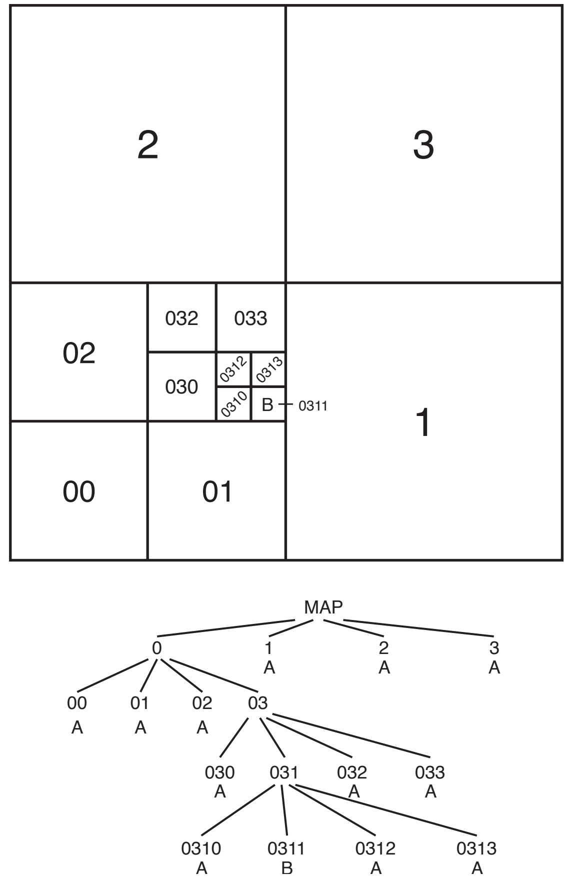


FIG. 884. A QUADTREE ILLUSTRATION.
After Paul Longley et al., *Geographic Information Systems and Science*, 3d ed. (Hoboken: Wiley, 2011), 268–69.

Multiple Representations

Since the mid-1970s the GIScience research community has devoted much attention to the simultaneous representation of the earth's surface at multiple scales. Many researchers believed that if the process of generalization could be automated, a single fine-resolution representation would suffice insofar as all coarser representations could be obtained from it by the execution of simple algorithms. In the early twenty-first century numerous applications, including Google Earth, demonstrated the importance of zooming, including the need to change scale smoothly, revealing more detail as the resolution became finer. Various approaches envisioned included "progressive transmission," whereby finer and finer detail is transmitted from server to viewer as the zoom occurs; storing data at multiple levels of resolution in a single integrated database; and real-time computation of each level of resolution from a single fine-resolution source. The first approach was widely implemented in such services as Google Earth; the second was addressed by the development of hierarchical data structures; and the third became the subject of intensive research.

Hierarchical data structures attempt to partition variation at different levels of resolution, storing the result in a single tree-like structure. In the quadtree each level of resolution differs by a factor of 2, the next finer level of resolution being defined by dividing each coarser cell into four parts (fig. 884). The quadtree concept emerged as a solution to the representation of map data at multiple resolutions in the late 1970s and achieved some success as the basis for geographic databases. In the 1990s comparable structures became the basis for virtual globes, allowing services like Google Earth to achieve a smooth and rapid zoom over several orders-of-magnitude differences in resolution. On the curved surface of the earth, however, it is impossible to achieve a regular, hierarchical tesselation of the form shown in figure 884, and only five regular solids exist with equal faces (the Platonic solids: the tetrahedron, cube, octahedron, dodecahedron, and icosahedron). Many designs for what are known as discrete global grids have emerged, and numerous criteria have been used to assess their advantages and disadvantages since all of them are to some

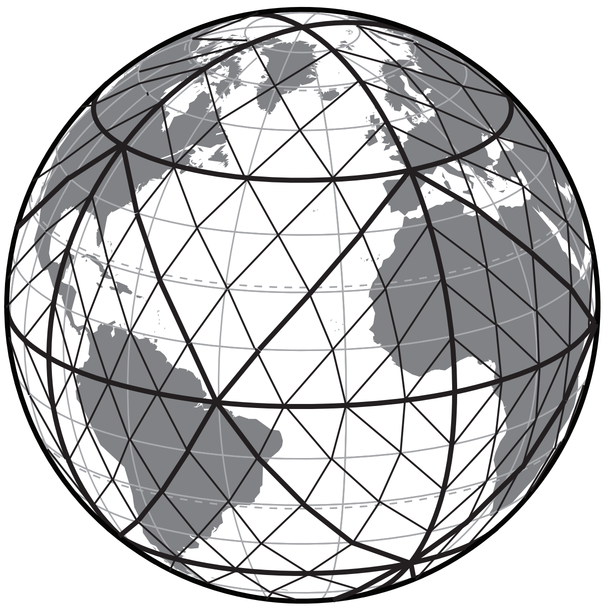


FIG. 885. DUTTON'S QTM. The earth is modeled as eight faces of an octahedron, with the vertices positioned as shown at the poles and around the equator. Each triangle is then subdivided into four smaller triangles by joining the midpoints of its edges; and the process continues to finer and finer resolution, potentially ad infinitum.

extent irregular. Figure 885 shows one such scheme, the quaternary triangular mesh (QTM) investigated by Geoffrey Dutton (1999) and others.

Summary

The concept of cartographic scale changed dramatically over the course of the twentieth century. In 1901 national mapping agencies were on the ascendancy, and it was possible to imagine that eventually the entire world would be covered by several series of maps at different and largely standard scales. Scale was expressed as the representative fraction, which acted as an effective surrogate for level of detail, positional accuracy, and content. This approach might be termed the "enlightened" phase of geographic data production and dissemination (Goodchild, Fu, and Rich 2007, 253–54).

By the end of the century the emergence of new technologies and new applications had turned this simple world upside down. No longer was the representative fraction a meaningful surrogate, and in the evolving digital world the parameter could not even be defined. A series of conventions of increasing complexity and obscurity had allowed the representative fraction to be preserved, but these eventually began to collapse under their own weight. Instead, a number of distinct and partially correlated indicators emerged to provide a multidimensional perspective.

One of the strongest reasons for moving beyond the representative fraction derived from the rapid expansion of services that made digital geographic data accessible to the general public. Services such as Google Earth were designed to be used by people who may have had no knowledge of the concept of representative fraction or its nuances. Such services needed to pass the child-of-ten test: they could be deemed to fail if a child of ten could not do something useful with them in ten minutes. Thus it is no accident that the approaches adopted by these services to convey the concept of spatial resolution avoid entirely any mention of the representative fraction. For example, Google Maps and MapQuest adopted a simple slider, with "+" indicating finer resolution and "−" indicating coarser, while Google Earth allowed the user to manipulate and display the apparent height of the viewer above the earth's surface.

Knowledge of the earth's surface resembles a patchwork, with some areas covered at fine resolution and others covered with coarser and perhaps older data, reflecting the inherent importance of knowledge about any area and the willingness of society to invest in that knowledge. As in many other aspects of the human condition, the prevailing neoliberal perspective has invaded even cartography, leading to a growing inequality in the world's mapping and a greater emphasis on economics as a driving principle. At the same time the ability of individuals to create and disseminate their own geographic data—to describe their own local world in their own terms—is growing rapidly, with the popularization of global positioning systems and collaborative online mapping services like Wikimapia.

MICHAEL F. GOODCHILD

SEE ALSO: Academic Paradigms in Cartography; Electronic Cartography: Electronic Map Generalization; Fractal Representation; International Map of the World; Metric System; Perception and Cognition of Maps: Map-Use Skills; Public Access to Cartographic Information; Standards for Cartographic Information; Tissot's Indicatrix; Topographic Map

BIBLIOGRAPHY:

Carroll, Lewis. 1894. *Sylvie and Bruno Concluded*. New York: Macmillan.

Dutton, Geoffrey. 1999. *A Hierarchical Coordinate System for Geoprocessing and Cartography*. Berlin: Springer.

Grafarend, Erik W., and Friedrich W. Krumm. 2006. *Map Projections: Cartographic Information Systems*. Berlin: Springer.

Goodchild, Michael F. 2004. "Scales of Cybergeography." In *Scale and Geographic Inquiry: Nature, Society, and Method*, ed. Eric S. Sheppard and Robert B. McMaster, 154–69. Malden: Blackwell.

Goodchild, Michael F., Pinde Fu, and Paul Rich. 2007. "Sharing Geographic Information: An Assessment of the Geospatial One-Stop." *Annals of the Association of American Geographers* 97:250–66.

Goodchild, Michael F., and David M. Mark. 1987. "The Fractal Nature of Geographic Phenomena." *Annals of the Association of American Geographers* 77:265–78.

Goodchild, Michael F., and James Proctor. 1997. "Scale in a Digital

Geographic World." *Geographical & Environmental Modelling* 1:5–23.
Levin, Simon A. 1992. "The Problem of Pattern and Scale in Ecology." *Ecology* 73:1943–67.
Mandelbrot, Benoit B. 1977. *Fractals: Form, Chance, and Dimension.* San Francisco: W. H. Freeman.
———. 1983. *The Fractal Geometry of Nature*. Updated and augm. ed. New York: W. H. Freeman.
Quattrochi, Dale A., and Michael F. Goodchild, eds. 1997. *Scale in Remote Sensing and GIS*. Boca Raton: Lewis.
Sheppard, Eric S., and Robert B. McMaster, eds. 2004. *Scale and Geographic Inquiry: Nature, Society, and Method*. Malden: Blackwell.
Snyder, John Parr. 1993. *Flattening the Earth: Two Thousand Years of Map Projections*. Chicago: University of Chicago Press.
U.S. Geological Survey. 1999. *Map Accuracy Standards*. Fact Sheet 171–99. Reston: U.S. Dept. of the Interior, U.S. Geological Survey. Online publication.
Zhang, Jingxiong, and Michael F. Goodchild. 2002. *Uncertainty in Geographical Information*. New York: Taylor & Francis.

School Atlas. See Atlas: School Atlas

Scientific Discovery and Cartography. Scientific discovery in this essay (in contrast to scientific discovery in physics, for example) refers to the finding of places on the earth or elsewhere in the universe; a place has not been discovered until it has been recorded in such a way that it can be visited or otherwise found again (Skelton 1958, 185). Discovery is typically done by deliberate exploration, although it may also include accidental discovery, which, as has been observed, often occurs when the discoverer is in the process of exploration, as, for example, Christopher Columbus's "discovery" of America in his attempt to reach Asia by a westward water route.

Methods of recording geographical discoveries include verbal description and lists of places, usually arranged alphabetically with coordinates, in gazetteers. Unlike these linear methods, maps, charts, and plans permit places to be seen in spatial relationship with other places in a global, regional, or local context (Monmonier and Schnell 1988, 1–7). Accordingly, maps (and similar devices) have been found to be efficient means of understanding relationships on the earth, parts of the earth, or other bodies (such as the moon [fig. 886] and the planets). As Marshall McLuhan observed, the map is one of a select group of communications media without which "the world of modern science and technology would hardly exist" (1964, 157–58). For this reason, maps are important not only in geography but also in archeology, astronomy, botany, geology, meteorology, and other spatially based sciences.

The surveying and mapping of the land and coasts has been undertaken since antiquity (Thrower 1999). By 1900, through the work of local, national, and colonial surveys, a large part of the land area of the earth was covered by general topographic maps. However, the resulting map series were uneven in quality and scale and varied in date. Areas not reached or mapped by the beginning of the twentieth century included the ice caps, centered on the North and South Poles, and the world's highest mountains, especially in Asia. The North Pole was claimed to have been reached by Frederick Cook (in 1908) and by Robert Peary and Matthew Henson (in 1909), and the South Pole was reached by Roald Amundsen and his party in 1911. Aerial reconnaissance followed, but in the case of the highest mountains on land, flight had preceded land ascent, which was not accomplished in the case of Mount Everest (the highest mountain on earth) until 1953 by Edmund Hillary and Tenzing Norgay. All of these events were a spur to mapmaking, but owing to world wars, which plagued the twentieth century, there was stagnation in some projects, while in others, such as maps for strategic purposes, there was greatly increased activity. Both of these trends are evident in the international multisheet map series at the scale of 1:1,000,000, the International Map of the World (IMW).

Although proposed in the last decade of the nineteenth century by Albrecht Penck, the earliest experimental sheets of the IMW were available only in the first decades of the twentieth century. Sovereign states were to be responsible for IMW sheets of their individual home countries and their colonies. A great setback came when the United States decided not to cooperate in this project. Even so, the private American Geographical Society of New York agreed to prepare all of the map sheets covering South and Central America, about one tenth of the total. Similarly, a large area of Asia called Greater India was mapped by the Survey of India, according to IMW specifications, which called for a modified polyconic projection. But by World War II the project was far from complete, and many of the sheets that had been made were out of date. Of the sheets in a projected complementary series of thematic maps, covering population, soils, geology, vegetation, and other distributions, very few were actually made.

Accordingly, another 1:1,000,000-scale project was proposed by the United States and its allies in World War II, the World Aeronautical Chart (WAC) series. A different projection (the Lambert conformal conic) and different symbolization were used for the WAC, and the coverage was quickly completed. At about the same time, the Soviet Union produced a global series of general map sheets, Karta Mira, at the scale of 1:2,500,000. In addition, individual countries produced thematic map sheets. Outstanding in this regard are the maps of the Land Utilization Survey of Britain at the scale of one inch to one mile. Through a diverse array of projects, most of earth's land areas were known and mapped by

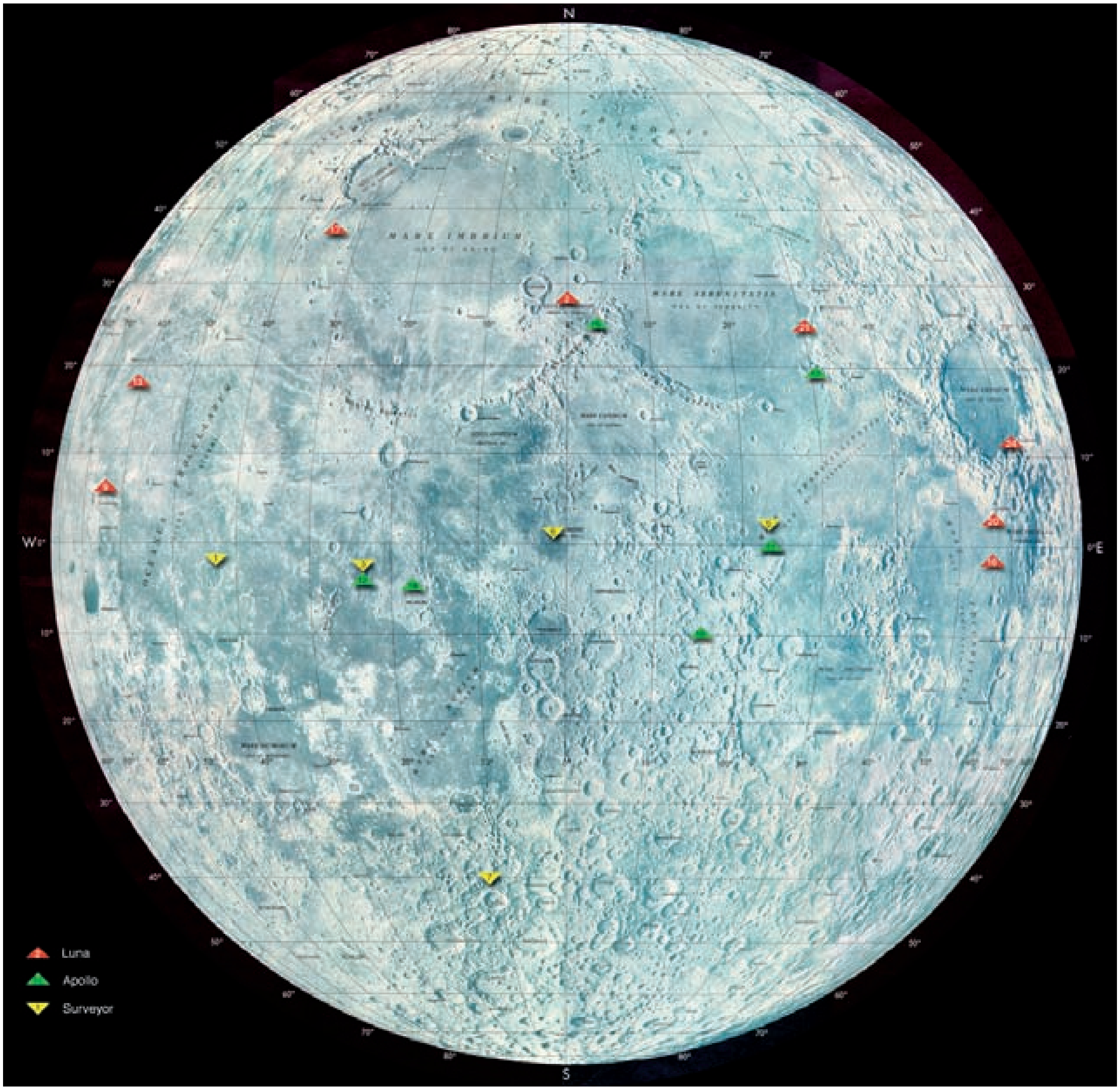


FIG. 886. LUNAR LANDING SITES MAP. Landing sites are shown for the Russian Luna missions (1959–76) and U.S. Apollo (1969–72) and Surveyor (1966–68) missions. Image courtesy of NASA Goddard Space Flight Center.

the year 2000, at least topographically and at the reconnaissance level (Böhme 1989–93).

Complementary to this map coverage are images from aerial surveys, often made with the object of producing photographs for mapping purposes (Newhall 1969). The science of photogrammetry, quintessentially a twentieth-century development, involves the making of maps from photos, typically overlapping vertical air photos. Such maps can be made faster than by ground surveys and, ideally, with greater accuracy and richness of detail. The instrument that made this possible is the binocular stereoscope, in addition to further developments such as the multiplex stereoplotter. Aerial photos, sometimes as mosaic orthophotomaps, were occasionally printed on the backs of maps (and later as separate maps) for the same area, to show such qualities as the "texture" of the landscape. Even though these mosaics could be annotated, they did not take the place of more traditional maps for many users, because their rich detail required interpretation by specialists.

Continuous surveillance images from the U.S. Landsat program and ad hoc images from the French SPOT (Système Probatoire d'Observation de la Terre) (fig. 887) and other missions extended aerial mapping activity from the 1970s onward (Lillesand and Kiefer 2000, 373–469). Although valuable, such space images held limited possibilities for stereoscopy and therefore did not replace overlapping vertical aerial photos taken closer to

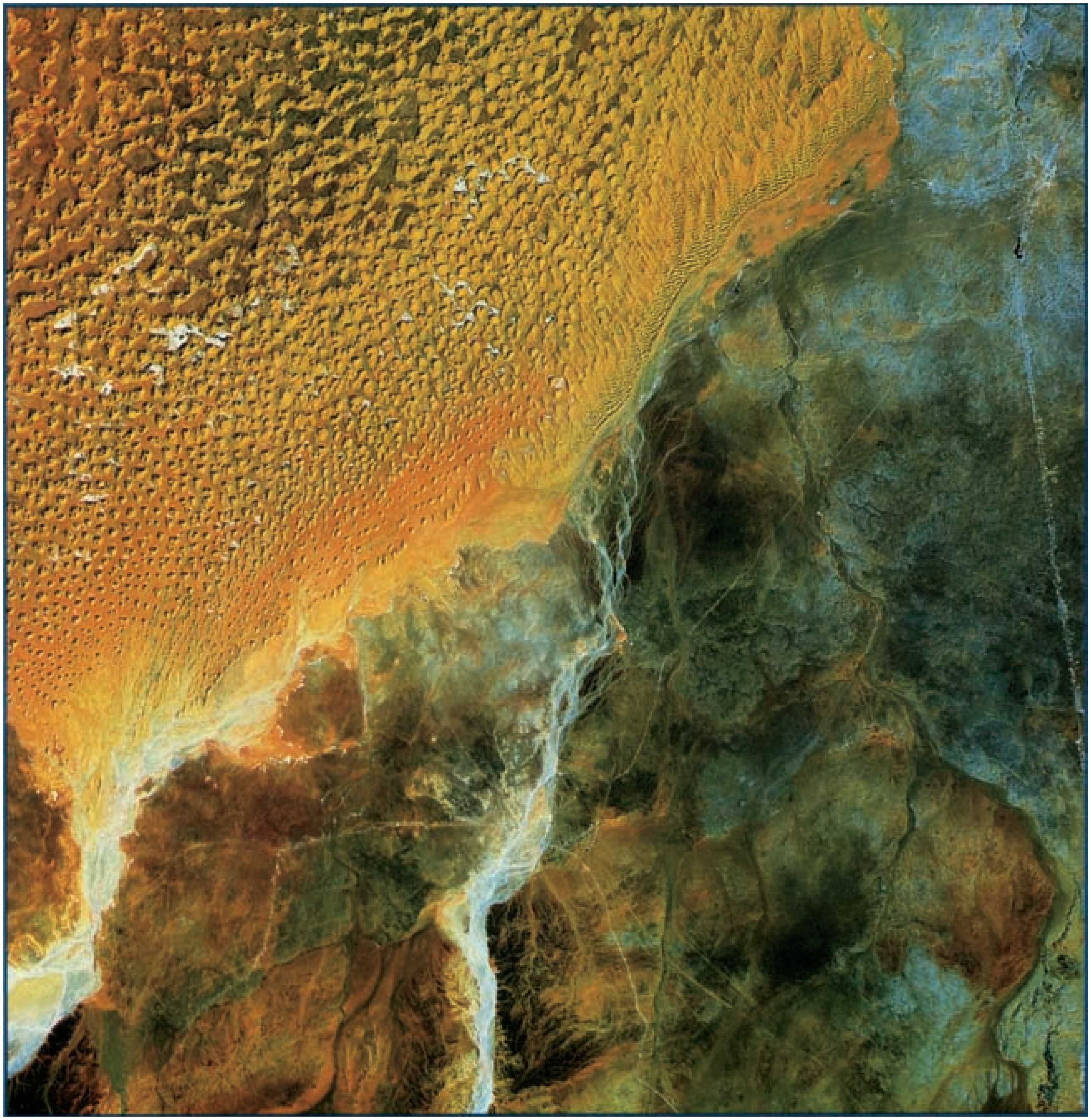


FIG. 887. LANDSAT THEMATIC MAPPER (TM) IMAGE, 1991. Created using visible and infrared portions of the spectrum showing the triangle of roads encircling the village of Shisar in southern Oman that suggested a possible location of the Lost City of Ubar.

Size of the original: 19 × 18.4 cm. From *EOSAT Landsat Data Users Notes* 7, no. 3 (1992), cover.

the earth for primary topographic mapmaking. Because of advances made in the twentieth century, including global positioning systems (GPS) and other space programs, all parts of the land surface of the earth have now been imaged and mapped, and, in this sense, discovered scientifically. Individuals can make their own terrestrial discoveries with that most ubiquitous of cartographic products, the automobile road map, produced in millions of copies in many countries of the world and widely available in the twentieth century.

The oceans and the seas, except for the coastal areas, gave up their secrets grudgingly. During the Scientific Revolution of the seventeenth century and later, attempts were made to measure the depths of the ocean basins by plumb line, without conspicuous success. In 1768 Benjamin Franklin (in collaboration with his cousin Timothy Folger) had printed in a limited number the first chart showing the Gulf Stream, a warm-water surface current in the Atlantic, and later Alexander von Humboldt mapped the surface ocean currents, warm and cold, worldwide. During the first half of the nineteenth century the American Matthew Fontaine Maury greatly advanced maritime navigation with his wind and current charts. Later, after much discussion and dissension, the International Meridian Conference, held in Washington, D.C. in 1884, approved Greenwich, England, as the global prime meridian and the center of twenty-four hourly time zones around the earth, which was almost universally adopted in the twentieth century. This was a tribute to Britain's major role in global hydrographic surveys, a consequence of which was Charles Darwin's theory of organic evolution.

In spite of all these and other scientific advances, remarkably little was known about the deep oceans until the second half of the twentieth century (Ritchie 1992). Mapping of this so-called pelagic zone awaited the development of echo sounding, or sonar, largely in the post–World War II era. Sonar permits continuous traces, or profiles, to be made across the ocean floor while a ship is in progress. By this means the crust of the earth can be imaged remotely. From a great many such traces, accurate charts of the landforms of the ocean floor could be made for the first time. These charts revealed a variety of underwater forms, as great as those on dry land, including mountains higher than Everest, individual sea mounts (sometimes volcanoes), deep canyons, and broad plateaus and plains. Arguably the greatest discovery of earth science is the presence of midocean ridges rising from the floors of the major oceans. From these it is inferred that the present continents are spreading from a single (or perhaps two) original continents. Evidence of this is provided by several features, including the morphology of the coasts, as between Africa and Brazil, and the lithology of the (postulated) formerly connected coasts, including the same rock types with the same impurities. Major credit for the theory of continental displacement, or continental drift as it is now called, goes to the German earth scientist Alfred Wegener. Although the theory was not widely accepted until several decades after his death and is now regarded as perhaps the most important concept in modern geophysics, it challenged the previously held idea of a more static earth. Two geophysicists, the British Edward Crisp Bullard and the American W. Maurice Ewing, continued this line of research, and their work was popularized by the submarine cartography of Marie Tharp (fig. 888) as well as of Richard Edes Harrison. Harrison also produced maps of surface, intermediate, and abyssal currents, which further emphasized the true three-dimensional character of the ocean basins. Prior to the twentieth century, half of the surface of the moon was better known through telescopic observations than the earth's deep oceans, suggesting that most of the world has been discovered in the last half of the twentieth century (Thrower 1999, 172–73).

Air and space was the last frontier to be scientifically investigated and delineated, although, as in case of the land and oceans, there are precedents. Although the thin and fragile envelope of the atmosphere that surrounds the earth is ubiquitous, little was known about its nature until relatively modern times. In the seventeenth century, after an experiment observing decreasing barometric pressure with elevation, Evangelista Torricelli stated that "we live submerged at the bottom of a sea of air" (Shea 2003, 33). The climbing of higher mountains and the study of meteorology was further advanced in the nineteenth century, when the Prussian Alexander von Humboldt with the French medical doctor Aimé Bonpland made the highest recorded human ascent (in the Andes) to that time. Later, with acknowledgment to Edmond Halley, who had published an isogonic chart of the Atlantic Ocean over a century earlier (1701), Humboldt applied the same principle to meteorology (Robinson and Wallis 1967). This was a map of isotherms in part of the Northern Hemisphere, which is the bellwether of the use of isometric lines in meteorology; many others, including isohyets and isobars, were invented in the nineteenth and twentieth centuries. That the dynamic patterns of storms and fronts was first appreciated during the Crimean War (1853–56) (Monmonier 1999, 43–44) underscores how much progress has been made recently in this field.

One of the most widely used cartographic products in daily newspapers and on television screens is the weather map (Monmonier 1989, 112–24). Data are received from thousands of weather stations located around the world, often at airports. Transmissions are made, in abbreviated numerical form, by radio or telephone and plotted on

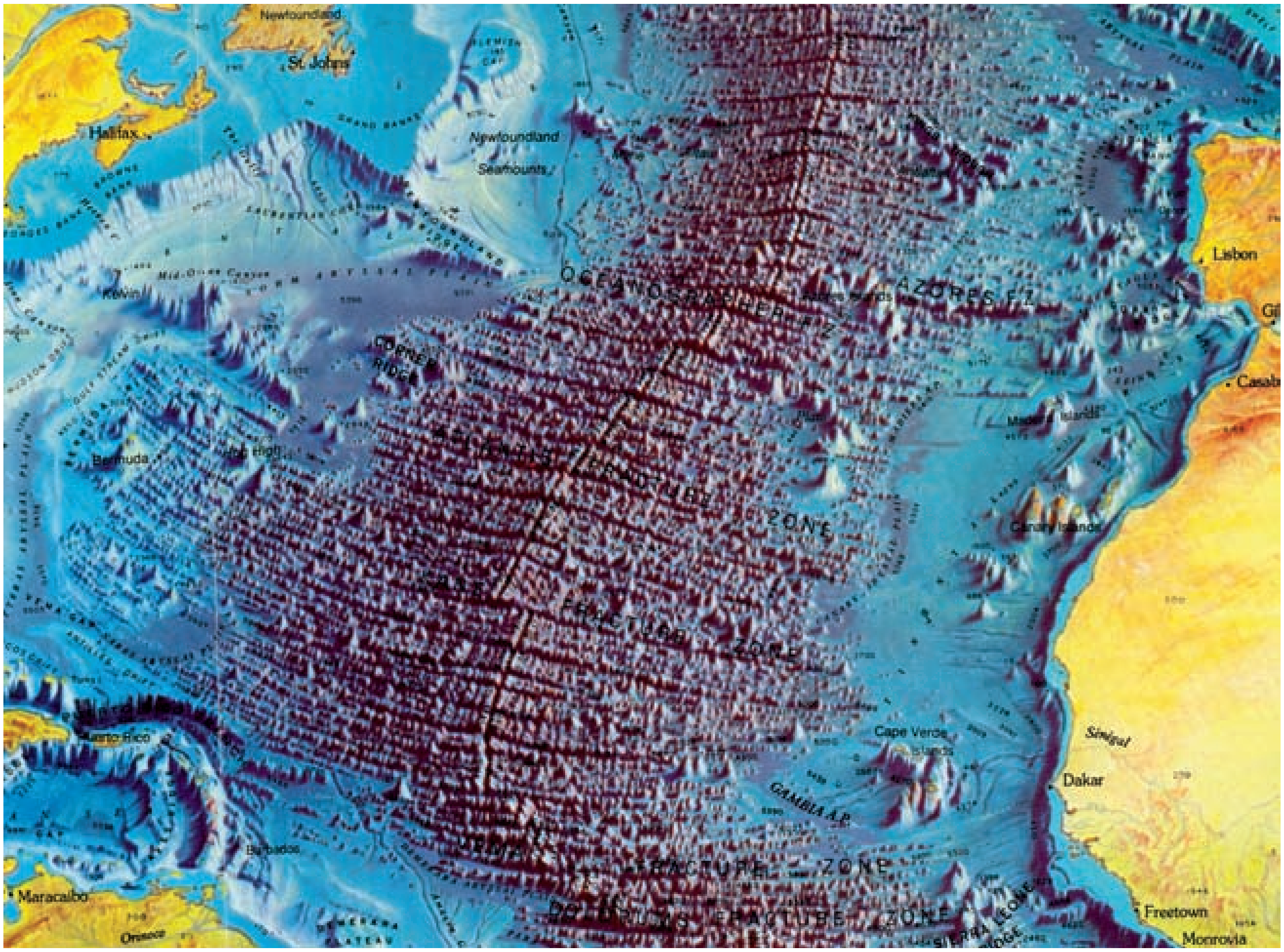


FIG. 888. DETAIL OF THE MID-ATLANTIC RIDGE FROM *WORLD OCEAN FLOOR*, BY BRUCE C. HEEZEN AND MARIE THARP, 1977.

Size of the entire original: 108 × 189 cm; size of detail: ca. 23.6 × 31.5 cm. Image courtesy of the Arthur H. Robinson Map Library, University of Wisconsin–Madison.

maps. The symbolization on these maps includes arrows for wind directions, isobars for barometric pressure, and heavier lines for fronts, differentiated as warm, cold, or occluded. Areal symbols are used for precipitation with different symbols for rain and snow. Completed maps are produced photoelectrically and relayed to stations that have machines capable of reproducing the originals. A sequential series of weather maps can illustrate the passage of pressure cells and fronts, and the growth and dissipation of storms. The resulting images (as frequent as one every three hours) can be projected, sequentially, as time-lapse "movies." This is a step toward animated mapping, which has wide appeal and is of great utility in cartography (Thrower 1961; Campbell and Egbert 1990). Patterns can be appreciated in animation that are not immediately apparent by inspection of a series of static maps. Thousands of movies have been made in which maps appear, an increasing number with animation. For example, an animated map can use time, the fourth dimension, to show an explorer's progress across Africa. One of the most important discoveries in the realm of air and space is the jet stream, which separates air masses of different atmospheric pressure. High-flying aircraft are speeded up or slowed down, depending on the direction of travel, by this dynamic phenomenon that was not discovered until the jet aircraft age (second half of the twentieth century).

One of the oldest traditions in scientific cartography is the study and use of map projections fundamental to an understanding of global relationships and discoveries. The tradition has interested some of the greatest minds in the past, from Hipparchus to Carl Friedrich Gauss. Three noteworthy twentieth-century cartographers who have contributed significantly to this field are J. Paul Goode, R. Buckminster Fuller, and John Parr Snyder. In 1923 Goode grafted lower-latitude parts of the sinusoidal projection (0°–40° N and S) onto poleward parts of the Mollweide (40°–90° N and S) to make the homolosine projection, resulting in an equal-area (equivalent) projection with the best features of both of its pre-twentieth-century ancestors. To further improve the shapes of the outlines of the continents, Goode interrupted the projection. Fuller invented the Dymaxion projection (see fig. 739), originally a cuboctahedron and later popularized as a icosahedron whereby he covered the globe with twenty equilateral triangles with a constant scale along their edges; it can be folded into a solid, globelike figure. Later, the Space Oblique Mercator (SOM) projection was proposed by Alden P. Colvocoresses and developed by Snyder, who calculated the necessary formulas to take into account earth rotation in respect to the changing ground tracks of Landsat orbits (Snyder 1993, 188–89, 196–98, 269–70). By 1964, Howard T. Fisher had developed SYMAP, a computer program that produces statistical maps using alphanumeric printers.

Twentieth-century cartographers have been the great beneficiaries of a legacy going back millennia. They are, indeed, as Isaac Newton (who postulated that the earth is an oblate spheroid) said of himself in 1676, "standing on the shoulders of giants."

NORMAN J. W. THROWER

SEE ALSO: Antarctica; Biogeography and Cartography; Climate Map; Figure of the Earth; Epidemiological Map; Geography and Cartography; Geologic Map; Geophysics and Cartography; Meteorology and Cartography; Oceanography and Cartography; Tharp, Marie

BIBLIOGRAPHY:

Böhme, Rolf, comp. 1989–93. *Inventory of World Topographic Mapping*. 3 vols. Ed. Roger Anson. London: On behalf of the International Cartographic Association by Elsevier Applied Science.

Campbell, Craig S., and Stephen L. Egbert. 1990. "Animated Cartography/Thirty Years of Scratching the Surface." *Cartographica* 27, no. 2:24–46.

Lillesand, Thomas M., and Ralph W. Kiefer. 2000. *Remote Sensing and Image Interpretation*. 4th ed. New York: John Wiley & Sons.

McLuhan, Marshall. 1964. *Understanding Media: The Extensions of Man*. New York: McGraw-Hill.

Monmonier, Mark. 1989. *Maps with the News: The Development of American Journalistic Cartography*. Chicago: University of Chicago Press.

———. 1999. *Air Apparent: How Meteorologists Learned to Map, Predict, and Dramatize the Weather*. Chicago: University of Chicago Press.

Monmonier, Mark, and George A. Schnell. 1988. *Map Appreciation*. Englewood Cliffs: Prentice-Hall.

Newhall, Beaumont. 1969. *Airborne Camera: The World from the Air and Outer Space*. New York: Hastings House.

Ritchie, G. S. 1992. *No Day Too Long: An Hydrographer's Tale*. Durham: Pentland Press.

Robinson, Arthur H., and Helen Wallis. 1967. "Humboldt's Map of Isothermal Lines: A Milestone in Thematic Cartography." *Cartographic Journal* 4:119–23.

Shea, William R. 2003. *Designing Experiments & Games of Chance: The Unconventional Science of Blaise Pascal*. Canton: Science History Publications.

Skelton, R. A. 1958. *Explorer's Maps: Chapters in the Cartographic Record of Geographical Discovery*. London: Routledge and Kegan Paul.

Snyder, John Parr. 1993. *Flattening the Earth: Two Thousand Years of Map Projections*. Chicago: University of Chicago Press.

Thrower, Norman J. W. 1961. "Animated Cartography in the United States." *International Yearbook of Cartography* 1:20–30.

———. 1999. *Maps & Civilization: Cartography in Culture and Society*. 2d ed. Chicago: University of Chicago Press.

Thrower, Norman J. W., and John R. Jensen. 1976. "The Orthophoto and Orthophotomap: Characteristics, Development and Applications." *American Cartographer* 3:39–56.

Scribing. Scribing of photographic negatives, also termed negative scribing, first became popular for map production in the 1950s, although conceived over a century earlier. Scribing involves removal of selected portions of actinically opaque coating from a transparent base layer with a sharp point or blade. Also known as the *cliché-verre* (glass-plate) technique, scribing on glass in England and France dates from 1839, the year of photography's invention (Nadeau 1989–90, 1:69–70, 2:372, 381). "Scribing" originally meant outlining wood- and metalworking patterns with sharp tools. Such patterns were duplicated photographically from scribed glass negatives in England during the 1880s (Woodward 1966, 58).

By 1900 scribing on glass had been used experimentally for maps in various European countries. Glass is ideally transparent, hard, and dimensionally stable, but fragile. Nevertheless, glass scribing was adopted after 1900 for topographic map production in several countries, including the Netherlands East Indies in 1927 (figs. 889 and 890) and the Soviet Union in 1937 (Koeman 1975, 153–54). Some mapmaking organizations revised master negatives by opaquing portions needing revision and scribing corrections in their place (Sachs 1952, 11).

General adoption of scribing in cartography came with improved materials and tools. In 1913 negative scribing on a flexible supporting material was suggested, but suitable transparent materials were not available (British patent 1143, 15 January 1913). By midcentury a number of new materials had been tried. Town plans of Zurich, Switzerland, were scribed in 1933 on coated Zellon, a noncombustible safety glass made from cellulose acetate (Koeman 1975, 154). Alternatives were thermally set plastic, vinyl, and polyester film (polyethylene terephthalate, patented 1941). The latter's toughness, flexibility, and dimensional stability soon made it the favored base material, although vinyl continued in use for ongoing projects (Moore 1975, 1–2).

Developing a good scribe coating was more difficult: transparent (for tracing a guide image) yet actinically opaque (for exposing press plates), soft and nonabrasive

FIG. 889. TOPOGRAPHIC MAP PRODUCTION BY SCRIBING ON GLASS AT THE TOPOGRAFISCHE DIENST OF BATAVIA, 1927.
From Th. J. Ouborg, "Het Reproductiebedrijf," in *75 jaren topografie in Nederlandsch-Indië* (Batavia: Topografische Dienst van Nederlandsche Indië, 1939), 61–67, facing 64.

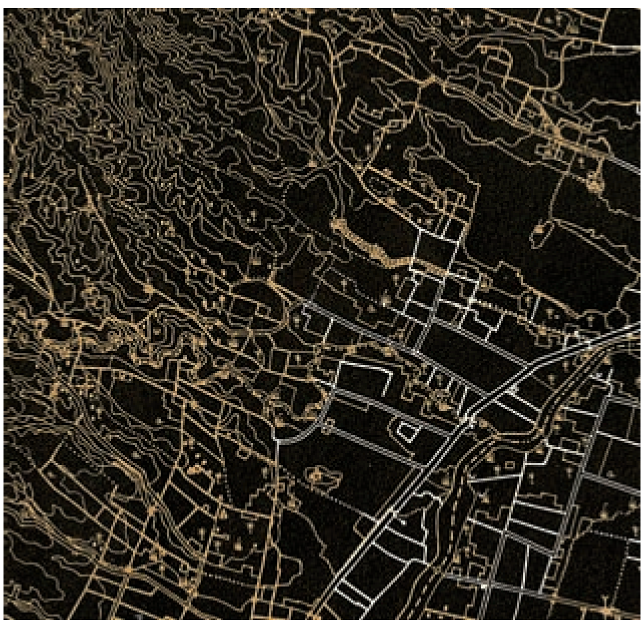


FIG. 890. DETAIL OF MAP IMAGE SCRIBED ON GLASS.
From Th. J. Ouborg, "Het Reproductiebedrijf," in *75 jaren topografie in Nederlandsch-Indië* (Batavia: Topografische Dienst van Nederlandsche Indië, 1939), 61–67, facing 63.

(for easy removal) yet sufficiently hard (for clean lines and intricate detail), and receptive to water-based photosensitizers. Mapping agencies began by coating their own sheets with whirlers, but pigment- and dye-coated plastics in yellow, rust, red, and other colors became commercially available and widely used (Moore 1975, 2).

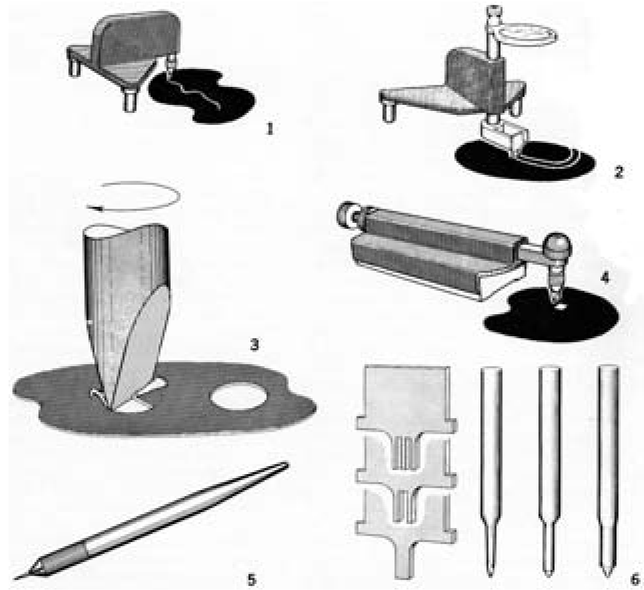


FIG. 891. TYPES OF SCRIBING INSTRUMENTS. (1) Rigid graver with point for linework, (2) swivel graver with double-line blade for linework, (3) dot graver for circular marks, (4) building graver for square marks, (5) pen-type graver for freehand work, and (6) single and multiple chisel-edged blades and needle points.
Size of the original: 12.8 × 13.8 cm. From Arthur H. Robinson, Randall D. Sale, and Joel L. Morrison, *Elements of Cartography*, 4th ed. (New York: Wiley, 1978), 366. Permission courtesy of John Wiley & Sons, Inc.

Early practitioners also crafted their own tools, such as a steel phonograph needle sharpened into a cone with a flat tip. Cheaper and more durable, these remained popular until the demise of phonographic recordings made them scarce. In their place, osmium and jewel points, as well as chisel-edged metal blades for wider lines, became available in standard sizes. Gravers ranged from handheld pen-type point holders to more elaborate self-standing rigid or swivel gravers for straight or curved, single or multiple lines (fig. 891). The gadgetry also included a turret graver holding multiple interchangeable points, dotting and building gravers, and point and blade sharpeners (Moore 1975, 3–6).

Introduced experimentally during World War II by the U.S. Coast and Geodetic Survey, scribing on plastic was promoted and adopted after the war for government use and soon spread into American commercial and academic cartography (Sachs 1952, 11–12). Glass remained in use longer in Europe (Heupel 1962, 15). Scribed lines approached the quality of copper engraving more closely than pen-and-ink drafting but were executed more quickly by less skilled lower-cost personnel. Direct negative scribing also eliminated the need to photograph drafted artwork, although putting guide images onto photosensitized scribecoat and stripping film still involved photography.

A constraint of scribing was that it was limited mainly to linework. Most lettering, point symbols, and area symbols had to be created on separate overlays. An assortment of tools and materials were developed to aid production of accompanying overlays, while precision punches facilitated their registration. Point symbols and lettering preprinted on adhesive-backed film were often applied as "stick-up" to positive overlays. Strippable film was used to make open-window masks for use when exposing percentage screen tints and negatives of area patterns. Because the scribed map was created on multiple overlays, compositing to check the map's overall content and appearance assumed critical importance. Color proofing with the Ansco Printon process, requisitioned from Germany, was introduced at the U.S. Army Map Service during World War II. Other color proofing systems were developed subsequently (Nadeau 1989–90, 1:75–76).

At the time when the computer began to invade the field of map production in the 1970s, scribing was at its zenith, and it continued in general use worldwide during the 1980s. By the late 1990s, though, its day had passed. Its epitaph in the cartographic literature of the late 1990s was the recurring praise for the high quality of the obsolescent scribed master negatives being scanned for conversion to digital technology.

KAREN SEVERUD COOK

SEE ALSO: Drafting of Maps: (1) Drawing Instruments, (2) Drawing Media; Reproduction of Maps

BIBLIOGRAPHY:

Heupel, A. 1962. "Die Bedeutung der Reproduktionstechnik für die Kartographie im Lichte neuer technischer Entwicklungen." *Kartographische Nachrichten* 12:10–17.

Koeman, C. 1975. "The Application of Photography to Map Printing and the Transition to Offset Lithography." In *Five Centuries of Map Printing*, ed. David Woodward, 137–55. Chicago: University of Chicago Press.

Moore, Lionel C. 1975. *Cartographic Scribing Materials, Instruments, and Techniques*. 2d ed., rev. Washington, D.C.: American Congress on Surveying and Mapping.

Nadeau, Luis. 1989–90. *Encyclopedia of Printing, Photographic, and Photomechanical Processes: A Comprehensive Reference to Reproduction Technologies, Containing Invaluable Information on over 1500 Processes*. 2 vols. Fredericton, New Brunswick: Luis Nadeau.

Sachs, Samuel G. 1952. "Map Scribing on Plastic Sheets versus Ink Drafting." *Professional Geographer* 4, no. 5:11–14.

Woodward, David. 1966. "A Note on the History of Scribing." *Cartographic Journal* 3:58.

Shelton, Hal. Hal Shelton was born Henry Wood Shelton Jr. on 20 June 1916 in New York State and grew up in southern California. In 1938 he graduated from Pomona College with a degree in scientific illustration. Shelton never intended to become a cartographer, but without other prospects during the Great Depression, he found temporary work with the U.S. Geological Survey (USGS) conducting plane table surveys. Thus began his affiliation with the USGS, which continued until the mid-1950s. For most of his later life he lived in Golden, Colorado, where he died on 10 November 2004.

During World War II Shelton worked as a topographic engineer mapping the western United States. Later in his USGS career he worked on assignments that used his artistic talent. He served as chief cartographic engineer for the USGS Shaded Relief Map Program. While on temporary duty with the U.S. Air Force, he designed aeronautical charts for use in the low light conditions of airplane cockpits. In 1954, Shelton redesigned the 7.5- and 15-minute USGS topographic maps. Although never adopted for publication, his innovative prototypes featured shaded relief, Kitirō Tanaka–style illuminated contours, and labels set in the Optima typeface.

Working freelance from the early 1950s onward, Shelton teamed up with Elrey Jeppesen, a publisher of aeronautical charts, to create the Jeppesen natural-color map series, Shelton's most significant contribution to cartography. The Jeppesen series of reference maps was aimed at the growing number of airline passengers. Seeking to make easily understood maps, and decrying the arbitrary and abstract appearance of conventional maps, Shelton's maps used natural colors similar to those seen on the ground by airline passengers. Beige represented arid areas, white appeared on the crests of snowcapped mountains, and dark green in forests—landcover information that was artfully merged with shaded relief (fig. 892; see also figs. 27 and 800). For Shelton, a successful map was one that any reader could grasp instantly without reference to a legend (Shelton 1985). He used an airbrush and paint brushes to apply pigments to zinc plates etched with base map information. A team of academic geographers hired by Jeppesen compiled the bases that guided Shelton's painting. Although made before the advent of satellites, the Jeppesen series proved so detailed and realistic that the National Aeronautics and Space Administration (NASA) used them to index photographs of the earth taken on early space missions. Natural color maps are now more easily made thanks to the widespread availability of satellite images and image processing software (Patterson and Kelso 2004).

In the late 1960s, Shelton ended his association with Jeppesen and started painting ski area panoramas, including one of Grenoble, France (used for the 1968 Olympics) and *Colorado: Ski Country USA*. He created illustrations for *Geology Illustrated* (1966), a text written by his brother John Shelton. Hal Shelton devoted the last two decades of his life to painting western landscapes, including a triptych titled "Canyon Lands"


FIG. 892. ITALY IN SHADED RELIEF AND IN SATELLITE VIEW. A natural-color map of Italy painted by Hal Shelton ca. 1968 (left) compared to a NASA satellite image taken in 2003 (right). (See also fig. 800.)
Left: size of the entire original: ca. 102 × 127 cm; size of detail: ca. 26.4 × 17.1 cm; image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C., H. M. Gousha Company Collections. Map © Rand McNally; R.L. 11-S-001. Right: image courtesy of Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC.

commissioned by the Geography and Map Division of the Library of Congress, which holds his original art created for the Jeppesen natural-color map series.

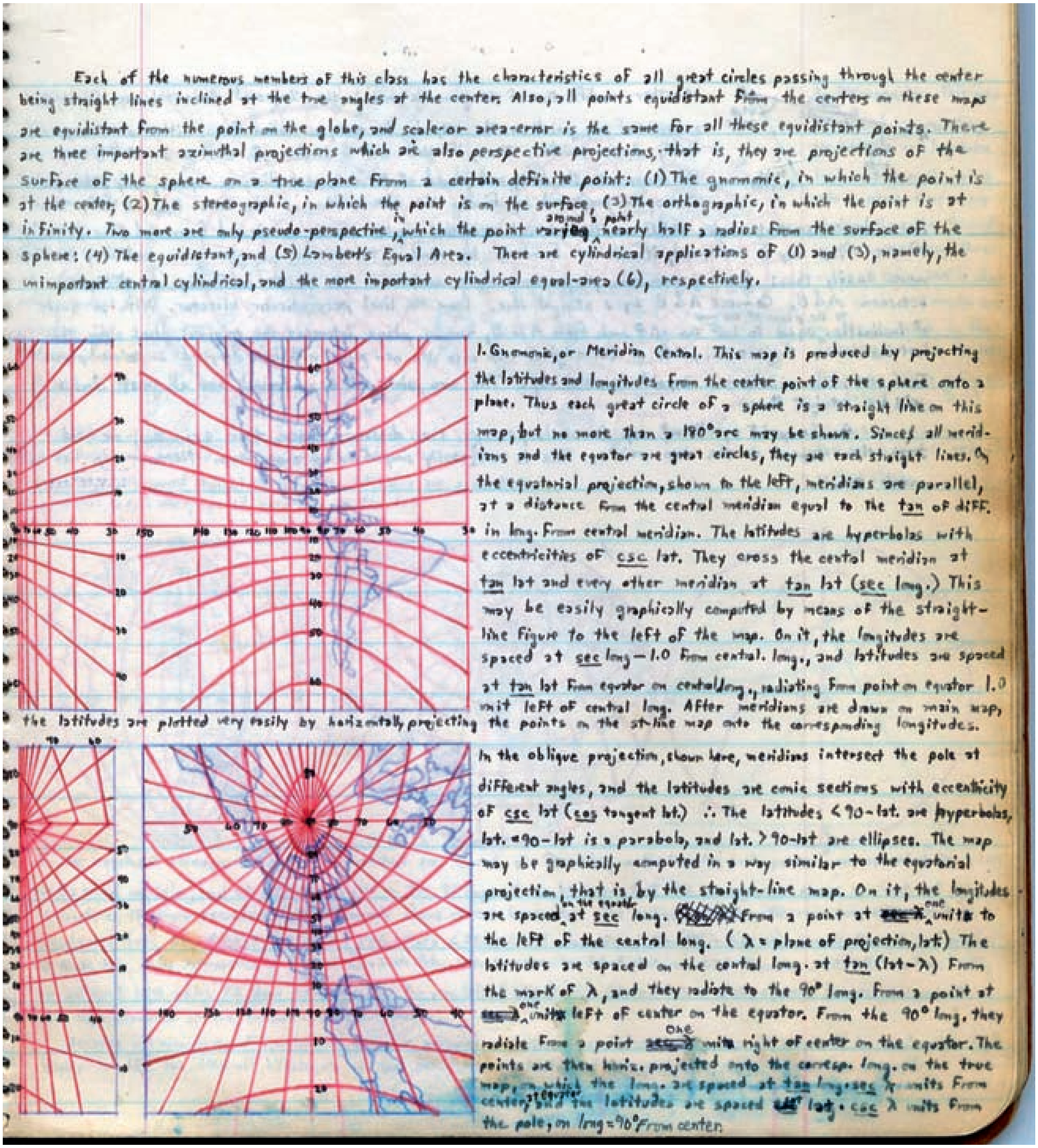
TOM PATTERSON

SEE ALSO: Aeronautical Chart; Airbrush; Relief Depiction: Relief Map

BIBLIOGRAPHY:
Patterson, Tom, and Nathaniel Vaughn Kelso. 2004. "Hal Shelton Revisited: Designing and Producing Natural-Color Maps with Satellite Land Cover Data." *Cartographic Perspectives* 47:28–55.
Shelton, Hal. 1985. Video interview conducted by Thomas K. Hinckley (Brigham Young University). Introduction by John A. Wolter, chief, Geography and Map Division, Library of Congress. Produced by the Motion Picture Broadcasting and Recorded Sound Division, Library of Congress. 51 minutes.

Snyder, John P(arr) John Parr Snyder was a talented amateur who solved one of the key problems of mathematical cartography in the twentieth century. He was born on 12 April 1926 in Indianapolis, Indiana. Snyder's work on map projections began at an early age. In 1942, when he was sixteen years old, he began collecting mathematical notes and drawings of projections (fig. 893) (Hessler 2004, 3–4; Urschel 2003). This fascination with the mathematical properties of maps and projections continued during his college years at Purdue University, where he received a degree in chemical engineering and composed several unpublished papers on the projection of surfaces (Hessler 2004; John Parr Snyder Collection, Box 11, Library of Congress). He then completed graduate work at the Massachusetts Institute of Technology.

In the late 1960s, while working as an engineer for the CIBA-Geigy Corporation, he began to pursue his cartographic interests more seriously, writing *The Story of New Jersey's Civil Boundaries, 1606–1968* (1969) and



Each of the numerous members of this class has the characteristics of all great circles passing through the center being straight lines inclined at the true angles at the center. Also, all points equidistant from the centers on these maps are equidistant from the point on the globe, and scale-or area-error is the same for all these equidistant points. There are three important azimuthal projections which are also perspective projections, that is, they are projections of the surface of the sphere on a true plane from a certain definite point: (1) The gnomonic, in which the point is at the center; (2) The stereographic, in which the point is on the surface, (3) The orthographic, in which the point is at infinity. Two more are only pseudo-perspective, in which the point ~~varying~~ around's point nearly half a radius from the surface of the sphere: (4) The equidistant, and (5) Lambert's Equal Area. There are cylindrical applications of (1) and (3), namely, the unimportant central cylindrical, and the more important cylindrical equal-area (6), respectively.

1. Gnomonic, or Meridian Central. This map is produced by projecting the latitudes and longitudes from the center point of the sphere onto a plane. Thus each great circle of a sphere is a straight line on this map, but no more than a 180° arc may be shown. Since all meridians and the equator are great circles, they are each straight lines. On the equatorial projection, shown to the left, meridians are parallel, at a distance from the central meridian equal to the tan of diff. in long. from central meridian. The latitudes are hyperbolas with eccentricities of csc lat. They cross the central meridian at tan lat and every other meridian at tan lat (sec long.) This may be easily graphically computed by means of the straight-line figure to the left of the map. On it, the longitudes are spaced at sec long − 1.0 from central. long., and latitudes are spaced at tan lat from equator on central long., radiating from point on equator 1.0 unit left of central long. After meridians are drawn on main map, the latitudes are plotted very easily by horizontally projecting the points on the st-line map onto the corresponding longitudes.

In the oblique projection, shown here, meridians intersect the pole at different angles, and the latitudes are conic sections with eccentricity of csc lat (cos tangent lat.) ∴ The latitudes < 90 − lat. are hyperbolas, lat. = 90 − lat is a parabola, and lat. > 90 − lat are ellipses. The map may be graphically computed in a way similar to the equatorial projection, that is, by the straight-line map. On it, the longitudes are spaced on the equator at sec long. [illegible] from a point at ~~sec λ~~ one units to the left of the central long. (λ = plane of projection, lat.) The latitudes are spaced on the central long. at tan (lat − λ) from the mark of λ, and they radiate to the 90° long. from a point at ~~sec λ~~ one units left of center on the equator. From the 90° long. they radiate from a point ~~sec λ~~ one units right of center on the equator. The points are then horiz. projected onto the corresp. long. on the true map, on which the long. are spaced at tan long. sec λ units from center at center, and the latitudes are spaced ~~sec~~ lat. · csc λ units from the pole, on long = 90° from center.

FIG. 893. PAGE FROM JOHN PARR SNYDER'S EARLY PROJECTION NOTEBOOKS.
Size of the original: ca. 19.7 × 17.5 cm. Image courtesy of the John Parr Snyder Collection, Library of Congress, Washington, D.C.

several papers on cartography during the Revolutionary War. In 1976 Snyder sent his first substantial work on projections to Arthur H. Robinson, editor at the time of the *American Cartographer*. The resulting publication, "A Comparison of Pseudocylindrical Map Projections" (1977), which Snyder did not expect to be published, is an example of what would become a trademark of his later publications, namely, the accurate compilation of projection literature that includes mathematical derivations and also corrects historical and mathematical errors.

Snyder began research on his most important projection, the Space Oblique Mercator (SOM) projection, after attending a 1976 conference on "The Changing World of Geodetic Science" at Ohio State University, where Alden P. Colvocoresses, cartographic coordinator for earth satellite mapping at the U.S. Geological Survey (USGS), described the geometry of the SOM. The projection had been invented for use with the newly launched Earth Resources Technology Satellite (ERTS 1), the first of a series later renamed Landsat. Colvocoresses lamented that although the geometry of projection could be described schematically, none of the scientists at the National Aeronautics and Space Administration (NASA) or at the USGS had been able to derive the differential equations necessary for its use in mapping applications (Urschel 2003). The SOM exemplified an entirely new class of projections insofar as it was not static and therefore had to account for the motion of the satellite and the earth, time becoming a projection parameter. Upon returning home to New Jersey, Snyder decided to attempt a derivation.

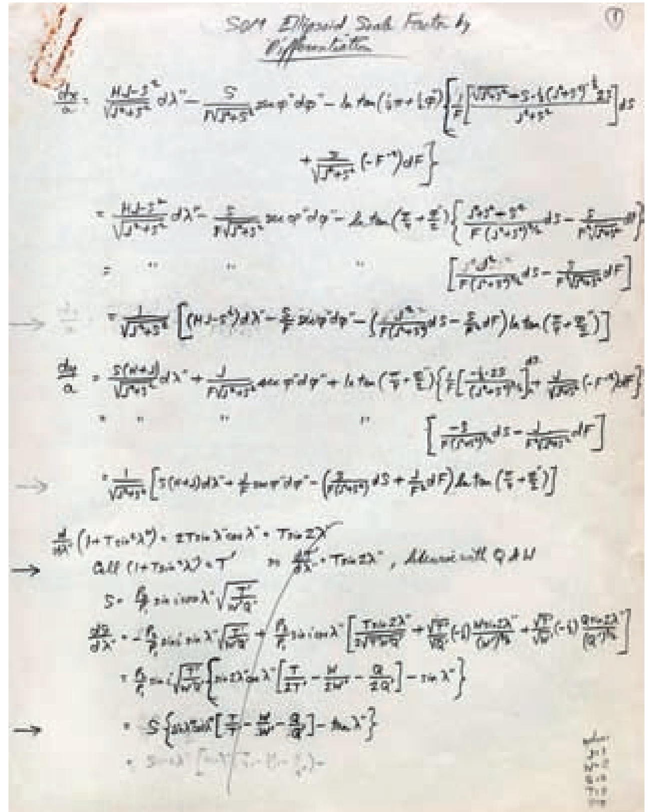


FIG. 894. NOTEBOOK PAGE SHOWING SOME ORIGINAL DERIVATIONS OF THE SOM.
Size of the original: ca. 27.6 × 21.5 cm. Image courtesy of the John Parr Snyder Collection, Library of Congress, Washington, D.C.

Snyder's initial solutions were crude formulas, calculated only for a few points on the earth (fig. 894), but after checking these derivations with his programmable calculator, he sent them to Waldo R. Tobler, a prominent academic cartographer well versed in mathematical theory (Hessler 2004, 8). Encouraged by Tobler, Snyder improved his equations, and in August 1977, just five months after he began work, he had derived a set of completed equations for the SOM (Snyder 1981). Impressed by Snyder's mathematical prowess, the USGS offered him a position, which he accepted in late 1977. The following year he received the USGS's John Wesley Powell Award for his work on the Landsat Project.

While employed at the USGS, Snyder continued to create new projections and wrote *Map Projections—A Working Manual* (1987), still in use in the twenty-first century. A talented programmer and early advocate for the use of computers in cartography, he employed many of the earliest technical programming languages and wrote *An Album of Map Projections* (with Philip M. Voxland, 1989), entirely based on the specialized FORTRAN written for the first Atari home computer. His computational methods found their way into the General Cartographic Transformation Package (GCTP), a software suite produced by the USGS that later became the basis for the commercial programs developed by Intergraph and the Environmental Systems Research Institute (ERSI).

Snyder was active in many professional organizations; collaborated with colleagues in Russia, Europe, and China; and used his writings to promote a broader international view of map projection research. He was also active in the civil rights movement in the United States and worked throughout his life on social justice issues. His career could be said to have culminated with *Flattening the Earth: Two Thousand Years of Map Projections* (1983), a comprehensive historical study envisioned early in the 1970s. During the final years of his life Snyder worked with Qihe H. Yang and Tobler on *Map Projection Transformation: Principles and Applications* (2000), which lays out the new developments in the science of projections brought on by the advent of geographic information systems and remote sensing and outlines new directions for map projection research. The book was published three years after Snyder's death on 28 April 1997.

JOHN W. HESSLER

SEE ALSO: Analytical Cartography; Projections: Cultural and Social Significance of Map Projections; Space Oblique Mercator Projection; U.S. Geological Survey

BIBLIOGRAPHY:

Hessler, John W. 2004. *Projecting Time: John Parr Snyder and the Development of the Space Oblique Mercator Projection*. Washington, D.C.: Geography and Map Division, Library of Congress.

Monmonier, Mark. 1998. "The Earth Made Flat." *New York Times Magazine*, 4 January, 33.

Snyder, John Parr. 1981. *Space Oblique Mercator Projection: Mathematical Development*. Washington, D.C.: U.S. Geological Survey.

Urschel, Donna. 2003. "Geography by the Numbers: Staff Member Solves Mystery of Mapping Equations." *Library of Congress Information Bulletin* 62:106–7.

Spatial Thinking. See Perception and Cognition of Maps

Social Theory and Cartography. Between 1900 and 2000, cartography and the institutions that sustained it changed dramatically. If eighteenth- and nineteenth-century cartography had been firmly lodged as a craft industry to prepare maps for military campaigns, national surveying, commercial and scientific exploration, and colonial administration, late nineteenth- and early twentieth-century cartography responded in more diverse ways to the changing social and technical conditions of modern life and to the emerging—and highly contested—social theories of modernity. The expansion of colonial administration continued rapidly in the early part of the twentieth century and with it the imperative to map places, people, and resources. Wars to end all wars perforated the century and with them the need to map topography in vital and pragmatic terms. Economic and urban transformation tied mapping to city and regional planning in new ways. And in the countryside, national cadastres created new opportunities for the expansion of private property regimes and for recreation and organization among the working classes. In the twentieth century, maps and mapping became an ever more central element of everyday life. This has been referred to as the geocoding of the social and natural worlds, suggesting that maps both reflect *and produce* the ways in which we understand social life (Pickles 2004).

This entry focuses on the relationship between mapping and social theory. First, it shows how cartography was a crucial element of social and theoretical struggles to define and shape metropolitan and peripheral states in the twentieth century. Far from a passive reflector, twentieth-century cartography was an active producer of new ways of viewing the world. One such spatial theory was indeed to represent the world as a given, external object of scientific representation. But this was only one of the various ways in which cartography represented social spaces. More broadly, cartography reflected and contributed to the diverse social theories of space that emerged in response to the modernization and globalization of the twentieth century. Spatial thought and practices were at the heart of these debates and struggles, and cartography was a lead technology in driving spatial and geopolitical imaginaries into the heart of modern social theory.

Second, cartography's engagement with social theory has always been a contested project aimed at defining a sociospatial logic and producing social theories of space that shaped new worlds. Recent developments in the history of cartography have begun to rethink earlier one-dimensional models of cartography as either a tool of power and state administration, what philosophers Gilles Deleuze and Félix Guattari called state science, or as a mere representational tool of science. In 1977 geographers David Woodward and J. B. Harley devised the idea of remaking the history of cartography into a thoroughly modern project that would, according to geographer Jeremy W. Crampton, "do nothing less than redefine their subject [so that maps] were to be understood not just as efficient documents recording the truth of the landscape, but as active instruments in the very production of that truth" (2004, 200). And in so doing, they examined the claims of traditional cartography to objectivity and naturalism. Such a move eventually expanded the lexicon of cartography beyond Western traditions to include indigenous and non-Western mapping traditions and institutions.

Social theory in the twentieth century was complex and contested. At its heart was the question of the Enlightenment and its relationship to representational epistemologies. The century opened with the turn from realism and naturalism to theories of everyday life, language, and practice (such as Marxism, phenomenology, ordinary language philosophy, and existentialism). The modernizing projects of national and international capitalism, imperialism, and colonialism were transforming social and economic life. In art, music, and theater the representational logics of realism were being rejected in favor of new logics of modernism (such as impressionism, expressionism, cubism, and surrealism). Maps, mapping, and cartography were often implicated in these movements, either contributing to them or reacting against them.

Discussed below are six ways in which social theory and cartography intersected, with important consequences for the understanding of the social lives of maps, mapping, and cartography.

Mapping Territory as State Science

The twentieth century opened with the expansion and consolidation of the modern nation-state, transformation of the conditions of social life in urban-industrial society, and trade and settlement networks extended to peripheral states. At the center of each of these was the deepening of what philosopher-sociologist Michel Foucault identified as the emergence of the problem of population, territory, and security, and the governance of self and others. In each of these contexts, cartography played important roles as a tool of administration and as a producer of new visual models for thinking. Geographer David N. Livingstone (2003, 163), concluded that "cartography provided rulers with administrative apparatus and imperial instruments as well as conceptual devices for comprehending and governing the world." Maps literally built countries, as historian Thongchai Winichakul (1994) and political scientist Benedict R. O'G. Anderson (1991) have shown.

Scientific surveys and mapping constituted the central technologies of land settlement—physically defining land parcels, subdividing land, and recognizing rights in land—prerequisites for colonial governance. The creation of mapping logics created spatial objects that were bounded territorially, allowing for interchangeable ownership in which space was produced and acted upon—what Anderson (1991, 175) called "map-as-logo."

Biopolitical Mapping and the Management and Administration of Populations

If mapping produced territory, it also produced the subjects of that territory, as citizen-subjects of the nation-state, racialized bodies of the colonial world, or laboring bodies, resources for work. The colonial project was thus also a project of modernity's encounter with cultural and geographical difference. Cartography too contributed to racialized science. This depended on categorizations, naturalizing racial distinctions and locating them geographically and environmentally. Maps were widely deployed in this endeavor, such as in William Zebina Ripley's maps of the races of Europe (see fig. 777) and the United States (Winlow 2006) or in Ellsworth Huntington's (1921) attempt to map and explain the racial inadequacies of Mexicans. Early twentieth-century cartography initiated a long tradition of racial science, which rendered social issues as racial and geographical problems, using naturalized racial categories and divisions in cartographic form.

Driven by national development and urban expansion at home and by commercial and colonial expansion overseas, cartography also became an essential tool of broader projects of planning and management in the twentieth century. The growing needs of settlement, infrastructure, and the management of rapidly industrializing and urbanizing states generated local demand for maps and supplied the underwriting for the training of cartographers. By 1895 the U.K.'s Ordnance Survey had completed a national set of topographic maps at twenty-five inches to the mile and, in an attempt to overcome regional duplication and rivalry, the U.S. Congress created the U.S. Geological Survey (USGS) in 1879, charging it with a variety of mapping tasks, including the production of a national map at the scale of not less than 1:250,000 (Schulten 2001, 23).

While the commercial success of these state enterprises was not assured, maps became increasingly ubiquitous in the early twentieth century. In the United Kingdom the topographic map became an important tool for working-class movements and country walking (Matless 1992). In the United States the mass production of maps was guaranteed with the commercial adoption of wax engraving by corporate cartographic enterprises like Rand McNally and Hammond Map Company.

Twentieth-century mapping produced new forms of cosmopolitanism, particularly in the United States, where many maps presented a more integrated global community centered on North America (Schulten 2001, 176). Hammond's *Pictorial Atlas of the World* of 1912 typified this emerging global commercial sensibility, using maps to enable the expansion of business operations (Schulten 2001, 179), while *Goode's School Atlas* of 1923 similarly centered on the United States as a major international political player, further aiming to deepen the sense of the United States *in* the world and the identity of Americans as global citizens (Schulten 2001, 187–95). For example, cartographer Richard Edes Harrison's maps in *Fortune* magazine broke with cartographic tradition to create architectural images of the globe in three-dimensions to render new spaces of the emerging air age, implying not only the country's strength but also a new vulnerability through the advance of technology (Schulten 2001, 214–26).

This expansion of cartographic institutions depended on market power and state authority for its funding and its status and underwrote its claims to being the objective arbiter of territorial and property boundaries. Some mappings were drawn with stunning whimsy, such as Joseph Stalin's line across Winston Churchill's *Times* map of Europe, carving up the European continent (Bohlen 1973, 152; discussion in Pickles 2004, 112–13). But even such cavalier inscriptions of boundaries were underwritten by state power to ensure their objectivity, and their effects were no less real, producing a Cold War geography that framed the entire second half of the twentieth century.

There were voices of dissent, most notably that of cartographer and librarian John Kirtland Wright, who claimed that the objectivist turn in cartography needed to consider the human and subjective nature of maps and the mapmaking and map reading processes. Maps functioned as human texts, producing and carrying cultural meaning. *Los Angeles Times* cartographer Charles Hamilton Owens similarly derided the limitations of traditional cartography and the maps it produced, arguing that such maps were inadequate to the changing geopolitical realities Americans faced in the world in light of World War II and its aftermath.

Nowhere was this emerging cartographic cosmopolitanism more directly expressed than in the attempts from 1890 to the 1970s to create the International Map of the World (IMW), and its successor project of the late twentieth century, the Global Map Project, which hoped to promote global environmentalism.

Cartesian Modernities and Cartesian Anxieties

As modern scientific cartography entered wider domains of life and science, modernist movements also called for new mapping experiments. The IMW was partly influenced by this turn to the objective and empirical, operating as a kind of twentieth-century wish image of a scientific and technical cartography that would provide objective information about the world (Pickles 1995).

This impulse was carried further by Wright, among others, as the role of mapping at midcentury took on a particular form through the justification of German war aims published by the German Library of Information in New York between 1939 and 1941. The publications of the German Library were replete with propaganda maps developed out of German geopolitics, creating a new form of persuasive cartography. Sociologist Hans Speier (1941) challenged the propaganda maps of the German Library publications, making clear that they gained their power by adapting the statistical and scientific tools of cartography to partisan ends. Without accurate data and clear mapping techniques, propaganda maps would fail (Pickles 1992). Geographer Denis E. Cosgrove (2007, 206) highlighted the link between wartime debates over U.S. participation in the war and academic debates about propaganda and scientific maps. Wright (1942, 527–28) insisted that maps represented the truth as well as maintained scientific integrity. Wright was well aware that linking social needs directly to cartography could be dangerous and required what geographer Louis Otto Quam (1943) would later articulate as "value-free" cartography. To challenge what geographer Samuel Whittemore Boggs (1947) called "cartohypnosis" and map librarian Walter W. Ristow (1957) identified as wartime journalistic maps, cartography had to be redefined as a highly specialized and standardized profession.

Thus in the 1940s, instead of focusing on the practices of mapping and the work that maps did, cartographic theory increasingly asked how its techniques could produce ever more accurate scientific maps. While cartographer Erwin Raisz's *General Cartography* (1938) outlined and defined the scope of this cartography, Arthur H. Robinson's *Elements of Cartography* (1953) argued persuasively that modern cartography was to be scientific and technical. The role of artistic questions in cartography was limited to design issues (Cosgrove 2007, 205). In this view, the task of cartography and geography was to represent the external world faithfully and accurately. Successful cartography depended on the degree to which this correspondence was achieved. Cartographic reason came to be understood as the belief that geographical or cartographic representations were direct representations of an external, independent world, and equally, the observer. In the United States, leading universities continued to pursue scientific accuracy in maps uncontested into the 1980s.

By midcentury, such cartographic theories of correspondence were influenced by new technologies of telecommunications and imagery and were increasingly explained in terms of communication theories in which information about the world was accurately transmitted (primary sense data) through a medium (the map) to a receiver (the map reader). The accuracy of the transmission of the information from the real world to the map reader was a measure of the accuracy, and hence the effectiveness, of the mapping process. Such foundational and objectivist epistemologies have variously been referred to as observer epistemologies, the "god trick" (Haraway 1988, 582), and "Cartesian Anxiety" (Bernstein 1983, 16–20), which Derek Gregory (1994, 70ff.) adapted as the "cartographic anxiety" to characterize a particular form of geographical imagination.

The Mangle of Practice and the Cartography of Networks

After World War II, mapping technologies changed rapidly, with aerial photography, satellite imagery, and increasingly powerful computers transforming the resolution, richness, complexity, and speed of the data and ideas that could be analyzed and presented. As a result, cartography's encounter with computer graphics, and later with geographical information systems (GIS), posed a serious challenge to craft cartographers and their view of accuracy and representation.

Digital cartography signaled another crisis of representation with its ability to produce an almost infinite series of maps in short order. Among early enthusiasts, there was an intense exhilaration from this proliferation of spatially referenced data and the creative potential it unleashed to map spatial relations anew. Many of these late twentieth-century techniques to visualize and interpret geographies did not necessarily correlate with physical distance or direction. Instead, modern topological cartographies emphasized connections, flows, and proximities, both on the ground—the London Underground map forgoes an accurate representation of above-ground streets in order to make the network of connections between subway stations more readable (see fig. 483)—and in virtual space, as with supply chain, telephone, or social network maps. While such maps were in use earlier, the latter half of the century saw an explosion in applications of and techniques for the interpreting of mapping topological spaces.

This explosion is linked with several major social events. World War II and the subsequent Cold War military-technology-science "mangle" helped produce graph theory and network analysis as significant fields of study within mathematics and computer science. Graph theory had its origins in the nineteenth century with Leonhard Euler, among others, but became a field of study in its own right only as part of operations research, which sought to assist wartime planners and post–World War II corporations in building more efficient supply chains and communications networks. In the 1960s and 1970s, network mappings also spilled over into transportation geography and planning.

Social network cartographies were enrolled in the service of warfare as the U.S. government attempted to probe the workings of al-Qaeda terrorist cells in the late 1990s and early twenty-first century. Activist cartographies also engaged with this network understanding, for example, the They Rule website, which allowed users to interactively map the social connections between directors of Fortune 500 corporations.

These network cartographies helped to delink cartography from physical space. Cognitive and mental mapping approaches from the 1960s and 1970s sought to humanize these spatial topologies and in turn informed new theories of map performance. Driven partly by social psychology and partly by modernist art and situationist urban movements in Europe, Kevin Lynch's *Image of the City* (1960) and later influential books by geographers Roger M. Downs and David Stea (1973, 1977) on cognitive mapping thoroughly uncoupled mapping practices from naturalist and realist social theories.

People's Cartographies

In the 1960s and 1970s the expanding ability to reproduce maps led to a rapid increase in the experimentation with and the use of maps in everyday life. Maps shaped the vision of whole earth (Cosgrove 1994), clarified the relational nature of uneven development (Kidron and Segal 1995), reframed how the natural world was seen (Wood and Fels 2008; Wood 2010), and increasingly began to adorn the dashboard, glove compartment, city directory, mobile phone, and computer screen. From *National Geographic*, to residential development, to genome mapping, to MRI (magnetic resonance imaging), to the Hubble Space Telescope, to Google Earth, the practices of mapping progressively informed and shaped daily lives.

For geographer William (Bill) Bunge and the participants in his Detroit and Toronto Geographical Expeditions, the increasing commercialization of mapping and the dominance of postwar state science led to calls for a reinvigoration of earlier forms of geographical and cartographic practice, spearheaded by an expeditionary force in which the skills of science were to be put to socially productive purposes in an unequal, segregated, and violent world. In just a few years, Bunge's mapping of inner city Detroit, his work with the Fitzgerald community (1971), and his *Nuclear War Atlas* (1988; see fig. 668) demonstrated new radical possibilities for a people's cartography committed to nothing less than participatory democratic politics. The maps were "simple," technical devices for graphically demonstrating the social injustices of nuclear weapons, urban segregation, and inner city degradation, and they began a movement that has since shaped critical cartography. As a critical understanding of the scientific turn in cartography developed, fueled in part by Denis Wood's samizdat papers taking apart every presumption of scientific and representational social theory in cartography, social movements began to develop a practice of mapping as a productive tool for building power and resistance. Public participation GIS and related techniques sought to help popular and indigenous movements use the languages and tools of cartography to make claims in courts of law or public debate (Sparke 2005; Cobarrubias and Pickles 2009).

In the late twentieth century, cartographers variously calling themselves militant, radical, or autonomist have produced and performed maps that call into question both the scientific standing of state cartography and the ontologies it reinforces. Cultural theorist Brian Holmes emerged as one of the key thinkers of new militant mapping among a proliferating group of international social movements, particularly through the Continental Drift seminar with the 16 Beaver Group. Bureau d'études was one such group operating out of Strasbourg. They mapped out the complex institutions and actors that produced particular geopolitical powers (such as the police, banking, and the European Union), and conducted the research involved in "The System" maps (see the Bureau d'études website). In gathering together knowledges from social movements from a variety of segments and countries, this type of militant cartography helped produce new assemblages of resistance, and the completed maps were similarly intended to spark new organizing strategies. Similarly, the Counter-Cartographies

Collective worked to destabilize the representational nature and fixity of scientific cartography and featured as an essential component the performance of their maps through workshops and participation in social movements.

New Cartography and the Pragmatics of Maps

For geographer Gunnar Olsson (2007, 4) the thought that mapping operated outside of rich historical traditions of symbol, myth, and meaning was unimaginable; theories of human knowledge that presumed a tabula rasa as a beginning point were deeply flawed. Instead, the drawing of a line, the creation of a boundary, and the inscription of a difference were always acts that created meaning and require interpretation. By doing these things, cartography became part of a diverse array of cultural practices and politics that was constantly producing and reproducing worlds. Such maps had interesting social lives and social theory began to read maps in terms of the lives they lived (Pickles 2004; Crampton 2004; Cosgrove 2007).

These activist social theorists produced a wide range of new cartographies and reshaped how to think about social theory and cartography beyond the twenty-first century. First, they challenged the claim that the map is a representation or a picture, instead emphasizing that the map was a system of propositions—in other words, an argument—and that it was also performative. This shift to mapping as performance opened late twentieth-century radical cartography to new alliances with artists and activists, blurring of the lines between art, cartography, and activism.

To these theorists, the map depended for its meaning and effect on various aspects of its context. As a result, maps, like literature and film, required a critical contextual reading to show how social assent is produced and reproduced (Pickles 1992). Map context became all-important. What literary theorist Gérard Genette called the paratext was further developed by geographers Denis Wood and John Fels (2008, 8–10) as the *paramap*, made up of *perimap* (the verbal and other productions that surround and extend the map) and *epimap* (other verbal and material elements on which the map depends or draws but that are not materially appended to it).

Whereas cartographers focused their attention on "the nature of maps," critical and deconstructive cartographers like Harley focused on "the new nature of maps," while others have turned instead to the ways in which mapping has facilitated the accommodation of nature in the modern nation-state (Wood and Fels 2008, 6). Such a notion of map reading was, of course, antithetical to any interpretation that saw meaning as resident in a particular map, or maps as representing or "picturing" in a one-to-one manner an external world.

The twentieth century thus closed with a challenge to the realism and naturalism with which it had opened and with mapping practice giving way to a thoroughly antifoundationalist cartography. Maps did not contain their nature or reflect an external nature. They produced natures through the drawing of lines, the addition of supplements (legends, dates, labels, symbols, etc.), and the propositional logics they embodied. In this sense, maps were vehicles for creating and conveying authority about the world, and they shaped our understanding of the world, often dominated by state-sponsored cartography. But, far from binding cartography, twentieth-century social theories opened up many possibilities for the proliferation of new cartographies and new users of maps across the social field.

JOHN PICKLES AND TIM STALLMANN

SEE ALSO: Academic Paradigms in Cartography; Harley, J(ohn) B(rian); Histories of Cartography; Persuasive Cartography; Projections: Cultural and Social Significance of Map Projections; Public Access to Cartographic Information; Societies, Geographical

BIBLIOGRAPHY:

Anderson, Benedict R. O'G. 1991. *Imagined Communities: Reflections on the Origin and Spread of Nationalism*. Rev. ed. London: Verso.

Bernstein, Richard J. 1983. *Beyond Objectivism and Relativism: Science, Hermeneutics, and Praxis*. Philadelphia: University of Pennsylvania Press.

Boggs, Samuel Whittemore. 1947. "Cartohypnosis." *Scientific Monthly* 64:469–76.

Bohlen, Charles E. 1973. *Witness to History, 1929–1969*. New York: W. W. Norton.

Bunge, William. 1971. *Fitzgerald: Geography of a Revolution*. Cambridge: Schenkman.

Cobarrubias, Sebastián, and John Pickles. 2009. "Spacing Movements: The Turn to Cartographies and Mapping Practices in Contemporary Social Movements." In *The Spatial Turn: Interdisciplinary Perspectives*, ed. Barney Warf and Santa Arias, 36–58. New York: Routledge.

Cosgrove, Denis E. 1994. "Contested Global Visions: *One-World, Whole-Earth*, and the Apollo Space Photographs." *Annals of the Association of American Geographers* 84:270–94.

———. 2007. "Epistemology, Geography, and Cartography: Matthew Edney on Brian Harley's Cartographic Theories." *Annals of the Association of American Geographers* 97:202–9.

Crampton, Jeremy W. 2004. "Exploring the History of Cartography in the Twentieth Century." *Imago Mundi* 56:200–206.

Downs, Roger M., and David Stea. 1977. *Maps in Minds: Reflections on Cognitive Mapping*. New York: Harper & Row.

Downs, Roger M., and David Stea, eds. 1973. *Image and Environment: Cognitive Mapping and Spatial Behavior*. Chicago: Aldine.

Gregory, Derek. 1994. *Geographical Imaginations*. Cambridge: Blackwell.

Haraway, Donna Jeanne. 1988. "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." *Feminist Studies* 14:575–99.

Huntington, Ellsworth. 1921. "The Relation of Health to Racial Capacity: The Example of Mexico." *Geographical Review* 11:243–64.

Kidron, Michael, and Ronald Segal. 1995. *The State of the World Atlas*. 5th ed. rev. London: Penguin.

Livingstone, David N. 2003. *Putting Science in Its Place: Geographies of Scientific Knowledge*. Chicago: University of Chicago Press.

Matless, David. 1992. "Regional Surveys and Local Knowledges: The

Geographical Imagination in Britain, 1918–39." *Transactions of the Institute of British Geographers*, n.s. 17:464–80.
Olsson, Gunnar. 2007. *Abysmal: A Critique of Cartographic Reason*. Chicago: University of Chicago Press.
Pickles, John. 1992. "Texts, Hermeneutics and Propaganda Maps." In *Writing Worlds: Discourse, Text and Metaphor in the Representation of Landscape*, ed. Trevor J. Barnes and James S. Duncan, 193–230. London: Routledge.
———. 1995. *Ground Truth: The Social Implications of Geographic Information Systems*. New York: Guilford Press.
———. 2004. *A History of Spaces: Cartographic Reason, Mapping and the Geo-coded World*. London: Routledge.
Quam, Louis Otto. 1943. "The Use of Maps in Propaganda." *Journal of Geography* 42:21–32.
Ristow, Walter W. 1957. "Journalistic Cartography." *Surveying and Mapping* 17:369–90.
Schulten, Susan. 2001. *The Geographical Imagination in America, 1880–1950*. Chicago: University of Chicago Press.
Sparke, Matthew. 2005. *In the Space of Theory: Postfoundational Geographies of the Nation-State*. Minneapolis: University of Minnesota Press.
Speier, Hans. 1941. "Magic Geography." *Social Research* 8:310–30.
Thongchai Winichakul. 1994. *Siam Mapped: A History of the Geo-Body of a Nation*. Chiang Mai: Silkworm Books.
Winlow, Heather. 2006. "Mapping Moral Geographies: W. Z. Ripley's Races of Europe and the United States." *Annals of the Association of American Geographers* 96:119–41.
Wood, Denis, with John Fels. 1992. *The Power of Maps*. New York: Guilford Press.
Wood, Denis, and John Fels. 2008. *The Natures of Maps: Cartographic Constructions of the Natural World*. Chicago: University of Chicago Press.
Wood, Denis, with John Fels and John Krygier. 2010. *Rethinking the Power of Maps*. New York: Guilford Press.
Wright, John Kirtland. 1942. "Map Makers Are Human: Comments on the Subjective in Maps." *Geographical Review* 32:527–44.

Societies, Cartographic.

Cartographic Societies in the United States and Canada. At the start of the twentieth century there were four major societies in the United States and Canada with a stated or implied interest in cartography or mapping: the American Geographical Society (AGS, founded 1851), the Surveying and Mapping Division of the American Society of Civil Engineers (ASCE, established 1852), the Canadian Institute of Surveying (CIS, founded 1882 as the Association of Dominion Land Surveyors), and the National Geographic Society (NGS, founded 1888). The next organizations to be established with cartography as a subject of interest were the Association of American Geographers (AAG, established 1904), the American Society of Photogrammetry (ASP, founded 1934), and the American Congress on Surveying and Mapping (ACSM, organized in 1941).

Each of these early organizations had interests broader than just cartography—generally geography, surveying, or engineering. In the late 1930s some individuals in the United States initiated the idea of a "national congress" on surveying and mapping (Dix 1991, 1–2). In 1941 the Committee on Surveying and Geodesy of the Society for the Promotion of Engineering Education, the Surveying and Mapping Division of the ASCE, the ASP, the Federal Board of Surveys and Maps, and the NGS sponsored a conference to launch this new organization. Attendees came from the United States, Canada, Mexico, and the Philippines, and included all U.S. government mapping agencies as well as numerous universities, commercial surveying and mapmaking firms, surveyors and mapmakers in private practice, and instrumentmakers (Dix 1991, 3). Initially called the National Congress on Surveying and Mapping, the society changed its name in January 1942 to the American Congress on Surveying and Mapping, to better reflect the fact that members were from Canada and Mexico as well as the United States. At the outset, ten regions and fourteen technical divisions were proposed. The regional divisions organized more quickly than the technical divisions. By February 1942 divisions of Surveying, Mapping, and Photogrammetric Instruments; Control Surveys; and Topographic Mapping had formed. Although a Cartography Division formed the following month, it was not notably active until 1948.

The ACSM's first publication was the *Bulletin*, which in 1944 became *Surveying and Mapping*. The ACSM enrolled its first women members in 1944. Robert H. Randall, the first ACSM president, also chaired the Cartography Commission (Comisión de cartografía) of the Pan American Institute of Geography and History (PAIGH)/ Instituto Panamericano de Geografía e Historia (IPGH) and participated in the first Consultation in Geodesy, Aeronautical Charts, and Topographic Maps, which the PAIGH sponsored. A further indication of the ACSM's international impact was an invitation to send a representative to a United Nations (UN) meeting of "experts on cartography" in 1949 (Dix 1991, 18). Invitations to participate in or collaborate with international organizations beyond the PAIGH and the UN grew, and included the CIS. Recognition on a national level came in 1950 with an invitation to consult for the Division of Geology and Geography of the National Research Council of the United States.

In 1974, the Cartography Division launched a new journal, the *American Cartographer*, with Arthur H. Robinson as editor. The journal's announced goal on its title page was "the Advancement of Cartography in All

Its Aspects." In 1990, the name was changed to *Cartography and Geographic Information Systems* to reflect technological change in the discipline. The name was changed again, in 1999, to *Cartography and Geographic Information Science* to reflect the field's increased scholarly sophistication.

By the 1980s the ACSM had three divisions: Cartography, Land Surveys, and Control Surveys. The largest division was the Land Surveys Division, whose members were primarily small businessmen. By contrast, members of the other two divisions were mostly salaried government scientists or academics. At the impetus of the Land Surveys Division, which craved greater autonomy, including the freedom to promote members' interests by lobbying the U.S. Congress, the ACSM was reorganized in February 1981, with member organizations (MOs) instead of divisions. The Cartography Division became the American Cartographic Association (ACA), the Land Surveys Division became the National Society of Professional Surveyors, and the Control Surveys Division became the American Association of Geodetic Surveying. Up until that point, each division had a board and a chairman, with the chair and an elected director serving on the ACSM board, and the presidency of ACSM rotated through the three divisions. Although presidential rotation remained intact, each MO now had its own president and other officers. In 1996 the ACA changed its name to the Cartography and Geographic Information Society.

An important contribution of the Cartography Division and its successor organizations was the inauguration of, and ongoing participation in, a long-running series of specialized conferences dealing with "automated cartography," as it was called in the 1970s. These AutoCarto events began in 1974 and have continued into the twenty-first century. Another cooperative effort was work with the AAG and the Urban and Regional Information Systems Association on conferences focused on geographic information systems (GIS) and land information systems.

The Cartography Specialty Group (CSG) of the AAG was established in 1979, a year after the AAG approved creation of special groups of members with common interests (MacEachren 1984). Committed to encouraging cartographic research, education, and map use, the group was instrumental in organizing cartographic sessions at the AAG's annual meetings. At the end of the century, the CSG sponsored or cosponsored fourteen paper sessions and two workshops at the 1999 annual meeting, held in Hawaii, on topics ranging from analytical cartography to visualization. In addition to a tradition of funding student research, the CSG, from its inception, designated a position on its board of directors for a student representative.

In 1988, the AAG recognized the Geographic Information Systems and Science Specialty Group (GISSSG). Many AAG members belonged to both specialty groups, and because of overlapping interests the two groups often sponsored joint sessions at the annual meeting. GISSSG's membership consistently exceeded that of CSG: in 1995, when GISSSG had 1,367 members, CSG's membership stood at 631. By 1999, the totals had fallen to 1,246 and 472, respectively, partly because of fewer multiple memberships.

Although the ACSM and the AAG have always had Canadian members, the primary Canadian mapping society has been the CIS. Two years after the formation of the International Cartographic Association (ICA) in 1959, the CIS applied for membership on behalf of Canada. Meetings were held over a number of years, and CIS presidents actively sought to increase participation by cartographers. These efforts eventually led to an invitation for the ICA to meet in Canada in 1972. The responsibility for Canada's membership in the ICA continued to reside with the CIS, later renamed the Canadian Institute of Geomatics (CIG). The Canadian Association of Geographers (CAG), some members of which taught cartography in Canadian geography departments, did not provide a venue for regular sessions on cartography, though some individual presentations at their conferences addressed cartographic topics (McGrath 1975, 218).

As the number of Canadian cartographers increased, other professional organizations formed to meet their needs. The Ontario Institute of Chartered Cartographers (OICC), established in 1959 primarily as a certification mechanism to help Ontario cartographers qualify for government jobs, had disbanded by the end of the century. A Canadian branch of the Society of University Cartographers (SUC), founded in the United Kingdom in 1964, formed at York University in Toronto in October 1970. It held at least one meeting, at York in 1971, but failed to survive as a distinct Canadian society (McGrath 1975, 218).

On 28 May 1975, eight people met at York University to discuss formation of an organization with broad appeal to Canadian cartographers (Gutsell 1975, 92). An inaugural meeting followed on 18 October 1975, when eighty-two registrants met in Ottawa to officially form the Canadian Cartographic Association (CCA)/ L'Association Canadienne de Cartographie (ACC). The association adopted as its journal the *Canadian Cartographer*, which had been started in 1964 by Bernard V. Gutsell. Initially named the *Cartographer*, the journal became the *Canadian Cartographer* in 1968, and was renamed *Cartographica* in 1980, when the University of Toronto Press took over its publication. Shortly after its formation, the CCA launched the newsletter *Car-*

touche, which later expanded into short articles as well as news items. Several special interest groups emerged to take responsibility for organizing sessions for the annual conferences, often held jointly with other mapping organizations. The five interest groups formed by 1990—Analytical Cartography and GIS, Cartographic Education, History of Cartography, Map Use and Design, and Map Production Technology—were still active in 2000.

Inspired by the CCA's early success, the Association Québécoise de Cartographie, also known as Carto-Québec, formed in 1976 to provide a focus for the province's French-speaking cartographers. Its journal, *Revue de Carto-Québec*, was published from 1980 to 1998. Membership, which was 170 in 1979, grew to nearly 350 by the end of the 1980s. In 1986 the association published a history that included an index to the first nine volumes of its journal; a second edition appeared in 1989. Annual conferences were held from 1979 onward, sometimes in conjunction with the CCA. This association dissolved in the late 1990s, and funds remaining in its treasury were given to the CCA to support French-language student-authored cartographic projects.

The Pacific Institute of Cartographers Society formed in the late 1970s, when automated methods started to dominate the field. It flourished in western Canada into the late 1990s, as a grassroots regional organization for people involved in mapping and drafting (Susan Haworth, personal communication, 2007). Although membership dwindled when the focus drifted away from practical activities, a remnant of the society continued through the 1990s as an endowment to the British Columbia Institute of Technology for a student award in conjunction with the British Columbia chapter of the Urban and Regional Information Systems Association (URISA).

In 1975 a National Commission for Cartography (NCC) was established with representatives from CIS, OICC, SUC, CAG, and the Association of Canadian Map Libraries to provide a fuller representation for cartographers in Canada. The CCA joined this group shortly after its formation. From 1976 to 1981 the NCC published a newsletter titled *Chronicle/Chronique* in affiliation with the Department of Geography at Carleton University. The NCC dissolved in the 1980s.

In 1980 the North American Cartographic Information Society (NACIS) formed to serve a diverse group of map librarians, map information specialists working in government offices, freelance mapmakers and small custom cartography firms, and academic cartographers, including staff cartographers in academic departments of geography. In addition to holding an annual meeting, NACIS publishes *Cartographic Perspectives*, a journal with a broad range of articles and technical material reflecting its varied membership. Map librarians joined NACIS partly because of dissatisfaction with the Special Libraries Association, parent organization of the Geography and Map Division. Other disaffected map librarians gravitated toward the Map and Geography Round Table of the American Library Association (MAGERT).

The American Society of Cartographers (ASC) was formed in 1965 by George N. James, then chief of the Louisville, Kentucky, field office of the Army Map Service for persons engaged in the field of cartography. The ASC had a strong local focus, primarily in the Louisville area, but with members in nearby Lexington as well. In 1975 a chapter in Washington, D.C., was formed, but differences of opinion on whether the organization should have a national or local focus caused the arrangement to dissolve. The organization apparently disbanded in 1994, when the military closed its Louisville mapping office.

The North East Map Organization (NEMO) was formed in the mid-1980s to promote communication among GIS professionals in government organizations within the Northeast United States. Its first meeting was held in October 1987 on the Storrs Campus of the University of Connecticut in conjunction with the fall meeting of state affiliates in the Northeast of the U.S. Geological Survey's National Cartographic Information Center. NEMO's conferences have included talks and demonstrations about the latest techniques and products in cartography and tours of facilities devoted to maps or map production. Activities in the early years of the twenty-first century included a map design competition.

As mapmaking technology advanced, other organizations with peripheral cartographic interests developed. The Association for Computing Machinery (ACM), founded in 1947 to advance information technology, developed a number of subdivisions, including the Special Interest Group on Graphics and Interactive Techniques (SIGGRAPH), which promoted development of electronic technologies relevant to cartography. URISA, established in 1963 and made up largely of planning professionals, has focused on GIS applications in urban and regional planning. AM/FM International was formally organized in 1982 to provide an educational focus on GIS as a tool for the development and management of public utilities. In 1998 the organization changed its name to the Geospatial Information & Technology Association (GITA). In contrast to the thirty-two people who attended an informal AM/FM conference in 1978, over 3,800 attended GITA's annual conference in 2000.

As a professional field or academic discipline, cartography witnessed a proliferation of societies with ever more narrow foci than the comparatively general interests of the organizations in existence in 1900. Reflecting the growth of cartography in general, some of these new groups prospered, while others atrophied. Among groups with a more distinct cartographic focus, the most prominent organizations as of 2000 were the ACSM's Cartography and Geographic Information Society (421 members), the AAG's Cartography Specialty Group (472 members), the CCA (286 members), and NACIS (519 members). Although aggregate membership might appear to have declined, trends in numbers of members are potentially misleading because in the 1980s, when job responsibilities were less specialized, membership in multiple organizations was more common than at the end of the century. Diminished numbers do not reflect reduced vigor.

ALBERTA AURINGER WOOD

SEE ALSO: Electronic Cartography: Conferences on Computer-Aided Mapping in North America and Europe; Societies, Geographical: Canada and the United States; Societies, Map; Societies, Map Librarianship; Societies, Photogrammetric and Remote Sensing

BIBLIOGRAPHY:

Bouchard, Richard. 1989. *Historique de l'Association québécoise de cartographie, 1976–1988*. 2d ed., rev. Sainte-Foy, Québec: L'Association.

Dix, Walter S. 1991. *Recollections of the American Congress on Surveying and Mapping, 1941–1991*. Comp. and ed. Jane R. Kennedy. [Washington, D.C.]: American Congress on Surveying and Mapping.

Gutsell, Bernard V., ed. 1975. "Cartographic Commentary: A Canadian Cartographic Association." *Canadian Cartographer* 12:92.

MacEachren, Alan M. 1984. "Cartography Specialty Group, Association of American Geographers." *American Cartographer*, vol. 11, supplement, p. 71.

McGrath, Gerald. 1975. "Whither Cartography in Canada: From Under- to Over-representation?" *Canadian Cartographer* 12: 217–21.

Morrison, Joel L. 1984. "American Congress on Surveying and Mapping and the American Cartographic Association." *American Cartographer*, vol. 11, supplement, pp. 68–70.

Post, J. B. 1980. "Some Thoughts on Organizations." *Bulletin*, Special Libraries Association, Geography and Map Division, no. 119:2–3.

Wood, Alberta Auringer. 1989. "Cooperation among Cartographic Information Specialists Associations." *Bulletin*, Special Libraries Association, Geography and Map Division, no. 156:2–13.

Cartographic Societies in Latin America. Cartography in Latin America during the twentieth century was carried out largely by military, geographic, and oceanographic institutes. Regional disputes, such as the war between Ecuador and Peru in the 1940s and the continuous territorial disputes between Bolivia and Chile, contributed to the lack of institutionalized cartography in the region. Internal upheavals, such as the Mexican Revolution in 1910, also hampered the development of cartographic societies and organizations. Brazil and Argentina, the region's traditional powerhouses, founded the Sociedade Brasileira de Cartografia, Geodésia, Fotogrametria e Sensoriamento Remoto (SBC), on 28 October 1958, and the Centro Argentino de Cartografía, on 23 November 1955. These are the only nonprofit civilian cartographic organizations in Latin America officially affiliated with the International Cartographic Association (ICA). The principal objective of the SBC, based in Rio de Janeiro, is enhanced cooperation between cartographic professionals and national universities with cartographic foci. To increase and disseminate cartographic knowledge, the SBC initiated the *Revista Brasileira de Cartografia* in 1979 and hosted twenty biennial cartographic conferences between 1963 and 2003. In 2000, the SBC was active in the reestablishment of Brazil's Comissão Nacional de Cartografia (CONCAR). In addition to its affiliation with the ICA, the SBC also has ties to the International Society for Photogrammetry and Remote Sensing and the International Federation of Surveyors. Similarly, the Centro Argentino de Cartografía's main objective is to contribute to cartographic research and knowledge. In 1987, it initiated a semiannual *Boletín*, focused on cartographic innovation and progress in national mapping. Based in Buenos Aires, the center has also organized national cartographic meetings, and in 2006, the SBC and the center began to plan a regional cartographic conference.

One of the principal contributors to cartographic knowledge in the Americas has been the Pan American Institute of Geography and History (PAIGH)/Instituto Panamericano de Geografía e Historia (IPGH). Founded on 7 February 1928, during the Sixth International Conference of American States in Havana, Cuba, PAIGH was headquartered from the beginning in Mexico City. PAIGH includes a general assembly, which determines its scientific, administrative, and financial policies and elects its officers, namely, the president, vice president, and secretary-general. The general assembly meets once every four years in one of the member states. The first general assembly took place in Rio de Janeiro in 1932, and the eighteenth general assembly met in Caracas, Venezuela, in 2005. Interim activities are planned and supervised by the Directing Council, which consists of the institute's officers and representatives of its member states: Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, the Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, the United States, Uruguay, and Venezuela. Permanent observer members are Spain, France, Israel, and Jamaica. (PAIGH signed an agreement of cooperation with the Organization of American States [OAS], which was formed in 1948. In 1962, following Castro's takeover of Cuba in 1959, the OAS banned Cuba from participation in OAS activities; since PAIGH had become an organ of the OAS, Cuba was excluded from PAIGH as well.)

PAIGH's directing council meets yearly in a member country. The general secretariat is responsible for all administrative aspects of the institute. PAIGH is a nonprofit organization financed by contributions of its member states and receipts from the sale of its publications. Between 1929 and 1961, it published more than 250 books, maps, and articles. In 2006, PAIGH signed a cooperative agreement with the American Geographical Society as well as a memorandum of understanding to further educational collaboration with the Association of American Geographers.

The Cartography Commission (Comisión de Cartografía) of PAIGH, established in 1941, was the first of the organization's four commissions. The seat of the commission changes every four years with the election of new officers. The commission's officers are also active in the ICA, and cooperation between ICA and PAIGH has increased since the 1990s. The Cartography Commission has six subcommittees that work on fundamental geospatial data issues, institutional support, cartographic standards, thematic applications, hydrography, and (since 1952) the annual cartographic magazine *Revista Cartográfica*. These subcommittees have changed significantly since the commission's inception because of advances in technology and changing needs of the commission. In addition to the *Revista Cartográfica*, the commission produced short movies with cartographic content during the 1950s. By the turn of the century, the journal was focusing on topics as varied as orthoimagery in Mexico, digital atlases in Argentina, the cartographic contributions of the Instituto Geográfico Agustín Codazzi in Colombia, and geodetic efforts in Venezuela.

CLAUDIA R. ASCH

SEE ALSO: Electronic Cartography: Conferences on Computer-Aided Mapping in Latin America; Societies, Map Librarianship; Societies, Photogrammetric and Remote Sensing

BIBLIOGRAPHY:

Instituto Panamericano de Geografía e Historia. 1956. *El Instituto Panamericano de Geografía e Historia: Su creación, desarrollo y programa de acción, 1929–1955*. Publication no. 206. Mexico City: IPGH.

———. 1961. *Informe quinquenal 1956–1961 del secretario general Arq. Ignacio Marquina*. Publication no. 234. Mexico City: IPGH.

———. 1978. *El Instituto Panamericano de Geografía e Historia*. Publication no. 370. Mexico City: El Instituto. In English, *The Pan American Institute of Geography and History*.

Cartographic Societies in Africa. During the nineteenth century learned societies such as the Royal Society (founded 1660), the French Société de géographie (1821), the Gesellschaft für Erdkunde zu Berlin (1828), the Royal Geographical Society (1830), the British Association for the Advancement of Science (1831), the Sociedade de Geografia de Lisboa (1875), and the Société royale belge de géographie (1876) played a decisive role in the exploratory cartography of Africa. Their role was drastically reduced after the partitioning of the continent in the late nineteenth century, when the surveying and mapping of the colonies moved from private enterprise to governmental and semigovernmental institutions, many of which operated from the colonies themselves instead of from the mother countries.

For the British dependencies the Royal Geographical Society (RGS) remained a valuable repository for the details of minor geographic explorations. The society retained its interest in the surveying and mapping of Africa, and successive officers in charge of the Geographical Section, General Staff of the British War Office served on its board. In 1909 the RGS, together with the Royal Society and the British Association, financially contributed toward the completion of the measurement of the Arc of the 30th Meridian in Uganda (Great Britain, Colonial Survey Committee 1909). During the 1920s and 1930s the Royal Society also actively participated in the British quest for the coordination of African surveys, which eventually led to the formation of the Directorate of Colonial (later Overseas) Surveys in 1946 (McGrath 1983).

The German Kolonialkartographisches Institut, founded within the publishing house of Dietrich Reimer in Berlin in 1899, carried out substantial private mapping in German East Africa, Cameroon, Togo, and German Southwest Africa before World War I. The maps were mainly route traverses, compilation maps, and cadastral drawings commissioned by private individuals and institutions. The institute was also commissioned to undertake official mapping for the German colonial authorities and produced a pioneering official map series for German East Africa and Cameroon on a scale of 1:300,000 and for Togo on a scale of 1:200,000 (Demhardt 2000).

Before World War I, most mapping operations in the Belgian Congo were restricted to the copper-rich Katanga province. From 1908 Katanga was administered by the privately managed government agency Comité spécial du Katanga (CSK). In 1919 the Service géographique et géologique (SGG) was established as a separate cartographic service within the CSK. Between the two world wars, the SGG undertook the systematic triangulation and mapping (topographic as well as thematic) of the southern part of Katanga on a scale of 1:200,000.

During the twentieth century many Anglophone countries such as Nigeria, Ghana, Kenya, Uganda, Tanzania, Zambia, Malawi, and South Africa established geographical societies, none of which played a significant role in mapping their respective countries. No cartographic societies were formed, and the interests of photogrammetrists and cartographers were taken care of by the local institutes of land surveyors, which were established by law in most countries. South Africa was an exception, however, in that the Photogrammetric Society of South Africa was formed in 1959. In the 1970s its name was changed to the South African Society for Photogrammetry, Remote Sensing and Cartography, and in the 1980s this name gave way to the South African Photogrammetry and Geo-Information Society (SAPGIS). After 2003 the development of a general awareness and knowledge of geographical information science was coordinated and promoted by the Geo-Information Society of South Africa (GISSA).

The African Organization of Cartography and Remote Sensing (AOCRS) was formed in 1988 under the auspices of the United Nations Economic Commission for Africa (ECA) to promote and coordinate member states' policies in the fields of surveying, mapping, and remote sensing. Although its name suggests a pan-African organization, AOCRS served only northern African and some central African countries during its first two decades. The only true pan-African body promoting cartography on the continent was the International Cartographic Association (ICA) Working Group "Mapping Africa for Africa," not established until 2003.

ELRI LIEBENBERG

SEE ALSO: Societies, Map Librarianship; Societies, Photogrammetric and Remote Sensing

BIBLIOGRAPHY:

Demhardt, Imre Josef. 2000. *Die Entschleierung Afrikas: Deutsche Kartenbeiträge von August Petermann bis zum Kolonialkartographischen Institut*. Gotha: Klett-Perthes.

Great Britain. Colonial Survey Committee. 1909. *The Surveys of British Africa, Ceylon, the Federated Malay States, Jamaica, Trinidad, British Honduras, Fiji: The Annual Report of the Colonial Survey Committee*, no. 608. London: His Majesty's Stationery Office.

McGrath, Gerald. 1983. *Mapping for Development: The Contributions of the Directorate of Overseas Surveys*. Monograph 29–30, *Cartographica* 20, nos. 1–2.

Cartographic Societies in Western Europe. The second half of the twentieth century can be characterized as the era of cartographic societies, at least in Western Europe. Although the Swedish cartographic society originated as early as 1908, and a precursor of the German cartographic society was formed in 1937 (it was disbanded in 1949) most European cartographic societies were founded and thrived during the second half of the twentieth century (table 46, which includes acronyms and abbreviations used in this entry).

The aim of the societies was not only to support the professional fields of cartography and of cartographers but also to provide a forum where people interested in maps and mapping could meet. The model adopted by most of the societies was that of the professional association. Exceptions were Austria, where a cartographic commission operated under the auspices of the Österreichische Geographische Gesellschaft, and Belgium, with a cartographic subcommittee of the Nationaal Comité voor Geografie of the Koninklijke Academie voor Wetenschappen, Letteren en Schone Kunsten van België. In Finland the situation was initially similar, but later the organization developed into a regular cartographic society (Suomen Kartografinen Seura). In northern Europe the professional association model came under pressure during the 1990s when several of the Scandinavian cartographic societies and also that of the Netherlands opted to merge their societies with those of professional colleagues in the related mapping sciences.

All of the cartographic societies held national meetings at least yearly. They typically operated with an internal structure of commissions specializing in specific subfields, sometimes acting as shadow commissions for corresponding International Cartographic Association (ICA) commissions. A number of them were responsible for organizing ICA conferences in London (U.K., 1964), Amsterdam (Netherlands, 1967), Stresa (Italy, 1970), Madrid (Spain, 1974), Bournemouth (U.K., 1991), Cologne (Germany, 1993), Barcelona (Spain, 1995) and Stockholm (Sweden, 1997). In addition to the references listed at the end of this essay, the many national reports produced for ICA's general assemblies from 1964 onward document the history of cartographic societies in Europe. Many national societies acted as hosts for the meetings, seminars, and workshops of ICA commissions. A European Cartographic Union was founded in 1999 but for the next decade did not organize any activities.

There was considerable intersociety cooperation. The German, Swiss, and Austrian cartographic societies usually had joint meetings and commissions and also shared a journal. They held some joint meetings with the NVK, while the latter did the same with the BCS. Societies in Scandinavia also held joint meetings. There were occasional cartographic excursions to other countries.

Because their meetings were general in content and were conducted in widely understood languages, the yearly BCS meetings (annual technical symposia) and DGfK meetings usually attracted the most foreign participants. A number of societies (such as the DGfK, NKTF, and KS) also operated on a regional level. They had local chapters whose activities were organized in parallel with the national activities: Norway had fifteen chapters, Sweden five, and Germany twenty. Elsewhere, regional activities consisted only of lecture programs held in a few locations where there were higher concentrations of cartographers.

In a few cases, membership was restricted to practicing cartographers, but most societies opened membership to professional cartographers and to people interested in maps alike. Membership categories differentiated among ordinary members, honorary members, and institutional members, the last being representatives of cartography-linked industries supporting the socie-

TABLE 46. European cartographic societies established in the twentieth century

Date	Country	Name	Comments
1908	Sweden	Stockholm Kartografiska Sällskapet	Changed later to Kartografiska Sällskapet (KS)
1937	Germany	Deutsche Kartographische Gesellschaft	Disbanded in 1949 at end of WW II
1950	Germany	Deutsche Gesellschaft für Kartographie (DGfK)	
1957	Finland	Suomen Kartografinen Seura	
1957	Netherlands	Kartografische Sectie van het Koninklijk Nederlands Aardrijkskundig Genootschap (KNAG)	Changed in 1975 to Nederlandse Vereniging voor Kartografie (NVK); merged in 2004 into Geo-informatie Nederland (GIN)
1957	Spain	Seminario Español de Estudios Cartográficos	Changed in 1977 to Sociedad Española de Cartografía, Fotogrametría y Teledetección (SECFT)
1958	France	Comité français de techniques cartographiques	Changed in 1962 to Comité français de cartographie (CFC)
1959	International	International Cartographic Association (ICA)/Association Cartographique Internationale (ACI)	
1960	Switzerland	Schweizerische Arbeitsgemeinschaft für Kartographie	Changed in 1969 to Schweizerische Gesellschaft für Kartographie (SGK)
1961	Austria	Österreichische Kartographische Kommission (ÖKK)	Part of the Österreichische Geographische Gesellschaft
1963	Italy	Associazione Italiana di Cartografia (AIC)	
1963	United Kingdom	British Cartographic Society (BCS)	
1968	Belgium	Belgisch Sub-comité voor Cartografie, Nationaal Comité voor Geografie, Koninklijke Academie voor Wetenschappen, Letteren en Schone Kunsten van België	Changed in 1995 to Belgisch Sub-comité voor Cartografie en GIS
1969	Norway	Norges Karttekniske Forbund (NKTF)	Changed in 2001 to GeoForum
1972	Denmark	Dansk Kartografisk Selskab	Changed in 2001 to GeoForum
1994	Greece	Hellenic Cartographic Society (XEEE)	

ties through their memberships. The BCS also had the special category of fellow (a blend of ordinary and honorary membership).

The programs of annual meetings consisted of either thematic sessions (like the yearly meetings of the ICA and XEEE) or more general paper sessions, like the annual technical symposia of the BCS. Special events often took the form of practical workshops on aspects of map design and techniques or evening lectures by guest speakers. The conference-type meetings (such as those of the BCS, NVK, KS, and DGfK) usually had exhibitions of cartographic material. Occasionally, for topics of wider interest, such societies held meetings in association with fellow national societies in other mapping sciences.

In almost all cases, education was cited as one of the main reasons for establishing the cartographic societies. They all contributed toward setting up professional training courses in cartography, either on a national or on a supranational basis, as was the case for the Scandinavian cartographic societies, which organized the Nordic Summer Schools in cartography. As the job market for persons with specific cartographic qualifications was always small, it was usually left to the national cartographic society to organize the relevant courses, ranging from map librarianship to remote sensing. Because of the many national languages in Europe, the potential number of participants for a particular national training course was usually small; only the courses organized by the DGfK (Niederdollendorfener Kurse) usually attracted many foreign participants. The BCS, DGfK, SGK, and NVK all sought to incorporate cartography programs at different levels into the national educational infrastructure. Some of those societies, such as the NVK, developed cartography programs on their own, often in the form of correspondence courses. Many societies published materials on careers in cartography and the requisite training programs. The BCS had a cartographic teachers group among its commissions.

As in all professional societies, there usually was some accumulation of important artifacts, which usually consisted of specially produced maps and atlases, which became part of the societies' archives, provided that they had adequate space to store them.

Most cartographic societies had commissions on education and on the history of cartography (in most cases participants in the latter formed a somewhat independent group). Cartographic techniques, automation, and geographic information systems (GIS) were also frequent commission themes. The Commission on High Mountain Cartography from the DGfK, SGK, and ÖKK worked directly with the corresponding ICA Commission on Mountain Cartography. While the ICA was producing its multilingual dictionaries, many countries had shadow commissions on terminology. Membership in the German-language commission on atlas cartography (DGfK, ÖKK, and SGK) was also open to members from a wider range of countries. The DGfK, NVK, and BCS also had map curators groups. Commission themes of Western European cartographic societies not represented among the ICA commissions were: copyright (CFC and DGfK), toponymy (ÖKK and SGK), environmental mapping (DGfK), map design (NVK and BCS), and documentation (DGfK and CFC). In the Netherlands the NVK's commission on map use had a special subsection on bicycle maps that produced and tested out specifications for them.

Many of the societies mentioned here promoted both the professional standing of their members and the standards of their profession by awarding prizes. The financial responsibility for the prizes was often borne by larger cartographic companies. Most of the societies also maintained a fund from which specific expenses, such as financial support for young cartographers to attend the ICA meetings, were to be paid.

In some countries, like Denmark, Norway, and Sweden, the cartographic societies also acted as groups lobbying to standardize, streamline, or otherwise influence current national mapping programs and make them more effective in answering current needs. The NVK was instrumental in starting up a geoinformation center. Although research in cartography was mostly left to the universities, more applied aspects were also dealt with within the cartographic societies: in the United Kingdom the BCS has a research committee.

The Deutsche Kartographische Gesellschaft published a yearbook, *Jahrbuch der Kartographie* (edited by Edgar Lehmann, 1941–42). From 1951 onward its successor, the DGfK, published the journal *Kartographische Nachrichten* and from 1961 onward also published the proceedings of its training courses in Niederdollendorf and Königslütter. The DGfK was also responsible for initiating the *Bibliotheca Cartographica* series (1957–72), an international multilingual bibliography of cartographic literature (published annually since 1974 as *Bibliographia Cartographica* by K. G. Saur) (Bosse 1970, 146–48). All other societies listed above published cartographic journals as well (table 47 lists some major twentieth-century journals associated with Western European cartographic societies). Many societies regularly published directories with membership lists, such as the *Kartographisches Taschenbuch* (DGfK), and also published occasional papers. Among the latter were publications such as guides to national map collections, directories of small cartographic companies, and instructions for obtaining required maps or geospatial information. Toward the end of the century, contacts were maintained increasingly through websites or by discussion lists or listservs on specific subjects (Matthews 1998).

Parallel with the mainstream cartographic societies, more specialized societies developed in some countries. The Society of University Cartographers (later renamed the Society of Cartographers) was founded in 1964 in the United Kingdom by practicing cartographers. The Charles Close Society, founded in 1980 in the United Kingdom for the study of Ordnance Survey maps, had a historical focus, as did Chartarum Amici, founded in 1964 in Finland. The Brussels International Map Collectors' Circle, founded in 1998 in Belgium, served as a forum for collectors of maps and atlases, map historians, and professionals in the antiquarian map trade. In some countries separate geographic information societies developed, like the Association for Geographic Information in the United Kingdom (Blakemore 1994).

Because of the relative nearness of Western European countries to one another, many of the ICA initiatives were realized largely through the cooperation of their cartographic societies. Examples were the international *Multilingual Dictionary of Technical Terms in Cartography* (1973) and the manual series *Basic Cartography for Students and Technicians*, which contained sets of exercises printed by various Western European member states (with help from Hungary and East Germany). The national societies also produced national reports for the ICA general assemblies, sent in maps for exhibition at its international cartographic conferences, and proposed officers for the ICA and members for the ICA commissions. During the second half of the twentieth century in Europe, cartographic societies not only contributed significantly to the progress of cartography within and between European countries but also multinationally through the ICA.

FERJAN ORMELING

TABLE 47. Twentieth-century Western European cartographic journals

Name	Date	Country
Tidsskrift for Det norske Utskiftningsvæsen	1908–51	Norway
Norsk tidsskrift for Jordskifte og Landmåling	1952–69	
Kart og Plan	1970–	
Kartographische Nachrichten	1951–	Germany
Kartografie: Mededelingen van de Kartografische Sectie van het Koninklijk Nederlands Aardrijkskundig Genootschap	1958–74	Netherlands
Kartografisch Tijdschrift	1975–2003	
Geo-Info: Tijdschrift voor Geo-informatie Nederland	2004–	
Bulletin du Comité français de techniques cartographiques	1958–62	France
Bulletin du Comité français de cartographie	1962–2001	
Le Monde des cartes	2002–	
Bollettino dell' Associazione Italiana di Cartografia	1964–	Italy
Cartographic Journal	1964–	United Kingdom
Bulletin of the Society of University Cartographers	1966–90	United Kingdom
Bulletin of the Society of Cartographers	1990–	
Sheetlines (journal of the Charles Close Society)	1981–	United Kingdom
Tidsskrift for Dansk Kartografisk Selskab	1983–95	Denmark
Kartbladet	1985–2002	Sweden
Kartbladet och Bildtechnik	2003–	
Geoforum Perspektiv	2002–	Denmark

SEE ALSO: Electronic Cartography: Conferences on Computer-Aided Mapping in North America and Europe; Societies, Geographical: Europe; International Cartographic Association; Societies, Map; Societies, Map Librarianship; Societies, Photogrammetric and Remote Sensing

BIBLIOGRAPHY:

Blakemore, M. J. 1994. "The Association for Geographic Information, Five Years On." In *The 1994 European GIS Yearbook*, ed. Peter J. Shand and Peter J. Ireland, 223–25. Oxford: NCC Blackwell and London: Hastings Hilton.

Bosse, Heinz, ed. 1970. *Deutsche Kartographie der Gegenwart in der Bundesrepublik Deutschland*. Bielefeld: Selbstverlag der Deutschen Gesellschaft für Kartographie.

Carson-Clarke, [A.], et al. 1989. "The SUC: 1964 to 1989." *Bulletin of the Society of University Cartographers* 23:1–4.

Laureti, Lamberto. 1989. "L'Associazione Italiana di Cartografia e il suo contributo scientifico e culturale nei primi venticinque anni di attivita." *Bollettino della Associazione Italiana di Cartografia* 77:63–67.

Leibbrand, Walter, ed. 1984. *Kartographie der Gegenwart in der Bundesrepublik Deutschland '84*. 3 vols. Bielefeld: Selbstverlag der Deutschen Gesellschaft für Kartographie.

Matthews, Fiona. 1998. "The Website of *The* British Cartographic Society." *Cartographic Journal* 35:89–90.

Neupert, Anita, and Ulrich Freitag, eds. 2000. *50 Jahre Deutsche Gesellschaft für Kartographie e.V*. Kartographische Schriften 5. Bonn: Kirschbaum.

Pelletier, Monique. 2006. "Créations du CFC et de l'ACI." *Le Monde des Cartes* 188:41–42.

Shirreffs, W. 1991. "The British Cartographic Society, 1987–1991." *Cartographic Journal* 28:105–7.

Cartographic Societies in Eastern Europe. Civil society in Eastern Europe developed at a much slower rate than in the western part of the continent. In the first half of the twentieth century, different cartographic activities were covered by separate organizations, usually according to the scale or primary function of the work. Large-scale mapping was attached to geodesy, land survey, and cadastre, while small-scale maps traditionally belonged to geography. The production of medium-scale topographic base maps was reserved for the military. The social structure of cartographers followed this division. As the disciplinary status of cartography remained vaguely defined, for most of the century cartographic societies in Eastern Europe were neither independent nor representative, although some professional organizations existed in nearly all the countries in the region.

After World War II the Soviet political and economic system was adopted in Eastern Europe, and the historically strong relationship with geography was transferred to cartography's affiliation with geodesy. The socialist states controlled the institutional development of the mapping field, including the activities of the newly founded professional societies.

Following Europe's social transformation after 1991, many of the former professional organizations changed or disintegrated. In a few Eastern European countries cartographic groups became independent societies, but in most cartography remained a cross-disciplinary field between land surveying and geography. By the end of the century, cartography was strongly tied to the rapidly growing field of geoinformatics.

For example, the Hungarian Geodéziai és Kartográfiai Egyesület was founded in 1956. A cartography section existed from the beginning, but its activities were dominated by topics related to cadastral mapping and surveying. Subsequently, technical developments in remote sensing led to its inclusion in the new name of the society, Magyar Földmérési, Távérzékelési és Térképészeti Társaság. In addition to regular lectures and seminars for professionals and the public, the society has published the bimonthly periodical *Geodézia és Kartográfia* since 1955. Small-scale and thematic mapmaking is represented by other academic organizations, mainly the Hungarian geographical society, Magyar Földrajzi Társaság, founded in 1872.

Geography played a more dominant role in Poland, where the Polish geographical society, Polskie Towarzystwo Geograficzne (PTG), organized a geodesy section in Warsaw in 1964 (from 1966 the section became a commission). In 1999 it was transformed into an independent division, and in 2000 the name became the PTG Komisja Kartograficzna. The PTG and the Polish cartographical publishing house jointly publish the quarterly journal *Polski Przegląd Kartograficzny*. The association of Polish cartographers, Stowarzyszenie Kartografów Polskich, founded in Wrocław in 1999, organizes professional conferences and (since 2000) a national map contest.

The Czechoslovak committee for cartography was founded in 1964; it split after the division of the country in 1993. In that year in Slovakia the Kartografická spoločnosť Slovenskej Republiky was founded in Bratislava, and at the same time a similar organization, Kartografická společnost České Republiky, was established in Prague. The Czech union of surveyors and cartographers, Český svaz geodetů a kartografů (ČSGK), an independent association, publishes the journal *Zeměměřického věstníku*. The Lithuanian surveyor's association, Lietuvos matininkų asociacija (LMA), dates to 1994 and engages in cartographic activities, and the Lithuanian cartographic society, Lietuvos kartografų draugiją, was established in 2002. The Ukrainian association of geodesy and cartography, Ukrayins'ke tovarystvo geodeziyi i kartografiyi, was established in 1991.

The Romanian cartographic society, Asociaţia Română de Cartografie, was founded in 1990 in Bucharest, but its activities diminished. Recently, it was suggested that it follow the general trend and extend the scope of the society to include cartography and geographic information systems. The Yugoslav Association of Cartographers, the cartography section of the Association of Geodetists of Montenegro, and the Albanian Society of Geodesy, Cartography and Photogrammetry, are all based at universities in Belgrade, Podgorica, and Tirana, respectively. In 1991 the Croatian chapter of the Society of the Yugoslavian Land Surveyors became independent and a new cartographic society was founded in 2001, Hrvatsko kartografsko društvo (Tutić 2002).

ZSOLT G. TÖRÖK

SEE ALSO: Electronic Cartography: Conferences on Computer-Aided Mapping in North America and Europe; Societies, Geographical: Europe

BIBLIOGRAPHY:

Ostrowski, Jerzy. 1993. "Komisja Kartograficzna (1964–1993)." In *Polskie Towarzystwo Geograficzne w siedemdziesiątą piątą rocznicę działalności*, ed. Teresa Kozłowska-Szczęsna, Jerzy Kondracki, and Wojciech Stankowski, 47–62. Warsaw: Polskie Towarzystwo Geograficzne, Zarząd Główny.

Szabó, Béla, and Sándor Zsámboki, eds. 2006. *Emlékkönyv a Magyar Földmérési, Térképészeti és Távérzékelési Társaság megalakulásának 50. évfordulója alkalmából (1956–2006)*. Budapest: MFTTT.

Tutić, Dražen. 2002: "Foundation of Croatian Cartographic Society = Osnovano Hrvatsko kartografsko društvo." *Kartografija i Geoinformacije* 1:168–69.

Cartographic Societies in Australia and New Zealand. The Mapping Sciences Institute, Australia (MSIA), originated as the Australian Institute of Cartographers in 1952. MSIA aims to advance cartography as a profession and create an adequate force of professionally trained cartographers. The first biennial conference was held in Sydney in 1974. In November 1995 the name became Mapping Sciences Institute, Australia. The society's Victoria and Queensland branches have infrequently held joint conferences with the Australian Map Circle. Its journal was *Cartography* (1954–2003). In 1964, MSIA became a national member of the International Cartographic Association.

The Surveying and Spatial Sciences Institute (SSSI) was created on 30 April 2009 by merger of the Spatial Sciences Institute (SSI) and the Institution of Surveyors, Australia (ISA). Prior to this, the Australasian Urban and Regional Information Systems Association (AURISA), the Remote Sensing and Photogrammetry Association of Australasia (RSPAA), and the Institute of Engineering and Mining Surveyors Australia (IEMSA) joined to form the SSI in April 2003. Their semiannual publication is the *Journal of Spatial Science*, which is jointly published with the MSIA. It embraces the former journals *Cartography*, the *Australian Surveyor*, and *Geomatics Research Australasia*. A quarterly *Spatial Science* magazine and a biweekly E-newsletter, *Spatial Matters*, are also issued. SSSI has five commissions, one of which is Spatial Information and Cartography (SICCom).

The Australian and New Zealand Map Society (ANZMapS) was established by merger of the Australian Map Circle (AMC) (1973–2009) and the New Zealand Map Society (NZMS) (1977–2008). The merger was approved on 15 March 2009 at the AMC annual general meeting; the NZMS approved the merger on 18 October 2008. Publications are the *Globe* (the AMC semiannual peer-reviewed journal) and the online *Newsletter*. The newsletter *Datum* ceased publication with the September 2008 issue, as did the *New Zealand Map Society Journal*. The AMC was established initially as the Australian Map Curators' Circle. In 1983 it dropped "Curators'." The NZMS was established as a subgroup of the New Zealand Cartographic Society, from which it became independent in 1987. Both societies' aims were to promote communication among those making, collecting, and using maps.

The New Zealand Cartographic Society, organized in 1971, is open to all interested in studying, producing, and using maps. Its aims are to promote and encourage cartography; inform the public of the role of cartography; conduct discussions, seminars, and lectures; actively investigate advances in cartography; and establish and maintain contacts with similar organizations world wide. Its journal was published from 1971 irregularly and discontinued in 1996. The quarterly newsletter *Cartogram* was introduced in 1975. Conferences continued to be held into the twenty-first century. The conference abstracts, papers, and presentations are issued as *GeoCart Proceedings*.

DOROTHY F. PRESCOTT

SEE ALSO: Societies, Map Librarianship; Societies, Photogrammetric and Remote Sensing

BIBLIOGRAPHY:
McCarthy, J. E. 1988. *Mapmakers of Australia: The History of the Australian Institute of Cartographers*. [Melbourne: The Institute]
Prescott, Dorothy F. 1983. "Direction Finding—Whither the Australian Map Curators' Circle." *Globe* 19:4–8.

Societies, Geographical.

Geographical Societies in Canada and the United States. Learned societies have long been indispensable centers of geographic activity. As unbiased arbiters supportive of others' endeavors, including efforts concerned with local or regional circumstance, they have at least indirectly fostered cartography and mapping. Although these organizations became more numerous (and more narrowly specialized) in the twentieth century, their efforts to stimulate public interest in things geographic began much earlier.

Geographers became a small part of the early intellectual groups that formed in North America. The American Philosophical Society was founded in 1743, and the American Academy of Arts and Sciences in 1780. Jedidiah Morse, Alexander von Humboldt, Carl Ritter, and Arnold H. Guyot—all identifiable as geographers—were among the American academy's early members. In 1848 the American Association for the Advancement of Science was formed, and in 1863 the National Academy of Sciences was established, with Guyot, Raphael Pumpelly, and George Davidson among its early members. It was from the geologists and natural scientists of these groups that American geography emerged.

The first anglophone American geographical society was the American Geographical and Statistical Society of New York, founded in 1851 and renamed the American Geographical Society of New York (AGS) in 1871. The AGS and the National Geographic Society (NGS), founded in 1888, were the two earliest and largest societies in the history of American geography. Both of these associations employed and otherwise engaged writers, editors, cartographers, draftsmen, and other scholarly operatives of national standing.

A number of smaller societies began to emerge, frequently with local or regional interests at the fore. In 1876, the Appalachian Mountain Club was founded with the express intention of encouraging travel in and study of the Appalachian mountains. The club mapped the White Mountains and constructed maps, paths, camps, and refuges. It came to be regarded as the parent society of park commissions and acted as trustee of public reservations in Massachusetts and elsewhere. Eight years later, in the wake of notable climatological works by Samuel Forry, Lorin Blodget, James H. Coffin, and others, the American Clinical and Climatological Association was founded. Its initial concern was with diseases plausibly cured by residence in a suitable climate or by bathing therapy, typically at spas with mineral-rich waters. In the next three or four decades the study of such relationships was popular with a number of geographers.

In 1881, on the other side of the country, the Geographical Society of the Pacific was founded. George Davidson, then a force in oceanographic studies at the University of California at Berkeley, was elected its first president. The society met regularly and occasionally published its *Transactions and Proceedings*. Ten years later, in 1891, the Geographical Society of California was established. David Starr Jordan was made president. Although only two numbers of the *Bulletin of the Geographical Society of California* were ever published, the society established a library, sponsored lectures, and promoted discussion of geographic topics.

The Sierra Club was organized in San Francisco in 1892 to facilitate both travel in and understanding of the mountain regions of the Pacific Coast and to preserve the forests and natural beauty of the Sierra Nevada

Mountains. John Muir, its first president, arranged annual sorties into Sierra wilderness. The club grew quickly to a membership of 500 persons.

Farther north on the Pacific Coast, the Mazamas were organized on 19 July 1894. Named after what early writers called various American ruminants (supposedly the Rocky Mountain goat), the group offered charter membership to anyone who climbed the 11,225 feet to the summit of Mount Hood on the official day of its founding. One hundred and ninety-three people scaled the mountain, and 105 joined as charter members. The group's main activities have been mountain exploration, mapping, and discovery.

On the east coast the Geographical Club of Philadelphia was founded in 1891, and renamed the Geographical Society of Philadelphia in 1897. The society soon had 500 members on its register and was led by the very able Angelo Heilprin. Its purpose was to advance both exploration of the planet and the science of geography. The society sponsored public lectures by nationally known geographers; published a quarterly *Bulletin* from 1898 to 1933; and established gold medals in the names of Elisha Kent Kane, Henry G. Bryant, and Heilprin. The society published its history in 1960 (Peary 1960).

The Alaska Geographical Society was organized in Seattle, Washington, in 1898. Its goal was "to encourage geographical exploration and discovery [and] to promote the great industrial, educational and material interests of Alaska and the islands and countries of the Pacific" (Goode 1903, 349–50). Its membership reached 1200 by 1903. Alfred H. Brooks, chief of the Alaska division of the U.S. Geological Survey, soon suggested the Alaska-Scandinavia analog and encouraged the society by his publications and direct support.

The Geographic Society of Chicago was founded in 1898 with Mary Arizona (Zonia) Baber as president. It had the dual purpose of diffusing geographic knowledge and improving the teaching of geography. It provided a reference room, and its library, lantern slides, and occasional bulletins were largely related to local geography.

In 1899 the Peary Arctic Club was established with the express purpose of supporting and furthering Robert E. Peary's polar exploration. Corporate sponsors included the Colgate Soap Company, the U.S. Steel Corporation, the Atlantic Mutual Insurance Company, and the Bankers Trust Company. Some $350,000 was raised, and in 1909 Peary was able to claim the prized North Pole. With its goal accomplished, the eleven-year-old club ceased operations. The episode brought the attention of North America and much of the rest of the world to the extent and reality of the frozen lands, cryogenic science, and the study of glaciation. It was in these years, from 1903 to 1906, that Roald Amundsen was the first to complete the voyage through the Northwest Passage and, in 1911, to become the first explorer to reach the South Pole.

Of a different genre was the Geographical Society of Baltimore, founded in 1902. Its aim was "the promotion and diffusion of geographical knowledge, more particularly of that which is of commercial importance to Baltimore" (Goode 1903, 350). Daniel Coit Gilman, geographer and first president of the Johns Hopkins University (1875–1901), assumed the presidency of the society. George Burbank Shattuck, biologist and soon to become a founding member of the Association of American Geographers, was elected secretary. Regular lectures and field trips were undertaken.

In the same year the Harvard Travelers Club was formed to promote "intelligent travel and exploration" (Goode 1903, 350). The club was founded by Harvard professor William Morris Davis, who in association with Copley Amory, Roland Burrage Dixon, James H. Kidder, and Archibald Cary Coolidge invited distinguished speakers to address the membership. The club has enjoyed a remarkable history of outstanding meetings. The American Alpine Club, also founded in 1902, attracted some geographers, and other members developed an interest in geography subsequent to mountain climbing and studying alpine environments.

In 1904 the Explorers Club was founded in New York City. This club has been essentially concerned with scientific investigation and terrestrial exploration.

In December of the same year, Davis founded the Association of American Geographers (AAG), with forty-eight charter members. Membership was by invitation, and admission requirements were formidable. Numbers grew slowly until World War II, when a rival organization, the American Society for Professional Geographers, founded by geographers working in Washington as part of the war effort, challenged the AAG's policy of exclusivity. In 1948 the two societies joined to form a reconstituted association with nine regional divisions. Precursors to these divisions were the New England Geographical Conference (founded in 1922) and the Association of Pacific Coast Geographers (founded in 1935). The AAG's Cartography Specialty Group, formed in 1979, has played a significant role as a North American cartographic society.

Meanwhile, the National Council of Geography Teachers, founded in 1915, became the National Council for Geographic Education in 1956. Its official publication, the *Journal of Geography*, was formed in 1902 by the merger of the *Journal of School Geography* (founded in 1897) and the *Bulletin of the American Bureau of Geography* (established in 1900). Working at times with the AAG and the NGS, "the Council" has attempted to bring geography more securely into the elementary and secondary school curricula and has done much to bring geography education to the attention of local, state, and national officials.

In 1925, the Society of Woman Geographers was formed in New York as an alternative to the Explorers Club, which did not admit women. According to the society's *Bulletin*, the founders "felt that there should be some medium of contact between women engaged in geographical work and its allied sciences" (reprinted in *Bulletin* 1976, 3). Explorer and writer Harriet Chalmers Adams was its first president. Its headquarters are located in Washington, D.C., and its records, donated to the Library of Congress in 1988 and 2001, reflect a diversity of activities. Membership has been elective, with members drawn from many parts of the world.

Though Canada produced the world's second national atlas in 1906, Canadian geography was somewhat slower than American geography to form scholarly societies. La Société de géographie de Québec was founded in 1877 to popularize geography and to make Quebec known to the rest of the world. The society published a bulletin from 1880 to 1934, and in 1881 sent geographers to represent Canada at the Third International Geographical Congress, held in Venice.

The Champlain Society was brought into being in 1905 by Edmund Walker. Since that time it has published more than ninety volumes concerning the environment and the history of Canada's exploration.

In 1929, the Canadian Geographical Society was founded in Ottawa by a group of federal civil servants with a mandate "to make Canada better known to Canadians and to the world" (quotation on the society's website). The *Canadian Geographical Journal* was first published in 1930 and now appears under the title *Canadian Geographic*. The Canadian Geographical Society was renamed the Royal Canadian Geographical Society in 1957.

The Canadian Association of Geographers/L'Association Canadienne des Géographes, founded at McGill University in Montreal in 1950, has been Canada's premier learned geographical society. It has published the *Canadian Geographer* since 1950, and the *Operational Geographer*, focused on applied geography, between 1983 and 1993.

GEOFFREY J. MARTIN

SEE ALSO: Academic Paradigms in Cartography: Canada and the United States; American Geographical Society; Geography and Cartography

BIBLIOGRAPHY:

Anonymous. 1903. "Directory of Officers and Councilors of Geographic Societies of the United States." *National Geographic Magazine* 14:392–94.

Bates, Ralph S. 1945. *Scientific Societies in the United States*. New York: J. Wiley & Sons.

Bryan, C. D. B. 1997. *The National Geographic Society: 100 Years of Adventure and Discovery*. Updated and enl. ed. New York: Henry N. Abrams.

Goode, J. Paul. 1903. "Geographical Societies of America." *Journal of Geography* 2:343–50.

Hamelin, Louis-Edmond. 1963. "Petite histoire de la géographie dans le Québec et à l'Université Laval." *Cahiers de Géographie de Québec*, no. 13:137–52.

Hamelin, Louis-Edmond, and Ludger Beauregard. 1979. *Rétrospective, 1951–1976*. Montreal: Association Canadienne des Géographes.

James, Preston Everett, and Geoffrey J. Martin. 1978. *The Association of American Geographers: The First Seventy-five Years, 1904–1979*. [Washington]: The Association.

Parry, Muriel (part 1), and Jacqueline Gustaves (part 2), eds. 1975. *Bulletin: The Society of Woman Geographers*. 50th anniversary issue.

Peary [Stafford], Marie Ahnighito. 1960. "History of the Society." In *The Geographical Society of Philadelphia, a Pennsylvania Nonprofit Corporation, Organized April 20, 1891, Incorporated November 10, 1893: History, 1891–1960*, 5–53. Philadelphia: Geographical Society of Philadelphia.

Wright, John Kirtland. 1948. "The Educational Functions of the Geographical Societies of the United States." *Journal of Geography* 47:165–73.

———. 1951. "The Field of the Geographical Society." In *Geography in the Twentieth Century: A Study of Growth, Fields, Techniques, Aims and Trends*, ed. Thomas Griffith Taylor, 543–65. New York: Philosophical Library.

———. 1952. *Geography in the Making: The American Geographical Society, 1851–1951*. New York: American Geographical Society.

Geographical Societies in Europe. The early twentieth century was the high-water mark of geographical associations. There were approximately 120 geographical societies in existence in 1900, 100 of which were located in European cities, more than half in France and Germany. Most were established during the preceding three decades (Butlin 2009, 275–324). The older and wealthier European societies, including the Société de géographie de Paris (1821), the Gesellschaft für Erdkunde zu Berlin (1828), the Royal Geographical Society (RGS) in London (1830), the Russkoye geograficheskoye obshchestvo (RGO) in Saint Petersburg (1845), and the Österreichische Geographische Gesellschaft in Vienna (1856), were venerable institutions by 1900, rooted in the nineteenth-century scientific culture in which they had developed (Lejeune 1993; Schelhaas and Hönsch 2001; Kretschmer and Fasching 2006). The smaller, more numerous late-nineteenth-century foundations, based in provincial ports and industrial cities, had a more practical and commercial ethos and saw themselves as champions of imperial trade.

The older and wealthier European geographical societies are important to historians of twentieth-century cartography because they were variously centers of map production, publication, and collection, though their creative significance declined in the second half of the century. Some societies possessed drawing offices where trained cartographers prepared impressive quantities of printed maps during the early twentieth century. Exploration was still the primary motivation at this time and most maps prepared by geographical societies were associated with expeditions into the remaining uncharted regions of the polar ice caps, the desert interiors of Africa and central Asia, the forests of Amazonia, and the high-altitude regions of the Himalayas. They were based on topographic surveys, sketches, photographs, and other data supplied by explorers and travelers, the objectives being to enable further exploratory missions and to publicize the results of successfully completed voyages.

Cartographers in the RGS, the largest of the European societies with over 5,000 fellows in the early 1900s, prepared maps and charts for the Antarctic expeditions of Robert Falcon Scott and Ernest Henry Shackleton before and during World War I and for the expeditions to Mount Everest led by George Mallory in the early 1920s, Eric Shipton in the 1930s, and John Hunt in 1953. In the mid-1950s continental European societies played a similar role in their own countries, though few could match the mapmaking capacity of the RGS. The Société de géographie de Paris was important for the Antarctic expeditions of Jean-Baptiste Charcot, for example, and in the many interwar surveys of the Saharan interior. The Berlin Gesellschaft für Erdkunde facilitated the Antarctic voyages of both Erich von Drygalski and Wilhelm Filchner, as did Det norske Geografiske Selskab in Christiana (Oslo) (1889) for Roald Amundsen's expeditions to both the Arctic and Antarctic. The Svenska Sällskapet för Antropologi och Geografi in Stockholm (1877) was important to the Antarctic voyages of Otto Nordenskiöld and the central Asian missions by Sven Anders Hedin, as was the RGO for the central Asian and Siberian explorations of Pëtr Kozlov, Vladimir Obruchev, and L. S. Berg. The Koninklijk Nederlands Aardrijkskundig Genootschap in Amsterdam (1873) launched eight major mapping surveys of New Guinea in the opening three years of the twentieth century, while cartographers employed by the Real Sociedad Geográfica de Madrid (1876) and the Società Geografica Italiana in Florence (1867) mapped and remapped Morocco and Libya from the early 1900s to the early 1930s (Van der Velde 1995). These explorations reflected a prevailing spirit of competitive nationalism, but the societies sought to preserve a measure of scientific cooperation, exchanging information and maps even during periods of international conflict and regularly bestowing medals and honors on explorers from other countries.

European societies also produced topographic and thematic maps for military and political purposes during and after World War I. At the request of the British War Office in London, an expanded team of RGS cartographers compiled a provisional series of around 100 1:1,000,000 printed sheets during the war, covering Europe, the Middle East, and North Africa, based on the recently agreed International Map of the World conventions, the objective being to use these sheets as a base map for postwar peace negotiations (Heffernan 1996). The Peace Conferences in Paris in 1919 and 1920 involved intensive cartographic battles in which maps acquired an unprecedented existential significance. Like the American Geographical Society in New York, which had hosted the so-called House Inquiry to research U.S. peace preparations through 1917 and 1918, the Paris Société de géographie became the headquarters of the Comité d'études from 1916 to 1919, a commission of leading academics tasked with drawing up France's geopolitical demands (Heffernan 1995). Their recommendations, published immediately after the war in a two-volume report and lavishly colored atlas, focused on the transfer of Alsace-Lorraine from Germany to France but also impacted on the wider European settlement, particularly for the borders of Romania and Hungary. The leading French geographer Emmanuel de Martonne, the commission's secretary, produced a sequence of maps to justify the massive territorial expansion of Romania, France's wartime ally, and the corresponding diminution of a new Hungarian republic, decoupled from its prewar imperial connections with Austria, this arrangement justified by ethnographic and linguistic data from late nineteenth-century censuses (Palsky 2002). The geographer-politician Pál Teleki and the geologist-explorer Ferenc Nopcsa countered de Martonne's proposal, which was largely accepted by the Treaty of Trianon in 1920, with their rival Hungarian maps. They employed over sixty cartographers in the Hungarian geographical society (Magyar Földrajzi Társaság) in Budapest (1872) to produce an alternative sequence of maps using ethnographic, linguistic, population density, and economic statistics from the 1910 census, culminating with the so-called *carte rouge* that summarized the Hungarian position (see fig. 473). This was circulated to national delegations in Paris and to foreign ministries and learned societies around the world along with an explanatory memorandum drafted by Teleki on behalf of the Magyar Földrajzi Társaság in a doomed attempt to reaffirm the geopolitical legitimacy of the old Hungarian borders (Ablonczy 2006, 49–50).

None of the European geographical societies developed interwar mapping projects comparable to the 1:1,000,000 *Map of Hispanic America* compiled by the American Geographical Society in New York. The cartographic output of the European societies was also noticeably less conspicuous during World War II and was largely untouched by the journalistic, propagandizing, geopolitical mapping that developed in other contexts. This was partly because the societies had minimal scope for independent action under the German occupation of continental Europe, though their eclipse as centers of cartographic production also reflected the growing power of military and civilian mapping authorities that no longer needed to rely on private institutions. The RGS's 1:11,000,000 map of Europe, North Africa, and the Middle East (eventually extended as far east as Rangoon), compiled in both Arabic and English editions between 1940 and 1942 to support the British Council's wartime propaganda efforts, was something of an exception and significant in its use of a photogravure process to generate a single 38″ × 25″ map sheet on a folded, easily reproduced paper-and-cotton base (Hinks 1942).

Several European societies succumbed to the disruption caused by World War II, and others were unable to meet the rising cost of leasing expensive urban property after 1945. In some cases, map collections assembled over several decades were divided, sold, or simply lost. The Berlin society's library and important map collection escaped wartime destruction, hidden away in a potash mine near Bernburg, but the material passed to the Staatsbibliothek zu Berlin in East Germany after 1945, leaving the relaunched society on the western side of the city cut off from its own resources. Restored to its rightful owners after unification in 1990, the collection remains in the safekeeping of the same library for want of suitable alternative accommodation (Schelhaas 2004). Other societies had made the same decision. The Paris society's library and map collection was relocated to the Bibliothèque nationale de France, for example, and the royal Spanish society's collections moved to the Biblioteca nacional de España. The royal Dutch society's collections are now in the library of the University of Amsterdam. Only a very few societies, most notably the RGS in London, maintain private premises and control of their own collections.

In these challenging circumstances, few societies retained a significant mapmaking capacity after 1945, although most continued to publish journals and related material, often richly illustrated with black-and-white and color maps. These maps, mainly produced by commercial mapmaking companies, provide a revealing commentary on changing cartographic styles and conventions and would repay systematic cartobibliographical analysis (Smits 2004).

MICHAEL HEFFERNAN

SEE ALSO: Academic Paradigms in Cartography: Europe; Geography and Cartography; Royal Geographical Society (U.K.)

BIBLIOGRAPHY:

Ablonczy, Balázs. 2006. *Pál Teleki (1874–1941): The Life of a Controversial Hungarian Politician*. Trans. Thomas J. DeKornfeld and Helen D. DeKornfeld. Boulder: Social Science Monographs.

Butlin, R. A. 2009. *Geographies of Empire: European Empires and Colonies, c. 1800–1960*. Cambridge: Cambridge University Press.

Heffernan, Michael. 1995. "The Spoils of War: The Société de Géographie de Paris and the French Empire, 1914–1919." In *Geography and Imperialism, 1820–1940*, ed. Morag Bell, R. A. Butlin, and Michael Heffernan, 221–64. Manchester: Manchester University Press.

———. 1996. "Geography, Cartography and Military Intelligence: The Royal Geographical Society and the First World War." *Transactions of the Institute of British Geographers*, n.s. 21:504–33.

Hinks, Arthur R. 1942. "Making the British Council Map." *Geographical Journal* 100:123–30.

Kretschmer, Ingrid, and Gerhard L. Fasching, eds. 2006. *Österreich in der Welt, die Welt in Österreich: Chronik der Österreichischen Geographischen Gesellschaft 150 Jahre (1856–2006)*. Vienna: Österreichische Geographische Gesellschaft.

Lejeune, Dominique. 1993. *Les sociétés de géographie en France et l'expansion coloniale au XIX^e siècle*. Paris: Albin Michel.

Palsky, Gilles. 2002. "Emmanuel de Martonne and the Ethnographical Cartography of Central Europe (1917–1920)." *Imago Mundi* 54:111–19.

Schelhaas, Bruno. 2004. *Institutionelle Geographie auf dem Weg in die wissenschaftspolitische Systemspaltung: Die Geographische Gesellschaft der DDR bis zur III. Hochschul- und Akademiereform 1968/69*. Leipzig: Leibniz-Institut für Länderkunde.

Schelhaas, Bruno, and Ingrid Hönsch. 2001. "History of German Geography: Worldwide Reputation and Strategies of Nationalisation and Institutionalisation." In *Geography: Discipline, Profession and Subject since 1870: An International Survey*, ed. Gary S. Dunbar, 9–44. Dordrecht: Kluwer Academic Publishers.

Smits, Jan. 2004. *Petermann's Maps: Carto-bibliography of the Maps in* Petermanns Geographische Mitteilungen*, 1855–1945*. 't Goy-Houten: Hes & de Graaf.

Velde, Paul van der. 1995. "The Royal Dutch Geographical Society and the Dutch East Indies, 1873–1914: From Colonial Lobby to Colonial Hobby." In *Geography and Imperialism, 1820–1940*, ed. Morag Bell, R. A. Butlin, and Michael Heffernan, 80–92. Manchester: Manchester University Press.

Societies, Map. The phenomenon of a group of map aficionados, primarily nonprofessionals, coming together regularly to view and learn about maps emerged strongly in the fourth quarter of the twentieth century in North America, with antecedents in the third quarter of the century and even earlier. There are, of course, a wide variety of more or less professional map organizations as well, and many of these welcome amateurs to their ranks. But the focus here is on societies that, from the beginning, had strong representation from people not trained as map professionals, especially collectors and other amateurs. Tony Campbell's "Map History" website has attempted to provide an up-to-date list of "map interest societies," including some of the more mixed sort alluded to above, while Dawn Youngblood summarized the situation as of 2006 (Youngblood 2006).

Erwin Raisz, writing in 1951, reported that "two generations ago a group of Bostonians interested in maps came together and called themselves the 'Cartophiles.' They left no records, and after a while their activities petered out" (44). But the Cartophiles were revived after World War II and held their inaugural meeting in January 1947. The group mirrored quite closely the typical makeup of most map societies today: it included cartographers, librarians, curators, collectors, and booksellers. It lacked officers or dues, the only official being the "card sender," who arranged meetings and sent out notices. Meetings were held at various institutions in the Boston area, usually involving a tour of a map collection or map-producing facility or a talk by a local or out-of-town speaker (Lovett 1955). Raisz, the cartographer and Harvard geographer, was a stalwart of the Cartophiles, and his death in 1968 weakened the society (Lovett 1980). In this respect as well, the experience of contemporary map societies mirrors that of the Cartophiles: most such groups, however much they cater to the interests of amateurs, rely heavily on a small core of professional mapmakers, curators, or dealers and usually have a strong relationship with an institution. When the Cartophiles held their eighty-fourth, and final, meeting in May 1977, Robert W. Lovett, curator of manuscripts and archives at the Baker Library, Harvard Business School, had been the card sender for at least twenty-two years.

Although they do not meet all the characteristics of a map society as sketched above (most notably, in not having regular meetings), two other groups catering to the interests of cartographic amateurs should be mentioned. The first was the Internationale Coronelli-Gesellschaft für Globenkunde, founded in Vienna in 1952 by the engineer and globe collector Robert Haardt. Haardt assembled a unique collection of globes, which forms the basis of the collection now at the Österreichische Nationalbibliothek, and launched the journal *Der Globusfreund* (Bonacker 1964). Both society and journal continue to flourish. In Britain, a sign of the growing need for sharing among cartographic amateurs was the Map Collectors' Circle, formed in London in 1963. It was the brainchild of antiquarian map dealer and popularizer R. V. Tooley, then a director of the prestigious booksellers Francis Edwards and manager of their map section. The circle flourished for a dozen years and published 110 cartobibliographical monographs, all edited (and many authored) by Tooley under the title Map Collectors' Series (Campbell and Kay 1987).

While the New England Cartophiles were still meeting, and before the map society phenomenon fully blossomed at the end of the 1970s, four other groups, all fitting the model of the largely nonprofessional group of map lovers, came into being in Helsinki, Tokyo, Chicago, and Vancouver. After the Cartophiles, the second map society (and the oldest continuously operating one) emerged in 1964 in Finland. Tove Olsoni-Nilsson, one of two antiquarians in Helsinki who dealt in old maps, had often urged her clients to form some kind of collector's group. In 1964, one of the collectors, Osmo Kiikka, a Helsinki engineer and manger of a paint factory, took the initiative to call a meeting on 13 March 1964. On that occasion, the group, called Chartarum Amicae (CA), was formed with fourteen members and Kiikka as chairman. For thirty-three years the group communicated by letters, but in 1977 they began publishing the newsletter *Chartarum Amici*. CA has never had an institutional home but has had from two to five meetings a year in restaurants and cafes, museums, and libraries for lectures, exhibitions, and seminars, all relating in some way to old maps (Leena Miekkavaara, personal communication, 2008).

Meanwhile, in Tokyo in 1970, an organization called the Nihon Chizu Shiryō Kyōkai 日本地図資料協会 (Japanese Map Association) was founded. This group had a most active publishing program, producing more than 300 issues of the monthly periodical *Gekkan Kochizu Kenkyū* 月刊古地図研究 (Antique Maps). It was reconstituted in 1995 under the new name Nihon Kotizu Gakkai 日本古地図学会 (Antique Map Society of Japan).

In January 1976, the Chicago Map Society (CMS), which calls itself on its website "the oldest map society in North America," was born. This group grew out of a series of adult education classes taught at the Newberry Library by David Woodward, who had become the Newberry's first full-time map professional in 1969. Although technically an independent organization, with its own bylaws and elected officers, the CMS has been inextricably linked with the Newberry during its whole existence. *Mapline*, the newsletter of the library's Hermon Dunlap Smith Center for the History of Cartography, began appearing in March 1976, and a subscription to the newsletter has always been included in CMS membership. Just two months after the first Chicago meeting, a dozen map lovers in British Columbia got together in Vancouver to found the Map Society of British Columbia (Woodward 2008).

The 1970s were a period of profound growth in interest in the history of cartography in North America, both in academia and among personal and institutional collectors, and the Chicago and Vancouver societies were quickly followed by a number of other similar groups, most still active in the early twenty-first century. Youngblood (2006) provides an excellent survey of map societies, with tabular information about publications, foundation year, and activities. Several with statewide membership (the Wisconsin, California, and Texas societies were the first) have successfully met the challenge of geographically dispersed participants by having fewer meetings, varying meeting places, or relying more on serial publications. A few (the Mercator Society of the New York Public Library, the Philip Lee Phillips Society of the Library of Congress, and the Osher Library Associates of the Osher Map Library, University of Southern Maine) are actually library friends groups and provide direct support to the collections with which they are associated. The Washington [D.C.] Map Society, with more than 350 members in 2007 and one of the most active groups in North America, has held eight meetings a year, published *The Portolan* (more journal than newsletter), and sponsored a prize for scholarship in the history of cartography.

On the international level, the earliest group made up primarily of nonprofessionals with a cartographic passion who have made the regular (if only biennial) meeting a part of their routine is the International Map Collectors' Society (IMCoS), founded in London in 1980. They have held annual dinners and map fairs in London and, since 1982, an annual symposium that, as of 2009, has met in twenty countries. From their founding they have published the quarterly *IMCoS Journal*.

By the close of the twentieth century, the map society was an important locus for collectors, map users, scholars interested in cartography, dealers, and just plain map lovers to meet and exchange ideas. Although concentrated in the United States and Europe, map societies and their roughly 2,000 members worldwide have had a noteworthy impact on the study of the history of cartography.

ROBERT W. KARROW

SEE ALSO: Collecting, Map

BIBLIOGRAPHY:

Bonacker, Wilhelm. 1964. "The First International Symposium of the Coronelli Weltbund der Globusfreunde (Coronelli World Society of Friends of the Globe)." *Imago Mundi* 18:83–84.

Campbell, Tony, and Terry Kay. 1987. "Ronald Vere Tooley (1898–1986)." *Imago Mundi* 39:80–81.

Lovett, Robert W. 1955. "The Cartophiles." *Bulletin*, Special Libraries Association, Geography and Map Division, no. 20:4–5.

———. 1980. Robert Lovett to Leon Yacher, 25 June 1980. Papers of Robert W. Lovett, 1931–1999. Harvard University Archives, Cambridge.

Raisz, Erwin. 1951. "The Cartophile Society of New England." *Imago Mundi* 8:44–45.

Woodward, Frances M. 2008. "Historical Map Society of British Columbia: A History in Progress." Unpublished typescript, rev.

Youngblood, Dawn. 2006. "The Evolution of Map Societies: A Global Phenomenon." *Journal of Map & Geography Libraries* 3, no. 1:79–102.

Societies, Map Librarianship. Starting with a single society founded in 1941 to facilitate wartime cooperation among American map libraries, map librarianship societies multiplied worldwide from the 1960s to the 1980s as map libraries and staff increased in number and as librarianship became increasingly professional (Wawrik 1980). Some map librarianship societies emerged as subgroups of general library or cartographic associations, while others, usually smaller and regional, formed independently. Such societies offered map librarians opportunities for specialized professional development, creation of map library standards and mutual support within the larger book-oriented library world. By the 1990s computerization was transforming that world, shifting the focus of map librarianship from collecting paper maps to providing access to "vapor" (i.e., electronic) maps produced with GIS resources and tools in various digital formats. The content of map library journals made a corresponding shift from collection development and map, atlas, and gazetteer reference to digital mapping issues and the staff, skills, equipment, and funding needed for the new technologies. Meanwhile map librarianship societies themselves moved from paper publications toward cheaper and wider online dissemination of professional information. Although differing in details, the following individual histories of map librarianship societies, discussed in the order of their founding dates, exemplify this overall pattern of development.

In response to the increased demand for maps during World War II, the Washington Chapter of the Special Libraries Association (SLA) formed a Geography and Map Group in 1941 to assist sharing of information and map resources in the United States. It achieved the status of a division within SLA in 1944 with a membership of fifty persons (Murphy 1982, 2). A report of SLA's joint week-long conference with the Western Association of Map Libraries in San Francisco in 1971 covered not only the substantive program of professionally relevant talks and tours but also the status of SLA publications and projects (Anonymous 1971). Publications of the SLA Geography and Map Division included: *Map Collections in the United States and Canada: A Directory* (3d ed., 1978), *Standards for University Map Collections* (1987), *Recent Practices in Map Libraries* (1971), *Introduction to Map Libraries* slide collection (1982), the *Bulletin*, Special Libraries Association, Geography and Map Division (1947–97), and *SLA/G&M News and Views* newsletter (1999–2003) (Mullins 1975; Murphy 1997). In October 2003 the Geography and Map Division merged with the Social Sciences Division of SLA and became the Geography and Map Section with a website for communication to the profession.

The postwar growth of cartography gave rise to cartographic societies whose membership included subgroups of map librarians. The British Cartographic Society was founded in 1963, and its Map Curators' Group (MCG) was created in 1966 (Wallis 1972, 295). In liaison with the Library Association, the MCG promoted the professional development of map librarians throughout the United Kingdom. In 2000 the MCG had 182 members, mingling librarians with map historians and map collectors. MCG annual meetings were convened in association with the British Cartographic Society. During the 1990s its recently formed subgroup, the British and

Irish Committee on Map Information and Cataloguing Systems (BRICMICS), provided a forum for appointed representatives to discuss issues affecting their map libraries and archives. The MCG first published *A Directory of UK Map Collections* in 1983. The fourth edition in 2000 included some 400 entries for national libraries, university collections, and local authority libraries with map collections. The newsletter of the Map Curators' Group of the British Cartographic Society began publication in 1983 and became quarterly under the title *Cartographiti* in 1984. Lis-maps, the British cartographic listserv founded in 1993, also provided an electronic means of professional communication for map librarians and others involved with cartography.

The Western Association of Map Libraries (WAML) was established in 1967, after earlier discussions, at a meeting of fifteen map professionals at San Francisco State College. Serving the needs of map libraries in western North America, WAML defined its geographical area as Alberta and British Columbia in Canada and Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming in the United States. By means of meetings and its *Information Bulletin*, WAML set out to give libraries within that geographical region opportunities to discuss mutual problems and interests, exchange information, and promote higher cartographic and library standards. WAML's Occasional Paper series became an important resource for map librarians, including the following titles: *Union List of Sanborn Fire Insurance Maps* (2 vols., 1976–77), *Map Index to Topographic Quadrangles of the United States, 1882–1940* (1986), and *A Cartobibliography of Separately Published U.S. Geological Survey Special Maps and River Surveys* (1990). By 2000 WAML numbered over 100 members, whom it kept informed about technological and other map library news by means of its website and email newsletter, *Electronic News & Notes*.

In 1967, a conference was also held in Canada to investigate forming an organization to serve the Canadian map library community. Some seventy attendees were involved in planning a variety of cooperative activities. Within the year thirty-seven persons became full founding members of the Association of Canadian Map Libraries. Two years later the first *Directory of Canadian Map Collections = Répertoire des collections de cartes canadiennes* listed eighty-seven map libraries. The membership had grown to 250 by the fifteenth annual meeting in Halifax, Nova Scotia, in 1981 (MacKinnon 1981–82, 130). In 1987 a change of name to the Association of Canadian Map Libraries and Archives (ACMLA) reflected the extension of membership to archival collections. ACMLA sought to encourage high standards for and use of geographic information as well as to provide communication networks and professional development for its members. The seventh edition of the *Directory* (1999) listed ninety map collections. Among its publications, the ACMLA's *Bulletin*, published three times a year, included substantial articles, bibliographies, and lists of new maps, atlases, books, and software. The following titles appeared in its Occasional Paper series: *Canadian Fire Insurance Plans in Ontario Collections, 1876–1973* (1995) and *Catalogue of Canadian Fire Insurance Plans, 1875–1975* (2002). Two other noteworthy publications were: *Guide for a Small Map Collection* (1981, 2d ed. 1984) and *Explorations in the History of Canadian Mapping* (1988). A program to preserve and provide access to the Canadian cartographic heritage resulted in the publication of 150 facsimile maps. The ACMLA website provided information to members, such as a description of the role of each officer and committee.

The Geography and Map Section of the International Federation of Library Associations (IFLA) was formed at IFLA's Copenhagen conference in 1969 after a campaign led by Walter W. Ristow, chief of the Geography and Map Division of the Library of Congress (Corley 1970). Initially a subsection of the Special Libraries Section of IFLA, it became a section of the Special Libraries Division of IFLA in 1977 (Wawrik 1980, 17). Its first official meeting was at the Moscow IFLA conference in 1970 ([Wallis] 1972, 53; Wallis 1972, 296). The Geography and Map Section's *World Directory of Map Collections* appeared in four editions (1976, 1986, 1993, and 2000). The first edition listed 285 collections in forty-five countries; by the fourth edition, the numbers had expanded to 714 collections in 121 countries. Another IFLA contribution to map librarianship, *ISBD (CM): International Standard Bibliographic Description for Cartographic Materials* (1977), led to the standardized cataloging of cartographic materials. In addition, the Geography and Map Section generated numerous publications in *INSPEL* (*International Newsletter* [later, *Journal*] *of Special Libraries*). It also developed an informative website.

The Australian Map Circle (AMC), known earlier as Australian Map Curators' Circle, was established in 1973. It promoted the growth and use of map collections in Australasia as well as professional development of map librarians and their communication with map producers and users. The *Globe*, its journal founded in 1974, published articles on cartographic topics, as well as the proceedings of AMC annual meetings in different cities (Treude 1975). Its *Newsletter* began publication in 1983, and its email group, *amcircle*, helped to close the information gap among geographically far-flung Australasian map librarians and other members. Its publications include *Checklist of Australian Map Catalogues and Indexes* (1982, 2d ed. 1985), *Unfolding Australia: Proceedings of the Joint Meeting of the International Map Collectors' Society and the Australian Map Circle*

(1992), and *Icons of Early Twentieth Century Australian Cartography* (2003).

The Werkgroep Kaartbeheer of the Nederlandse Vereniging voor Kartografie was established in 1975. It sought to foster professional training, good practices, and communication among map curators. It also provided information about map collections in the Netherlands. The Nederlandse Vereniging voor Kartografie published a directory of map collections in the Netherlands, *Gids voor kaartenverzamelingen in Nederland* (1980).

First organized at the Ligue des Bibliothèques Européennes de Recherche (LIBER) meeting in Denmark in 1978, the Groupe des Cartothécaires de LIBER was officially established at the Paris meeting of 1980. It grew from eighteen founding members to more than 250 by 2000. By serving as a locus for collaboration and communication, it aimed to educate librarians and map users about the uses of cartographic information in both electronic and paper formats. Its biennial meetings in different European cities considered themes relevant to map libraries and reports from national correspondents. The experience of hosting a meeting fostered interaction among map librarians within more than one country. Its meetings also offered stimulating international contacts to map librarians from small countries lacking national societies. The website of the Groupe des Cartothécaires de LIBER includes an indexed bibliography of articles published by its members in the LIBER *Bulletin* and *Quarterly*.

The American Library Association's (ALA) Map and Geography Round Table (MAGERT) was established in 1980. ALA was the organization to which most United States library administrators belonged, so the MAGERT-ALA connection was advantageous to map librarians and fostered networking within their own institutions. MAGERT contributed to the field by publishing *Meridian: A Journal of the Map and Geography Round Table of the American Library Association* (1989–99), *Base Line: A Newsletter of the Map & Geography Round Table* (1980–, available first in print and later online via the MAGERT website), and three editions of *Guide to U.S. Map Resources* (1986, 1990, and 2006). In 2005 MAGERT began publishing *Coordinates: Online Journal of the Map and Geography Round Table, American Library Association*, with Series A, peer reviewed articles, and Series B, essays, project reports, and technical notes. MAGERT committees provided forums for discussion of current issues and for projects in cataloging and classification of cartographic material, geographic technologies (such as GIS), education, publication, and map collections management.

The International Society for the Curators of Early Maps first met informally in Dublin, Ireland, in 1983 at the International Conference on the History of Cartography (ICHC), of which it became a subgroup. Officially founded in 1987, it met with the ICHC in alternate years in different countries and issued an occasional newsletter.

Even after the surge of map librarianship association foundings during the 1960s and 1970s passed, the European network of national associations of map librarians continued to grow. In 1985 in Germany the Arbeitskreis der Kartenkuratoren of the Deutsche Gesellschaft für Kartographie held its first meeting. In the mid-1980s in France the Commission Documentation of the Comité français de cartographie brought together map librarians and archivists and map publishers. In Sweden the Kartarkivarieföreningen of the Kartografiska Sällskapet was founded in 2002. The Asociacíon de Cartotecas Públicas Hispano-Lusas was formed in Madrid in 2003 and was renamed Grupo de Trabajo de Cartotecas Públicas Hispano-Lusas (Ibercarto) in Seville in 2004.

ALICE C. HUDSON

SEE ALSO: Collecting, Map; Libraries, Map; Libraries and Map Collections, National; Public Access to Cartographic Information; Societies, Cartographic

BIBLIOGRAPHY:

Anonymous. 1971. "San Francisco Conference." *Bulletin*, Special Libraries Association, Geography and Map Division, no. 85:41–44.

Corley, Nora Teresa. 1970. "The Formation of the Geography and Map Libraries Subsection of the Section of Special Libraries, IFLA: A Canadian View." *Bulletin*, Special Libraries Association, Geography and Map Division, no. 80:40–45.

MacKinnon, William. 1981–82. "Association of Canadian Map Libraries 1981 Conference." *Archivaria* 13:130–31.

Millea, Nick. 2005. "Map Library Usage in Europe: A Vision for the Future? An Assessment of a Questionnaire Conducted during the Summer of 2003." *Journal of Map & Geography Libraries* 1, no. 2:51–83.

Mullins, Lynn S. 1975. "The Bulletin of the Geography and Map Division, Special Libraries Association: A History and Review." *Bulletin*, Special Libraries Association, Geography and Map Division, no. 100:3–25.

Murphy, Mary. 1982. "1941–1981: Forty Years of the Geography and Map Division in SLA." *Bulletin*, Special Libraries Association, Geography and Map Division, no. 128:2–9.

———. 1997. "The Geography and Map Division 1982–1997." *Bulletin*, Special Libraries Association, Geography and Map Division, no. 187:12–15.

Treude, Mai. 1975. "*The Globe*, Journal of the Australian Map Curators' Circle: A Review." *Information Bulletin, Western Association of Map Libraries* 7, no. 1:45–46.

[Wallis, Helen]. 1972. "Geography and Map Libraries Subsection: Secretary/Treasurer's Report, Budapest, August 1972." *INSPEL* 7:53–54.

Wallis, Helen. 1972. "Progress in the Map World." *New Library World* 73:295–96.

Wawrik, Franz. 1980. "Kartensammlung und Kartenbibliothekar." *Biblos* 29:7–17.

Societies, Photogrammetric and Remote Sensing. The history of professional societies for photogrammetry and remote sensing spans nearly the entire twentieth century. The first society of photogrammetrists was established in 1907 as a local concern of a tightly knit community of Central European geodesists. At the end of the century, significant international societies of geospatial data analysts—interdisciplinary, networked all over the globe by computers and satellites, and concerned with sustainable development and integrated graphical interfaces—continued to emerge. Despite their substantially disparate missions, constituencies, and tools, all of these organizations have a common history. Over the last hundred years, individuals, firms, and government agencies have expended tremendous amounts of energy and resources in their efforts to create new ways to depict, measure, and interpret images of the earth. At virtually every turn, the general scope and specific directions of these efforts have been supported and mediated by the major professional societies of photogrammetry and remote sensing.

If there is a single institution whose evolution most consistently mirrors the intellectual and institutional stories of the relevant sciences themselves, it is surely the International Society for Photogrammetry and Remote Sensing (ISPRS). It began officially as the International Society for Photogrammetry (ISP) in 1910. Its two immediate institutional precedents were national societies established in Austria (1907) and Germany (1909) (Lamboit 1974, 6). Three factors help to explain why this particular region became the birthplace for professional photogrammetric societies. First, the German-speaking nations had long cultivated a robust scientific tradition, particularly in the field of precision instruments for measuring and plotting data. Second, the region's mountainous terrain acted as a kind of natural laboratory, encouraging scientists to pioneer novel photogrammetric methods, especially as municipal water, electricity, road, and industrial engineering projects gained momentum. Finally, the Moravian geodesist Eduard Doležal tirelessly proselytized for a scholarly organization of international scope. Doležal edited the first six volumes of the *International Archives of Photogrammetry* ("and Remote Sensing" was later added to its title), the first journal in its field and still a leading scholarly organ at the end of the century (Kelsey 1986). He also spearheaded the ISP's first International Congress of Photogrammetry, held in Vienna in 1913, as well as the second and third, held after World War I in Berlin (1926) and Zurich (1930). Like the *International Archives*, the quadrennial congresses were vital international scholarly forums through the remainder of the century.

From the outset, the ISP faced two kinds of challenges and opportunities that defined in microcosm those later confronted by earth imagers and image interpreters the world over. War presented the first major type of challenge and opportunity. A nascent professional enterprise in Central Europe could not thrive during World War I, and scientists who were considered German had to work hard in the war's aftermath simply to reestablish their social legitimacy within the small yet rapidly growing international photogrammetric community. Both factors explain the long gap in time between the first and second International Congresses of Photogrammetry. On the other hand, World War I—just as World War II and the Cold War would do later—jump-started the careers of individual photogrammetrists as well as photogrammetric techniques generally. Pilots, photographers, camera manufacturers, and aerial image interpreters used the war-torn terrain of Western Europe as a proving ground to develop specialized sets of skills over which only they, as newly minted professionals, claimed sole legitimate authority. While it developed suddenly, this new professional niche proved to be long-lasting. In the 1920s and thereafter, photogrammetry, a term that formerly referred to the measuring of distances from photographs of all kinds, became very closely associated with aerial photography and topographic mapping (Collier 2002).

The other kind of challenge and opportunity was the ongoing effort to define a professional society's proper goals. The original motives of Doležal and his colleagues had been clear. They wanted to host conferences, coordinate government work with private enterprise, publish a journal to disseminate research findings, develop and publicize new technologies, and recognize and reward extraordinary achievements. Other activities, however, were not foreseen. These emerged only as photogrammetric techniques, the clients and audiences for geographic knowledge, and membership within the society itself all developed and interacted in unpredictable ways. Managing growth was one such area of recurring concern. The ISP had attracted twenty member nations by 1937 and seventy-three by 1985; the number of individual photogrammetrists increased commensurately. To cope with these newcomers and to maintain professional boundaries, the ISP chose to erect formal standards that practicing photogrammetrists had to meet. Ethical guidelines were formulated after World War II; in 1950 the International Training Centre (ITC) was founded in the Netherlands; in 1951 the ISP established a Committee on Photographic Interpretation.

Another area of concern was an entirely different kind of growth. Doležal himself had suggested that potential applications of photogrammetry included such "farsighted topics" as the "protection of ancient monuments, the study of human movement and even of cloud formations" (Kelsey 1986, 95). But he could not predict the myriad ways in which such technological systems as digital cartography and GIS would expand the sheer scope of what counted as imaging—and to whom those practices would be valuable—in the decades following World War II. The ISP and its kindred societies did their best to accommodate these changes and nourish them. The most telling indication came in 1980, when the ISP formally became the ISPRS. Exactly like many of the national societies it coordinated, the ISPRS's interests, as stated in its bylaws, included not just "cartography, geodesy, [and] surveying," but also "natural, Earth and engineering sciences, and environmental monitoring and protection . . . industrial design and manufacturing, architecture and monument preservation, medicine and others."

The stories of the major national remote sensing societies in the United States and Great Britain follow the ISPRS's in broad outline. Both societies pioneered certification and training programs for prospective professionals; both published esteemed journals (*Photogrammetric Engineering and Remote Sensing* and *Photogrammetric Record*, respectively). But their distinctive elements shed light on the place of professional societies within the political economy of twentieth-century geographic knowledge production. What characterized the American Society for Photogrammetry and Remote Sensing (ASPRS) from its founding in the 1934 (as the American Society for Photogrammetry, or ASP) was its pragmatism and diversity. Members hailed from federal agencies such as the Tennessee Valley Authority and the Soil Conservation Service; county and municipal planning boards; academic departments of geology, forestry, and geography; branches of the military; and private camera and aerial surveying firms. By the heyday of the Cold War, the ASP's "applied science" emphasis was in full swing, and leading photogrammetrists such as Amrom H. Katz "pursued careers that exemplify the complex mixtures of academic research, public and clandestine government service, and private corporate employment" (Cloud 2002, 267). A similar corporate-academic-government-military mix characterized Britain's Remote Sensing and Photogrammetry Society (RSPSoc; founded in 1952 as the Photogrammetric Society). Particularly telling are the three organizations that remained members throughout the life of RSPSoc: Anglo-Saxon Petroleum Co. Ltd (now BP Exploration Co. Ltd); Ordnance Survey; and Henry Wild Surveying Instruments Supply Co. Ltd (now LH Systems GmbH) (Atkinson and Newton 2002, 578). The ASP changed its name in January 1975 with no fanfare and only a little debate. Katz criticized remote sensing as a fiscally wasteful and often imperialistic practice. As he put it, only "astronauts and farmers" really cared about "this earth-resources business"—one wanted to fly, the other wanted data (Katz 1976, 196). The story in Britain was different. Rather than make a name change to acknowledge the organically expanding reach—literal and social—of geographic imaging technologies, old-guard geodesists and topographers at the Photogrammetric Society had to contend warily with the upstart "interpreters" of the Remote Sensing Society (founded independently in 1974). The tensions surrounding their eventual merger attest to the enduring social power of professional boundaries, even in an area of high-flying global reconnaissance (Kirby 2003).

Interpretation has been at the heart of remote sensing practices ever since the launch of the first Landsat (1972–78). Indeed, one reason why so many different kinds of remote sensing societies have come onto the scene in the last few decades is the intellectual freedom to create knowledge from the many types of images offered by Landsat and its numerous descendants and rivals. Some of these professional societies began as communities devoted to the technical mechanics of "sensing at a distance" (Colwell 1984, 1305) The IEEE (Institute of Electrical and Electronics Engineers) Geoscience and Remote Sensing Society (GRSS; founded as the Geoscience Electronics Group in Dallas, Texas, in 1961) and the International Center for Remote Sensing of Environment (ICRSE; founded in Ann Arbor, Michigan, in 1962) are prominent examples. Since 1981, GRSS has administered the International Geoscience and Remote Sensing Symposium (IGARSS), while since the 1990s the ICRSE's mission has deliberately embraced sustainable development. Other societies, meanwhile, have evolved to create their own peculiar niches as facilitators of research and coordinators of institutions. The Organisation européenne d'études photogrammétriques expérimentales (OEEPE) was established in 1953 by five European nations to foster research and the development and implementation of technology and to promote collaboration throughout Europe among national mapping agencies, academic institutions, the private sector, and user groups. In 2002 the organization changed its name to EuroSDR (European Spatial Data Research). The European Association of Remote Sensing Laboratories (EARSeL), founded in 1977 under the sponsorship of the European Space Agency, the Council of Europe, and the Europe Commission, grew by the early twenty-first century to include about 250 member laboratories. The Association for Geographic Information, founded by the British government in 1985, has acted as "a multidisciplinary organisation 'dedicated to the advancement of the use of geographically related information'" (Saxby 2006, 163n92). This is not a far cry from the ASPRS's 1998 shift to its new motto: "the imaging and geospatial information society."

Changes of this sort make it difficult to determine whether the freedom of individuals to interpret all manner of remotely sensed data have led to more diversity or more conformity in map design, cartographic practice, and geographic knowledge. Some critics have suggested that prevailing land classification categories, imposed by Western science, remain too rigid and simplistic to represent adequately the diversity of land use practices in many parts of the world (Robbins and Maddock 2000). Other developments in Asia, meanwhile, suggest that diversity in cartographic styles persists. The Indian Society of Remote Sensing (ISRS), established in 1969, focused from the outset on the planning and management of natural resources and the environment; with over 3,500 members in the early twenty-first century, it continued to grapple with real-world problems regarding resource management, environmental assessment, and disaster management. The National Remote Sensing Center of China (NRSCC; Zhongguo guojia yaogan zhongxin 中国国家遥感中心), unlike most learned societies a subdivision of a federal ministry (of science and technology), has had an explicit mandate to develop national policies and long-term plans for promoting remote sensing science and technology, including geospatial data systems and satellite navigation. One factor impelling the creation in 1992 of the African Association of Remote Sensing of the Environment (AARSE) was "the inadequate human and institutional capacity to . . . evolve a sustainable development strategy," according to their website.

The International Society for Digital Earth (ISDE), founded in 2006, a century after Doležal's Austrian society, reflects a vast increase in the quantity of geospatial information, a greater openness of this information to different interpretations and purposes, and lowered technological and financial barriers to participation. One of the ISDE's initial aims was to create a browser to help users access geospatial data in real time (Foresman 2008). Thanks to the daily professional work conducted over a century by members of ISPRS, ASPRS, RSPSoc, and their contemporary national societies, young organizations like the ISDE could aim at much more than farmers and astronauts. In their visions, "remote sensing" itself had become less an end and more a means to meet the demands for geospatial data by users all over the globe.

ALEX CHECKOVICH

SEE ALSO: Societies, Cartographic

BIBLIOGRAPHY:

Atkinson, Keith B., and I. Newton. 2002. "The Photogrammetric Society: 1952–2001." *Photogrammetric Record* 17:577–600.
Cloud, John. 2002. "American Cartographic Transformations during the Cold War." *Cartography and Geographic Information Science* 29:261–82.
Collier, Peter. 2002. "The Impact on Topographic Mapping of Developments in Land and Air Survey: 1900–1939." *Cartography and Geographic Information Science* 29:155–74.
Colwell, Robert N. 1984. "From Photographic Interpretation to Remote Sensing." *Photogrammetric Engineering and Remote Sensing* 50:1305–7.
Davidson, John I. 1984. "Fiftieth Anniversary Issue: Introduction." *Photogrammetric Engineering and Remote Sensing* 50:1273–74.
Foresman, Timothy W. 2008. "Evolution and Implementation of the Digital Earth Vision, Technology and Society." *International Journal of Digital Earth* 1:4–16.
Katz, Amrom H. 1976. "A Retrospective on Earth-Resource Surveys: Arguments about Technology, Analysis, Politics, and Bureaucracy." *Photogrammetric Engineering and Remote Sensing* 42:189–99.
Kelsey, J. 1986. "The 75th Anniversary of ISPRS." *Photogrammetric Record* 12:93–96.
Kirby, R. P. 2003. "The Merger of the Photogrammetric Society and the Remote Sensing Society." *Photogrammetric Record* 18:59–74.
Lamboit, P. 1974. "History of the Photogrammetric Society." *Photogrammetric Record* 8:5–18.
Robbins, Paul, and Tara Maddock. 2000. "Interrogating Land Cover Categories: Metaphor and Method in Remote Sensing." *Cartography and Geographic Information Science* 27:295–309.
Saxby, Stephen. 2006. "Public Policy and the Development of a UK National Geographic Information Strategy." *International Journal of Law and Information Technology* 14:147–94.

Software.

Mapping Software. The development of mapping software in the second half of the twentieth century helped ordinary people create presentable, publishable maps. Whereas the crafting of professional-looking maps with manual techniques generally required specialized training, computer-assisted mapping not only impelled a huge increase in the number of maps produced but also greatly expanded the role of maps in science, education, government, and ordinary life. Initially rooted in the U.S. software industry—the country's early prominence in computer manufacturing and software publishing made it the undisputed leader in computer-assisted cartography, at least through the 1990s—these developments were in use worldwide by end of the century. In focusing on the United States and emphasizing evolutionary development rather than international diffusion, this entry in no way denies the effects of the Internet and the globalization of the world economy as well as important innovations by software entrepreneurs in other countries, notably Canada, Germany, and the United Kingdom.

Because mapping software creates maps from preexisting geographic data, its history closely follows developments in the creation of map data in standard formats and the systematic coverage of wide areas. No less important were developments in computer operating systems, programming languages, storage media, and display technology. As memory, storage, and graphics capabilities improved, computer mapping became a mass-market commodity embedded in consumer electronics

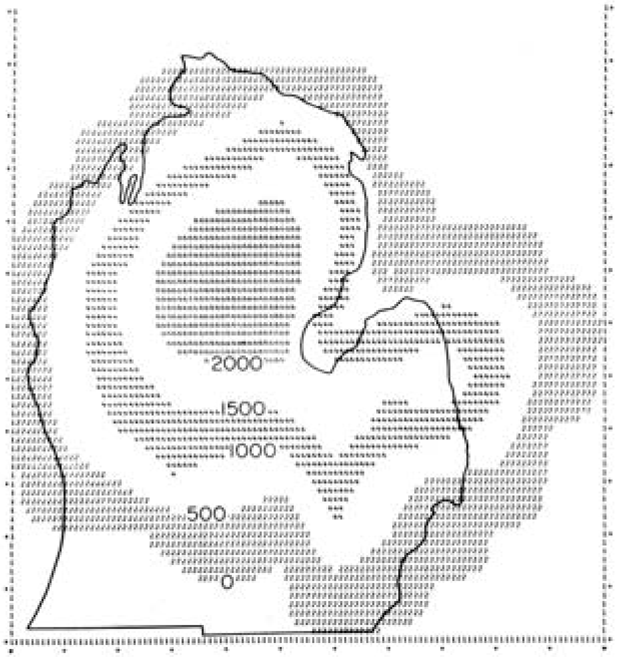


FIG. 895. COMPUTER-GENERATED CONTOUR MAP. Briggs and Pollack created a model of sedimentation in Michigan and published a series of computer-generated contour maps in *Science*. State outlines and contour labels were hand drafted on line printer output.
Size of the original: 12.2 × 11.3 cm. Original in L. I. Briggs and H. N. Pollack, "Digital Model of Evaporite Sedimentation," *Science*, n.s. 155 (1967): 453–56, esp. 455. This reproduction from John W. Harbaugh and Graeme Bonham-Carter, *Computer Simulation in Geology* (New York: Wiley-Interscience, 1970), 7 (fig. 1–5). Permission courtesy of John Wiley & Sons, Inc. Reprinted with permission from the American Association for the Advancement of Science.

or delivered over the World Wide Web (WWW). Unlike early adapters, who needed to understand programming, later users could generate maps by devising short sequences of commands for off-the-shelf software. Application programs evolved from specialized entities in discrete fields such as GIS (geographic information systems), remote sensing, CAD (computer-aided design), contouring, and terrain analysis into generalized programs that combined multiple functionality and data types in a single package (fig. 895).

Mapping software evolved for several distinct user groups. National mapping agencies recognized automation as an efficient strategy for reducing costs, expediting production, and producing maps on demand without the expense of a cumbersome inventory of paper maps. Scientists, administrators, and planners needed maps for their professional duties, and mapping software facilitated the interactive creation of customized or general-purpose maps describing particular phenomena within specific regions. Eventually, mapping software moved into mainstream use with electronic navigation charts for commercial shipping and similar WWW programs and in-vehicle systems for motorists.

Mapping software relies on vector and raster data, and in the 1960s and 1970s, mapping programs fell clearly into one camp or the other. Vector data include coastlines, roads, hydrography, and political boundaries. Digital elevation models (DEMs) constitute the most useful raster data for maps because they allow a three-dimensional depiction of relief, but satellite or aerial imagery can yield a map base rapidly and economically. In the 1970s mapping software relied heavily on vector outlines of states, counties, or similar regions to create maps symbolizing a particular variable for every data area within a region. In the 1990s mapping software typically combined vector and raster data.

Early Developments

Waldo R. Tobler (1959) was perhaps the first to summarize the field of automated cartography and present a vision for its future. He likened the creation of maps on the computer line printers of the late 1950s to using a manual typewriter and showed how a computer guided by a deck of punched cards could create a crude map of the United States (fig. 896).

Computer mapping began in the early 1960s, when a few visionaries recognized the potential of cumbersome mainframe computers. Punched cards provided input for both programs and data, and line printers were the only means of displaying results. Cartographic printouts usually had to be cleaned up for publication, with text and lines added manually. Because the crude output fell far short of publication standards, much of the early development came from disciplines eager for an easy way to view data. Line printers of the era produced ten characters per inch on a horizontal line thirteen inches long, in contrast to a vertical resolution of six characters (or lines) per inch. Map height was virtually unlimited if the printer was set up not to leave blank lines around the perforation between successive fanfold pages, but a map wider than thirteen inches was possible only if the user printed the map in multiple strips, to be trimmed and taped together.

Two institutions contributed to the explosion of computer mapping in the mid-1960s: the Harvard Laboratory for Computer Graphics and Spatial Analysis, established by Howard T. Fisher, and the Kansas Geological Survey, which began publishing computer programs in 1963. Programs were distributed as decks of cards with source code in a language such as FORTRAN. Users at other institutions typically had to modify the source code to get the program to run at their local computer center. The computer industry at the time emphasized

FIG. 896. COMPUTER MAP OF THE UNITED STATES. Tobler published this computer-generated outline map of the United States, which took fifteen minutes to produce from a deck of 343 punched cards. Size of the original: ca. 7.7 × 13.9 cm. From Tobler 1959, 532. Permission courtesy of the American Geographical Society, New York.

hardware, rather than software, which manufacturers like IBM provided almost as an afterthought, if at all.

The Harvard Laboratory's SYMAP program came on 3,000 cards with FORTRAN IV source code for an IBM709/7094. SYMAP produced contour, choropleth, and proximal maps for line printers. J. C. Robertson (1967, 113), who introduced British mapmakers to SYMAP, judged the program "ready for immediate application in certain spheres if cartographic minds can accept a product whose standards are vastly different from those based on long established cartographic principles." Following SYMAP, the Harvard Laboratory created a series of additional programs culminating in a full GIS by the late 1970s.

Early Geologic Mapping Software

Geological methods like trend surface analysis or Fourier surface mapping could convert a few sample points into a smooth output surface that did not tax the capabilities of a line printer. Geographers Richard J. Chorley and Peter Haggett (1965), who explored the early development of trend surface programs, credited much of the development to geologist William C. Krumbein. In addition to a series of progressively more warped smooth surfaces that emphasize regional trends, trend surface analysis allows the separate display and analysis of local deviations. Many of the original programs for trend surface analysis came from the Kansas Geological Survey, where the relatively simple geology of the continental craton encouraged the use of simple geometrical models.

In 1967, when J. M. Forgotson and C. F. Iglehart examined potential uses of computers by exploration geologists, three of their six categories involved computer mapping: trend surface analysis, structure and isopach maps, and facies maps based on computed values. Except for two cartoon figures, all the maps they presented had been manually redrafted for publication, understandable insofar as few journal editors at the time agreed with geographer Torsten Hägerstrand's assertion (1967, 2) that computer-produced "maps are even printable without redrawing if we are willing to accept their peculiar aesthetic characteristics." The inadequacies of line printers and even early pen plotters required extra steps: the computer could merely carry out the computations, and a draftsman could retrace the rough output in ink and add typeset or carefully lettered labels. In some situations the mapmaker could expedite production by superimposing a manually drafted boundary overlay or even an overlay printed on clear plastic.

Mapping Software Goes Mainstream

The *New York Times* traced the rise of computer mapping during the 1970s. Science reporter John Noble Wilford (1973) noted that the U.S. National Ocean Survey had printed its first computer-drawn maps, and two years later the *Times* illustrated an article on computer-aided cartography with a three-dimensional map from

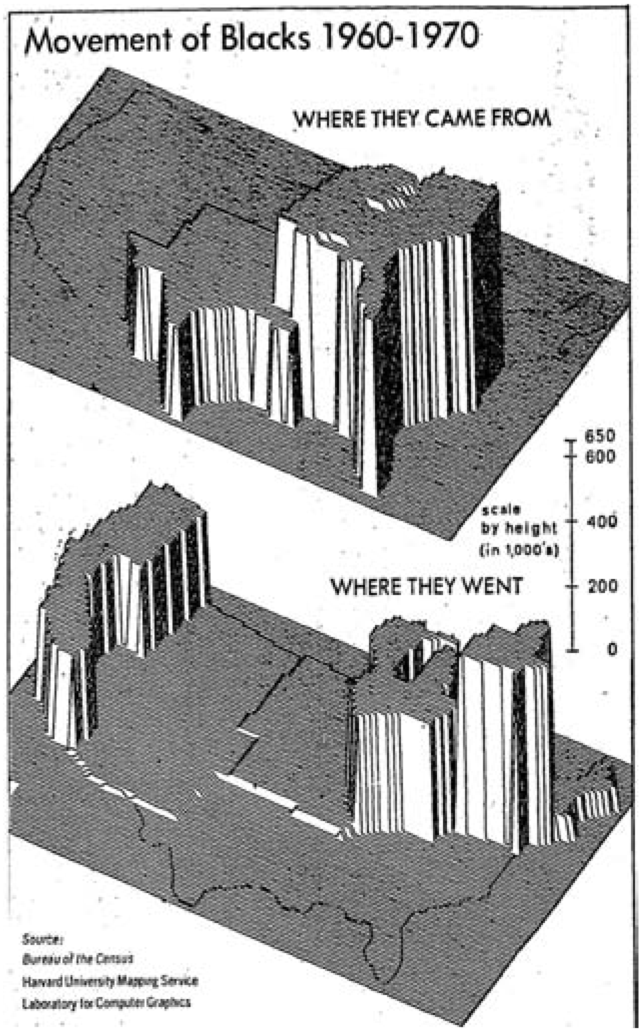


FIG. 897. "MOVEMENT OF BLACKS, 1960–1970." In early 1975 the *New York Times* showed Census Bureau data in three dimensions using the Harvard Laboratory for Computer Graphics software.
Size of the original: ca. 19.3 × 12 cm. From Anonymous 1975. Image courtesy of the *New York Times*.

the Harvard Laboratory (fig. 897) (Anonymous 1975). In 1980 the newspaper characterized scanning projects under way at the U.S. Geological Survey (USGS) and the Defense Mapping Agency (DMA) as a "revolution" (Reinhold 1980), and throughout the 1980s, its reviews of mapping programs geared to general users reflected the rise of the personal computer and the mass marketing of a wide range of software.

In 1981 the IBM personal computer (PC) brought computing into offices, laboratories, and homes and confirmed the professional application of interactive desktop computing recognized by hobbyists in the pioneering Apple II, introduced in 1977. Prices dropped as the mass market created efficiencies of scale. Mapping programs benefited from increased storage, faster processors, enhanced random access memory, better graphical displays, improved desktop scanners, and more efficient printers and plotters. Microcomputers drove out minicomputers and dedicated graphics terminals. Companies like Digital Equipment Corporation and Tektronix, which made the VAX computer and graphics terminals that had showcased the Harvard Laboratory's software, did not survive. The Apple Macintosh arrived in 1984, and homegrown software blossomed, including applications for mapping. People wrote and shared software in languages like Basic and Turbo Pascal, and general computer magazines like *Byte* and *PC Magazine* included source code and assumed that a substantial portion of their readers were hobbyist programmers. As the PC industry matured and programs became more complex, fewer users could program and most relied on commercial software.

Improved hard copy fueled acceptance of computer mapping. While national mapping agencies could afford large-format pen plotters, most users chose the near letter-quality graphics possible on dot matrix printers (fig. 898) with codes standardized by Epson, a Japanese company. Mass-market laser printers appeared in the mid-1980s; prominent pioneers included Hewlett-Packard's LaserJet in 1984 and Apple's LaserWriter

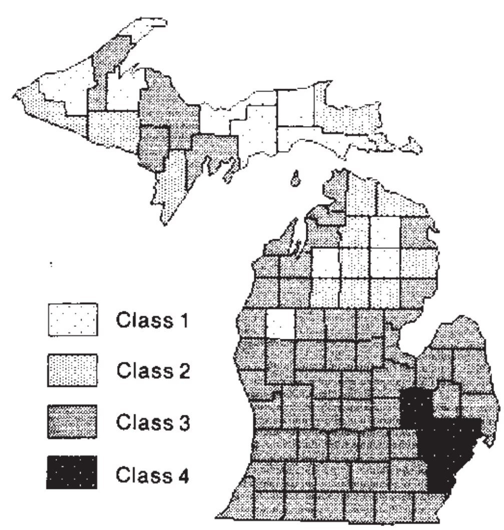


FIG. 898. DOT MATRIX PRINTER MAP. Plumb and Slocum showed how to create cartographic output from a dot matrix printer, which was available at moderate cost to anyone with an inexpensive dot matrix printer in the mid-1980s as personal computer use exploded.
Size of the original: 6.7 × 6.5 cm. From Gregory A. Plumb and Terry A. Slocum, "Alternative Designs for Dot-Matrix Printer Maps," *American Cartographer* 13 (1986): 121–33, esp. 123 (fig. 2) (authors indicated illustration had been reduced 60 percent). Reproduced by permission of Taylor & Francis.

in 1985. Color inkjet printers soon emerged, led by Hewlett-Packard's DeskJet in 1988. With their superior image quality and higher graphic-arts resolution, color printers were much more expensive than black-and-white dot matrix printers until the mid-1990s.

A computer's operating system was a source of either efficiency or frustration. With Microsoft DOS (disk operating system), used by the early IBM PCs, every program required the complicated installation of a printer driver. By contrast, Microsoft's later Windows operating system allowed users to buy a printer with confidence that it would work. Microsoft incorporated printer drivers into Windows 2 in 1987–88, and the 1992 release of Windows 3.1 further widened the popularity of Windows and its graphical user interface. The addition of TrueType fonts in 1991 made font installation and management similarly easy for Windows users. Scalable fonts were readily integrated with a mapping program's cartographic symbols.

The International Association for Mathematical Geology founded *Computers & Geosciences* in 1975; the journal had a broad focus, and the typical issue included several mapping programs. Initially it published source code from camera-ready copy, which was difficult to use because of the tedious retyping and checking required for long programs. After experimenting with other distribution mechanisms, the journal eventually posted source code on an Internet server, freeing valuable journal space at the same time. During the 1980s the Computer Oriented Geological Society (COGS) held several conferences and quickly grew to 1,100 members. In 1989 COGS discontinued its journal in favor of a cooperative arrangement with *Computers & Geosciences*, and the society soon disappeared entirely. From 1985 to 1993 the American Association of Petroleum Geologists published *Geobyte*, which contained technical articles, software reviews, and advertisements of new products. *Geobyte* published over thirty papers on contouring and mapping, and a 1986 review compared and evaluated twenty-two computer mapping systems (Anonymous 1986). Detailed ratings covered six programs for mainframe computers, six for minicomputers, and ten for personal computers. The Association of American Geographers (AAG) had a Microcomputer Specialty Group, which provided an annual award for the best computer program. This morphed into a Computer Applications Specialty Group, which disappeared as computers became ubiquitous.

Digital Data Sets and Common Formats

Creation of digital maps depends upon data to drive mapping software. Even users eager to display only their own data generally need background layers such as coastlines, boundaries, water bodies, and roads, and the increased availability of these data sets in the 1970s and 1980s was a huge stimulus for the development and use of mapping software.

In the late 1950s the U.S. Army Map Service was creating plastic relief maps by scanning paper maps and topographic profiles (Noma and Misulia 1959). These scans provided a prototype for the digital terrain elevation data used for automated terrain contour matching in cruise missiles. As DEMs became available from the USGS and the DMA, the list of common applications grew to include military terrain analysis, intervisibility analysis, slope mapping and cross-country mobility, and terrain visualization. Digital elevation data also supported automated hill shading (Horn 1981). Starting in 1989, research geologist Richard J. Pike and his coworkers at the USGS published high-resolution shaded relief maps of the United States, Italy, and the Mediterranean seabed. These computer-generated maps nearly matched the classic landform maps of cartographer Erwin Raisz, and the algorithms became a mainstay in mapping software. The Shuttle Radar Topography Mission (SRTM), launched in 2000, produced free DEMs covering most of the earth at resolutions of three and thirty arc seconds, and shaded relief images using the SRTM's superb terrain representation became a favored base map for reporting scientific results.

The U.S. Department of State and the Central Intelligence Agency (CIA) created the vector World Data Bank in the 1970s and 1980s. World Data Bank I, which contained about 115,000 points digitized from maps at a nominal scale of 1:12,000,000, was widely used for plotting world maps. World Data Bank II, released in 1977, which contained six million points digitized from maps at about 1:3,000,000, was adequate for small-scale maps of continents. These freely available data were widely distributed in a variety of custom formats, and many computer programs made it easy to extract and plot the data.

The U.S. Census Bureau created a digital database to support data collection for the decennial census. The original GBF/DIME (Geographic Base File/Dual Independent Map Encoding) files grew out of work in the mid-1960s and played a pivotal role in the development of GIS. These files covered about 2 percent of the land area of the country and presaged the TIGER/Line (Topologically Integrated Geographic Encoding and Referencing) system, which first appeared in 1989. TIGER files provided seamless coverage of the streets, water bodies, and major cultural features for the United States and its territories (fig. 899). TIGER data supported creation of comprehensive base maps and, with the WWW, the interactive creation of maps online. Readily available on CD-ROM, and eventually through free downloads on the Internet, TIGER data became ubiquitous (fig. 900).

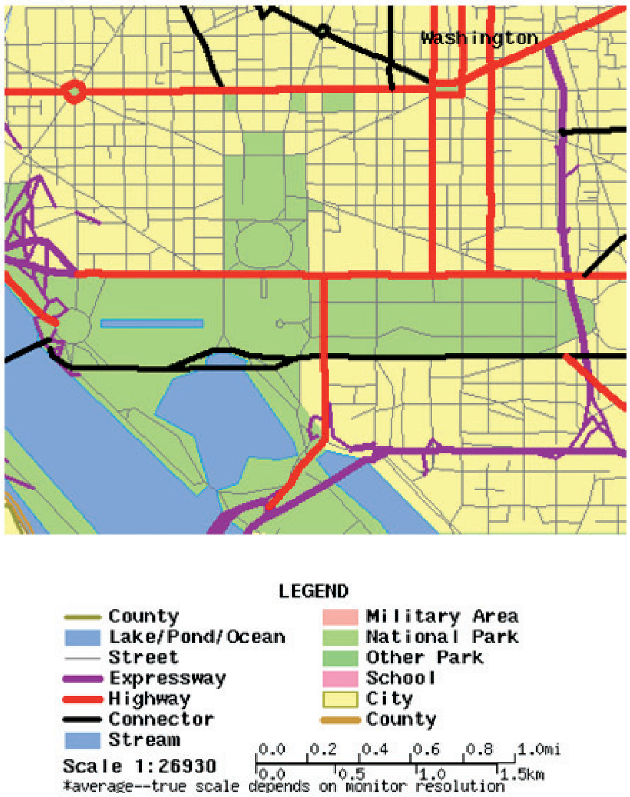


FIG. 899. MAP OF WASHINGTON, D.C., AREA USING THE 1998 TIGER DATA SET. The TIGER data set originally produced for the U.S. Census Bureau allowed creation of maps with basic features. Because of its coverage and no copyright restrictions, the data were widely used and eventually allowed interactive mapmaking on the World Wide Web.

A significant improvement over the World Data Bank II emerged in 1992, when the DMA released the Digital Chart of the World (DCW). Although Environmental Systems Research Institute (ESRI) had produced the data set by digitizing aeronautical charts at 1:1,000,000, fifteen years later the DCW remained the most comprehensive, freely available data set covering the entire world. DMA released the data in its new VPF (vector product format) on moderately priced CD-ROMs, but without copyright so that users like the Pennsylvania State University Libraries could freely redistribute the data in a variety of formats.

Common data formats also facilitated the growth of computer mapping. Despite efforts by mapping organizations and technical standards agencies to create and promulgate formats like the Spatial Data Transfer Standard (SDTS), the two most popular data formats to emerge were ESRI's shapefiles and GeoTIFF. ESRI introduced the vector shapefile format in the early 1990s, and the firm's dominant position in the GIS industry quickly led to an abundance of shapefile data and wide acceptance of shapefiles as a de facto data standard. By contrast, a consortium of companies and organizations in remote sensing created the GeoTIFF format for raster data. As with shapefiles, GeoTIFF gained prominence because data providers wanted their data to be readily useful and software programmers wanted to contend with only the most common formats.

Mapping Programs and Software Packages

Several mainframe mapping packages produced by government mapping agencies achieved widespread distribution. The CIA's Cartographic Automatic Mapping (CAM) program appeared in the 1970s and was converted for microcomputers as MicroCAM, which was distributed by the AAG's Microcomputer Specialty Group. MicroCAM used digital databases, such as World Data Bank II or DCW; as an artifact of the 1990s, created before the advent of common interchange formats, it relied on idiosyncratic formats, which made it difficult to use after data formats became standardized.

In 1981 the National Mapping Division of the USGS produced the General Cartographic Transformation Package (GCTP). The original FORTRAN procedures provided forward and inverse projection for about two dozen cartographic projections; GCTP was later recoded in the C programming language favored by developers of interactive mapping software. Distribution of GCTP on magnetic tape helped software developers incorporate map projection and consequently standardized the mathematics of projections. Further standardization followed the publication in 1987 of John Parr Snyder's *Map Projections—A Working Manual*, which provided additional algorithms for countless software developers.

In the mid-1980s, a number of desktop mapping programs appeared. In 1986, academic cartographer Michael P. Peterson released MacChoro, the only mapping program available at the time for Macintosh computers. The original MacChoro produced choropleth maps, and a second version, released in 1988, created map animations. In 1986, a group of students at Rensselaer Polytechnic Institute founded Navigational Technologies, Inc., to create in-car navigation systems that combined inertial navigation hardware with geographic software. When the task proved overly daunting, the firm renamed itself MapInfo and refocused on geographic software for the personal computer market. Designed principally for Windows computers, MapInfo supported a variety of mapping applications using demographic data for households and areal units.

In the mid-1980s, the U.S. military created a number of terrain analysis programs. One of the first was MicroFix, which ran on an Apple II linked to a videodisc

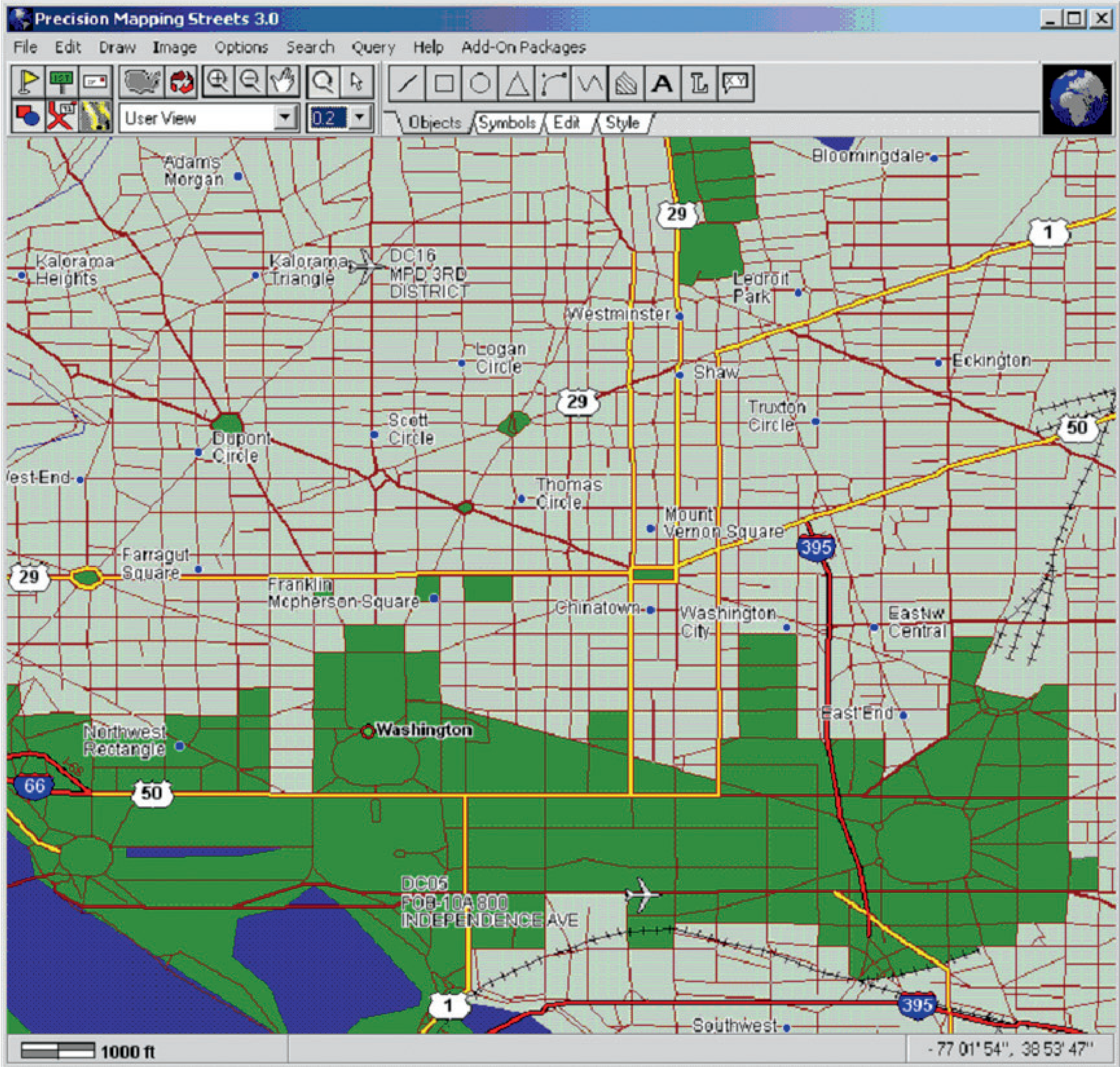


FIG. 900. STREET MAP OF WASHINGTON, D.C., AREA. The 1997 program Precision Mapping Streets 3.0 used U.S. Census Bureau TIGER files to provide the basic map data and featured a graphical user interface to compose maps. Image courtesy of Peter L. Guth. Permission courtesy of UnderTow Software Corporation, North Andover.

containing registered images of terrain maps; vector overlays could be created and plotted for army intelligence and terrain analysis applications. TerraBase, created at West Point for MS-DOS machines, used DEMs to produce three-dimensional block diagrams, contour maps, viewshed maps, and intervisibility plots. The package exemplified the flexibility possible through incremental iterative software development (Peuquet and Bacastow 1991). In 1990 the U.S. Air Force initiated work on FalconView, a program for mission planning that supplemented commercial GIS and imagery analysis software; later versions were customized for the navy and army. All of these military applications packages required maps as base layers.

Briefly during the 1990s, the USGS and the National Imagery and Mapping Agency (NIMA, formerly the

DMA), produced mapping software for viewing their data. Although both agencies had traditionally considered themselves data producers, some officials saw mapping software as a way to generate demand for their new data formats. A student intern at the USGS's Mid-Continent Mapping Center in Rolla, Missouri, wrote initial code for the DLGV32 program, but development stopped when the internship ended. DEM3D, a second USGS program that displayed DEMs but proved impossible to maintain, illustrated the tensions within a mapping agency uncertain about its responsibility to go beyond data creation (Moore 1999). Similarly, NIMA produced NIMAMUSE and VPFVIEW to display their digital data but could not afford to support the software.

By contrast, Generic Mapping Tools (GMT), a project initiated in 1988, exemplified the vitality of an endeavor run by volunteers who updated it for over two decades with support from the National Science Foundation (Wessel and Smith 1991). A command line suite of about sixty programs, GMT created maps with thirty supported projections. Although its main use has been in the earth sciences, it easily produced geophysical map overlays with earthquake locations, fracture zones, magnetic anomalies, and many other features (fig. 901).

Large statistical software packages, with a repertoire of histograms and pie charts, added a map extension that typically included county and state boundary files for making choropleth maps. Particularly influential were SAS and SPSS, marketed respectively for business decision making and the social sciences and readily available at most university computer centers during the 1980s. After mapping software converged with GIS programs in the 1990s, the software market bifurcated and most statistical packages lost their cartographic capability. Microsoft's Excel 2000, a widely used spreadsheet data analysis program for personal computers, had mapping capabilities, but Excel 2002 and later versions lacked a mapping add-on. Unwilling to abandon cartography completely, Microsoft introduced MapPoint 2000, a business-oriented graphics package able to create statistical maps of demographic data organized by ZIP codes or census units.

By the mid-1990s, a number of factors allowed companies to market inexpensive mapping programs and electronic atlases to the general public. The dominance of Windows had created a huge market attractive to software developers, and the Windows graphical user interface fostered interactive mapmaking as well as hands-on analysis of spatial data. The Census Bureau's TIGER data provided royalty-free vector base data, and creative data structures and data compression algorithms could pack a road network covering the entire United States onto a single CD-ROM. By the end of the century the consumer electronics industry was marketing inexpensive Global Positioning System (GPS) receivers with mapping capabilities especially attractive to motorists and hikers.

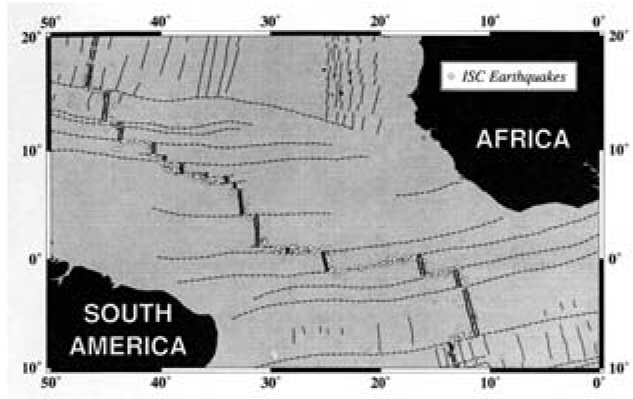


FIG. 901. BASE MAP CREATED BY THE GENERIC MAPPING TOOLKIT (GMT). This map shows marine magnetic anomalies, fracture zones, the Mid-Atlantic Ridge, and earthquake epicenters. GMT uses a series of command line–driven programs to create maps.
Size of the original: 7.4 × 12.1 cm. From Wessel and Smith 1991, 445 (fig. 3). Permission courtesy of John Wiley & Sons, Inc.

Mapping Software in Larger Systems

Developed by the American military, GPS proved useful to field commanders during the Persian Gulf War of 1990–91 but did not become fully operational until 1995. Expensive systems for civilian use had been available since 1989, but these early GPS receivers had no map display; users eager to view positions on a map had to connect the receiver to a computer. By 1995, Magellan was marketing an in-vehicle GPS navigation system, which heralded the integrated device with a screen that could be built into the dashboard, or attached to the dashboard or windshield. These systems required vector map data, and their increasingly sophisticated "mapping engines"—high-performance built-in mapping software merited a new name—kept the direction of the travel at the top of the screen and provided a three-dimensional view of the upcoming landscape. This mapping software left few options to the user but made mapping software a consumer commodity.

In the mid-1990s the International Hydrographic Organization and the International Maritime Organization adopted standards whereby an electronic chart and display system aboard a ship could comply with the International Convention for the Safety of Life at Sea, which required reliable and up-to-date charts. Compliance required not only charts with an approved vector format from government hydrographic offices but also display software that produced a reliable and faithful representation consistent with traditional cartographic standards. The chart would show the current position calculated by the GPS and automatically scroll as the vessel moved. Within rigid constraints, this placed mapping software in life-and-death situations on the bridges of ships. Although some interim and recreational systems used scanned raster map data as a cheaper alternative, efficient updating dictated the use of vector data.

Mapping software moved online with the rise of the WWW in the late 1990s. MapQuest's web service, inaugurated in 1997, allowed users to type in an address, view a street map, and get directions. Competitors duplicated the service and added digital imagery as an additional layer that could be toggled on and off. Google Maps created a new data format whereby interested individuals could add data to its free maps; electronic pushpins inserted on the map provided a link to photos supplied by the user or ads supplied by Google.

Summary

Mapping software evolved from a specialized market of interest to a few professional cartographers to a commodity affecting a large and diverse group of user communities, whose constituents often had little or no formal training in map use or computer technology. By the end of the twentieth century mapping software running on mobile phones, automobile navigation systems, and the WWW was providing vast numbers of users with customized, often intuitive views of the world. GIS and other mapping software gave mapmakers and other specialized users enormous power and flexibility for exploring and exploiting geographic data.

PETER L. GUTH

SEE ALSO: Drafting of Maps; Harvard Laboratory for Computer Graphics and Spatial Analysis (U.S.); SYMAP (software)

BIBLIOGRAPHY:

Anonymous. 1975. "Computer-as-Mapmaker." *New York Times*, 26 January, sec. 4, 7.

———. 1986. "CEED II: Mapping Systems Compared, Evaluated." *Geobyte* 1, no. 5:25–40.

Chorley, Richard J., and Peter Haggett. 1965. "Trend-Surface Mapping in Geographical Research." *Transactions of the Institute of British Geographers* 37:47–67.

Forgotson, J. M., and C. F. Iglehart. 1967. "Current Uses of Computers by Exploration Geologists." *American Association of Petroleum Geologists Bulletin* 51:1202–24.

Hägerstrand, Torsten. 1967. "The Computer and the Geographer." *Transactions of the Institute of British Geographers* 42:1–19.

Horn, Berthold. 1981. "Hill Shading and the Reflectance Map." *Proceedings of the IEEE* 69:14–47.

Moore, Larry. 1999. "Government Freeware for Viewing U.S. Geological Survey Digital Cartographic Data." In *From Image to Information: Proceedings, 1999 ASPRS Annual Conference*. CD-ROM.

Noma, Arthur A., and Michael G. Misulia. 1959. "Programming Topographic Maps for Automatic Terrain Model Construction." *Surveying and Mapping* 19:355–66.

Peuquet, Donna J., and Todd Bacastow. 1991. "Organizational Issues in the Development of Geographical Information Systems: A Case Study of U.S. Army Topographic Information Automation." *International Journal of Geographical Information Systems* 5:303–19.

Reinhold, Robert. 1980. "Revolution Changes the World of Maps." *New York Times,* 23 September, C-2.

Rhind, David. 1977. "Computer-Aided Cartography." *Transactions of the Institute of British Geographers*, n.s. 2:71–97.

Robertson, J. C. 1967. "The SYMAP Programme for Computer Mapping." *Cartographic Journal* 4:108–13.

Snyder, John Parr. 1987. *Map Projections—A Working Manual*. Washington, D.C.: United States Government Printing Office.

Tobler, Waldo R. 1959. "Automation and Cartography." *Geographical Review* 49:526–34.

Wessel, Paul, and Walter H. F. Smith. 1991. "Free Software Helps Map and Display Data." *EOS (Transactions, American Geophysical Union)* 72:441, 445–46.

Wilford, John Noble. 1973. "U.S. Nautical Charts, Once Adorned by Mrs. Whistler's Son, Now Drawn by Computer." *New York Times*, 12 August, 36.

———. 1983. "Mapping in the Space Age." *New York Times Magazine,* 5 June, 46–50, 55–57.

Illustration Software. Beginning in the late 1980s, illustration software provided an affordable microcomputer-based alternative to manual map production methods such as pen-and-ink drawing, hand engraving (scribing) of film negatives, stick-up lettering, and peel-coats (Mattson 1989). It also enabled cartographers to employ new laser imagesetting technology to prepare the color-separated film negatives required for offset printing instead of using the prevailing photomechanical methods (Mattson 1990).

Illustration software emerged as a new product category in 1987, when Adobe Systems, Inc., released Adobe Illustrator 1.0 in the wake of Apple Computer's 1986 launch of the Macintosh Plus personal computer and the LaserWriter Plus printer. The LaserWriter produced xerographic images by interpreting digital files encoded with Adobe's PostScript page description language. Illustrator enabled graphic designers to draw and edit lines, polygons, symbols, and typography using a computer mouse or tablet and to print these at medium resolution using the LaserWriter (300 dots per inch [dpi]) or at high resolution using PostScript laser imagesetting devices (2,400 dpi and higher). In 1985, Paul Brainerd, chairman of Aldus Corporation—makers of PageMaker page layout software and, later, FreeHand illustration software—coined the term "desktop publishing" to describe the capabilities of these emerging PostScript-based hardware and software products (Sosinsky 1991, esp. 15).

In PostScript files sent from Illustrator to printing devices, a line is represented as a series of Bezier curves, each consisting of the coordinates of an "anchor point" and two "handle points" that define the shape of the line segments on each side of the anchor. A polygon is a

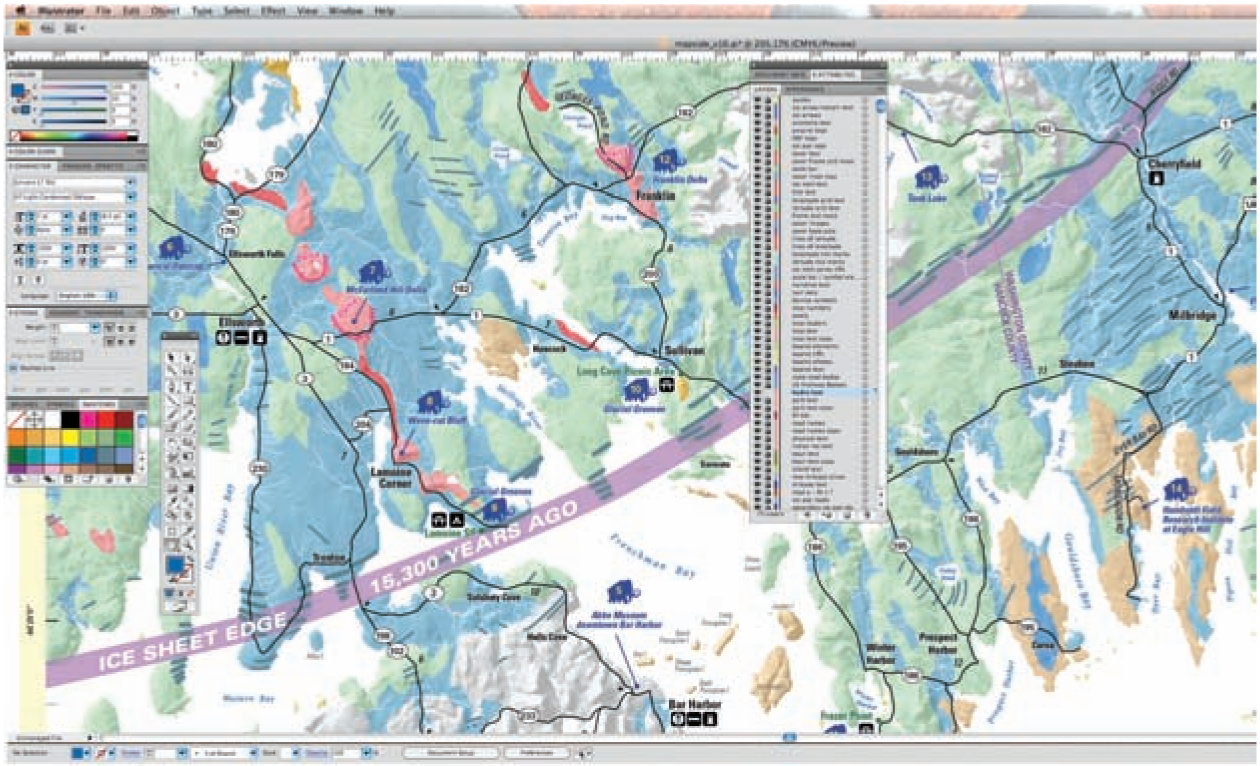


FIG. 902. ADOBE ILLUSTRATOR INTERFACE. The interface shows design windows, map layers, and a portion of a map designed by Michael Hermann. Image courtesy of Michael Hermann, University of Maine Canadian-American Center, Orono, Maine.

line that begins and ends at the same anchor point, and can be filled with a color or pattern. Illustrator users draw PostScript lines and polygons by manipulating on-screen graphic representations of the anchor and handle points using a mouse pointing tool and by controlling the graphic attributes of these elements through a variety of windows and palettes (fig. 902). They place PostScript fonts and symbols using text editing tools similar to, but more flexible than, those found in word processing software.

In response to the rapidly growing desktop publishing market, competing illustration software products followed soon after Adobe Illustrator 1.0. In 1988, Aldus FreeHand introduced several features that were particularly appealing to cartographers. One was the ability to draw freehand (rather than point-by-point) lines. This made it easier to trace scanned images of source maps. Another attractive feature was the ability to assign graphic elements to discrete layers, like the layers of photomechanical film so familiar to cartographers of that time. In 1989, Corel Corporation's CorelDRAW introduced illustration software to Microsoft Windows users. CorelDRAW featured a collection of filters that allowed users to import digital files from computer-aided design (CAD) packages like Autodesk AutoCAD that were already widely used for engineering and facilities management applications. Windows versions of Adobe Illustrator and Aldus FreeHand followed soon after.

Illustration software is closely related to CAD. In the second half of the twentieth century, CAD software replaced mechanical drafting for many architects, engineers, and land surveyors. Like illustration software, CAD provides a graphical user interface for producing digital drawings in vector form using a mouse pointing tool or digitizing tablet. The digital elements of CAD drawings, like drawings produced with Illustrator or similar products, include points, lines, and polygons that are referenced to two-dimensional grids with x, y coordinates. Illustration software and CAD differ fundamentally from mapping software and geographic information systems (GIS) in that the coordinate locations of digital drawing elements are not georeferenced. In other words, the coordinates encoded in CAD drawings and illustration files do not refer explicitly to unique locations on the earth's curved surface, as do latitude and longitude coordinates, for instance. Both CAD and illustration software were used in the late twentieth century for map production and publication projects, especially those that permitted the earth to be treated as a flat surface. Many cartographers preferred illustration software over CAD because it was relatively inexpensive, and because illustration software provided tools needed specifically for the graphic design of printed pages rather than the engineering design of buildings and other objects.

Because the map production methods in use among a cross-section of public agencies and private firms has not been documented, indirect measures and anecdotal evidence are needed to judge the impact of illustration software on professional practice in twentieth century cartography. One such measure is a survey of production technologies taught in introductory cartography classes in higher education institutions in the United States and Canada. In 1990–91, James F. Fryman and Bonnie R. Sines found that computers were used in only slightly more than half of 193 responding institutions, and that illustration software accounted for only 7 of 214 software packages cited by instructors. By 1995, however, a repeat survey revealed that 82 percent of 145 respondents had adopted computer-assisted methods, and that 43 percent (62 respondents) used illustration software to teach introductory cartography. Furthermore, Fryman (1996, 12) found that instructors characterized illustration software as the "most 'important'" software type they used—more important than thematic mapping software (such as Atlas*Graphics and Surfer), GIS software, or CAD. It is important to note, however, that this rapid uptake of illustration software by cartography teachers in North America was not representative of cartographic education in the developing world (e.g., Ormeling 1996; Ikhuoria 1995), where computing resources remained scarce.

Several leading private-sector firms that specialized in printed map products also adopted illustration software in the late 1980s and early 1990s. For example, in 1988 R. R. Donnelley & Sons Cartographic Services produced its first two-color telephone directory maps using Illustrator 88 (Daniel Etter, personal communication, 2007). Established that same year in Greenville, South Carolina, the U.S. branch of Michelin Maps and Guides adopted Aldus FreeHand immediately for cartographic production, and published its first guide book in 1991 using desktop publishing techniques. This was a departure from Michelin's home office in Paris, which continued to rely upon photomechanical methods for its European map series until the mid-1990s (Peter Wrenn, personal communication, 2007). Allan Cartography (Medford, Oregon), makers of the Raven Maps series and other products, began its transition to FreeHand in 1994, by which time large-format laser imagesetting had become viable (Allan 1999; Lawrence Andreas, personal communication, 2007).

Two milestone publications bracket the technological transition at the National Geographic Society—the 1988 *Historical Atlas of the United States*, which was produced by manual methods, and the seventh edition of the *National Geographic Atlas of the World*, published in 1999 using physical and political plates produced by digital means, including illustration software (ESRI, Inc. 2005; Allen Carroll, personal communication, 2007). By the end of the twentieth century, the cartographic production workflow at several leading mapping firms relied upon the Adobe Illustrator PostScript format (or related image formats) to serve as a bridge between the georeferenced database management capabilities of GIS software and the graphic design capabilities of Illustrator and FreeHand. Not all firms adopted this approach, however. Rand McNally, for instance, has relied primarily on proprietary data management and map production techniques based on GIS since the late 1980s (Andy Skinner, personal communication, 2007). In general, however, while cartographic managers in North American commercial firms recognize the increasing capabilities of GIS software for cartographic design, illustration software remained a key element of the state of the art. A collection of profiles of governmental organizations, commercial companies, and freelance cartographers in the United Kingdom at the outset of the twenty-first century suggested that the persistence of illustration software was not limited to North America (Forrest, Fairbairn, and Chilton 2007, 153–76).

Illustration software found a niche in late twentieth-century cartography because it provided an alternative to labor-intensive and space-consuming manual production methods without compromising the aesthetic qualities of fine printed maps. Meanwhile, early mapping software packages like SYMAP in the 1960s and later GIS software in the 1980s demonstrated the potential of computer-assisted management, analysis, and visualization of georeferenced data. Thematic maps produced with early specialized mapping and GIS software tended to be crude by the standards of professional cartographers, however. In the early 1990s, cartographers began to use PostScript encoding to bridge the gap between specialized mapping and illustration software. The earliest adopters modified PostScript printer files exported from mapping and GIS software so that the files could be opened and edited in Adobe Illustrator (Rosenthal 1989; DiBiase 1991). Soon thereafter, ArcView software by Environmental Systems Research Institute (ESRI) incorporated an option to export Illustrator-compatible PostScript files for map finishing in illustration software. A new software product called MAPublisher by Avenza Systems, Inc., which appeared in 1995, allowed mapmakers to open, edit, and work with GIS data and associated database tables directly in Illustrator or FreeHand. Not until the late 1990s were comparable graphic design tools incorporated into commercial GIS software (i.e., ESRI's ArcGIS 8.x). A milestone in the incorporation of cartographic design tools in GIS software was the publication in 2001 of the atlas *Mapping Census 2000* by Cynthia A. Brewer and Trudy A. Suchan, every page of which was produced from start to finish using ArcGIS software. At the end of the century, illustration software had become for some organizations, most notably the U.S. Census Bureau, an application of last resort (Trainor 2007; Timothy F. Trainor, personal communication, 2007), to be used only for very specialized cartographic design tasks not easily accomplished with standard GIS software. For many other individuals and firms, however, illustration software remained a key tool for the design and production of printed maps.

DAVID DIBIASE

SEE ALSO: Drafting of Maps

BIBLIOGRAPHY:

Allan, Stuart. 1999. "The Digital New World Order: A View from the Private Sector." *Cartography and Geographic Information Science* 26:201–14.

DiBiase, David. 1991. "Linking Illustration and Mapping Software through PostScript." *Cartography and Geographic Information Systems* 18:268–74.

Environmental Systems Research Institute (ESRI), Inc. 2005. "*National Geographic Atlas of the World, Eighth Edition*, Updated with GIS." *ArcNews*, Summer, 30–31.

Forrest, David, David Fairbairn, and Steve Chilton, eds. 2007. "Cartographic Activities in the United Kingdom, 2003–2007, National Report to the International Cartographic Association's 14th General Assembly, Moscow, Russia, August 2007." *Cartographic Journal* 44, no. 2.

Fryman, James F. 1996. "Cartographic Education in the United States and Canada." In *Cartographic Education in Transition: An International Perspective*, ed. C. Peter Keller and Ute Janik Dymon, Monograph 48, *Cartographica* 33, no. 3:5–13.

Fryman, James F., and Bonnie R. Sines. 1990–91. "Anatomy of the Introductory Cartography Course." *Cartographic Perspectives* 8: 4–10.

Ikhuoria, Isi A. 1995. "A Study of the Status of Academic Cartography and GIS in Nigeria." *Cartographica* 32, no. 4:43–54.

Mattson, Mark T. 1989. "Desktop Mapping at Temple University." *Cartographic Perspectives* 3:3–12.

———. 1990. "Imagesetting in Desktop Mapping." *Cartographic Perspectives* 6:13–22.

Ormeling, Ferjan. 1996. "Realities of Teaching Cartography in the Developing World." In *Cartographic Education in Transition: An International Perspective*, ed. C. Peter Keller and Ute Janik Dymon, Monograph 48, *Cartographica* 33, no. 3:33–38.

Rosenthal, Iden. 1989. "The Best of Both Worlds: Linking the WORLD Projections Package with Macintosh Drawing Programs." *Cartographic Perspectives* 2:16–17.

Sosinsky, Barrie A. 1991. *Beyond the Desktop: Tools and Technology for Computer Publishing*. New York: Bantam Books.

Trainor, Timothy F. 2007. "Census Cartography 2007: Reflections, Status, and Predictions." *Cartography and Geographic Information Science* 34:169–71.

Image Processing Software. Digital image processing developed in the late 1960s and early 1970s. The term describes the use of computer algorithms to perform image processing on digital images. Computer-based processing allowed a much wider range of algorithms to be applied to the input data than the previous analog image processing, such as additive color viewing and spot densitometry, which had reached a significant level within the countries participating in Interkosmos, the Soviet space program (Akademie der Wissenschaften der DDR et al. 1983). It prevented problems such as the buildup of noise and signal distortion during processing. It also permitted the use of much more complex approaches for image processing and could hence offer both more sophisticated performance at simple tasks and the implementation of methods that would be impossible by analog means. Within the last three decades of the twentieth century, raster-based digital image processing gained increasing importance in comparison to vector graphics. By the end of the century, digital imagery represented an inevitable integral constituent of most geoinformation systems.

Many of the early techniques of image processing, or digital picture processing as it was often called, were developed in the 1960s in the United States at the Massachusetts Institute of Technology, the National Aeronautics and Space Administration's Jet Propulsion Laboratory (Moik 1980), the University of Maryland, Purdue University, Bell Labs, and a few other places. In Europe and Japan, applications like wire photo standards conversion, medical imaging, character recognition, photo enhancement, and—of particular importance for the development of cartography—satellite imagery were developed.

Initially, the cost of processing was fairly high due to the computing equipment of that era. In the 1970s, digital image processing proliferated when cheaper computers and dedicated hardware became available. Images could then, for some dedicated problems, be processed in real time. When during the 1980s general-purpose computers became faster, they started to take over the role of dedicated hardware for all but the most specialized and computation-intensive operations. Thus, around 1980, the first satellite image maps were produced (Colvocoresses 1984).

In 1989, the first textbook dedicated to cartographic applications of digital satellite imagery was published (Buchroithner 1989). With faster computers and signal processors available in the late 1990s, digital image processing became the most common form of image processing and is—as in remote sensing and cartography—the preferred tool because it is not only the most versatile but also the cheapest.

By the 1990s the following five major categories of image processing operations emerged: image compression, image restoration, image enhancement, image rectification (for cartographic purposes, geocoding), and image information extraction. Today, image compression is familiar to most people. It involves reducing the amount of memory needed to store a digital image and also the processing times, for example, when applying a principal component analysis (PCA). Image compression techniques gained increasing importance with the emergence of higher-dimensional spectral imagery and ultra-high spatial resolution. Image restoration and image enhancement techniques are used to correct image defects, which could be caused by the digitization process or faults in the imaging conditions, for example, bad meteorological conditions during data capture of remote sensing imagery.

Image restoration can be divided into radiometric corrections (mainly due to relief effects or atmospheric disturbances) and geometric corrections of actual imaging faults of the sensor (mainly in the early days of remote sensing). The early and influential paper by Pat S. Chavez (1975) led to the increasing importance of atmospheric modeling of geoimages during the 1980s and, in particular, the 1990s. Image enhancement consists of radiometric enhancement and spatial enhancement, which apply filtering techniques (convolution).

Image information extraction (or image measurement extraction) comprises all methods aimed at gaining either thematic or metric information contained in an image. This is frequently referred to as image analysis or scene analysis, two umbrella terms for extraction of both descriptive and geometric information (cf. also pattern recognition). The various methods of image classification represent the core of it. Within the last two decades of the twentieth century multidimensional image processing, part of which is multichannel image processing, utilized multiple images, for example, spectral bands of one sensor or imagery deriving from different sensors. This "data fusion" opened new dimensions in the classification of surface materials. In the late 1980s the emergence of hyper-spectral remote sensing data led to the application of manifold input data sets. The use of multivariate data became, with the increasing availability of multisensor imagery, more and more important during the 1990s.

Also in the 1990s, digital terrain models (DTMs) were increasingly integrated into the processing of remotely sensed imagery by not only using them to improve relief-dependent classifications for both topographic and thematic maps but also for visualization purposes, draping image texture over the DTMs and thus creating photo-realistic landscape views. The availability of comparatively cheap off-the-shelf image processing packages, and later open-source software, was beneficial to the increased use of digital imagery in cartography, whether or not it was remotely sensed. At the end of the twentieth century there was no single, clearly dominant software package.

MANFRED F. BUCHROITHNER

SEE ALSO: Map: Images as Maps; Remote Sensing: Data Handling and Information Extraction from Remotely Sensed Imagery

BIBLIOGRAPHY:

Akademie der Wissenschaften der DDR et al., eds. 1983. *Fotografische Fernerkundung der Erde: Experimente auf der Orbitalstation "Salut-6" = Komicheskoye zondirovaniye zemli: Eksperimenty s borta orbital'noy stantsii "Salyut-6."* Berlin: Akademie-Verlag.

Buchroithner, Manfred F. 1989. *Digitale Methoden, Reliefkartierung, geowissenschaftliche Applikationsbeispiele*, vol. 2 of *Fernerkundungskartographie mit Satellitenaufnahmen*. Vienna: Deuticke.

Chavez, Pat S. 1975. "Atmospheric, Solar, and MTF Corrections for ERTS Digital Imagery" (abstract). In *Proceedings of the American Society of Photogrammetry Fall Convention*, 69–69a. Falls Church: American Society of Photogrammetry.

Colvocoresses, Alden P. 1984. "The Status and Future of Satellite Image Mapping." *Proceedings of the Eighteenth International Symposium on Remote Sensing of Environment*, 3 vols., 2:957–60. Ann Arbor: Environmental Research Institute of Michigan.

Moik, Johannes G. 1980. *Digital Processing of Remotely Sensed Images*. Washington, D.C.: National Aeronautics and Space Administration.

Geographic Information System (GIS) Software. The term geographic information system(s) (GIS) was coined in the 1960s by the developers of Canada Geographic Information System (CGIS), the first known GIS application. GIS shares some of its characteristics with computer-aided design (CAD), a technology used by engineers, architects, planners, and others to produce blueprints for buildings, furniture, airplanes, watches, and similar designs. Like GIS, CAD has been used to produce maps, but whereas in a CAD graphic capabilities are at the heart of the system, at the core of GIS are functionalities for querying and managing geographical databases. Like CAD, GIS is a relatively recent technology; many of its early pioneers remained professionally active in universities, private companies, research centers, and government agencies into the twenty-first century. Writing in 1991, J. T. Coppock and David Rhind described the history of GIS as composed of four stages: the first extended from the 1960s to about 1975, with individual personalities playing a critical role; the second, from 1973 until the early 1980s, was characterized by government-funded research, with a diminished role of the individual or the institution; the third, from 1982 to the late 1980s, was characterized by commercial dominance; and the fourth, current at the time of Coppock and Rhind's paper, was the stage of user dominance, competition among vendors, and embryonic standardization. To complete the chronology, the last decade of the twentieth century saw the widespread diffusion of GIS among the academic, government, and private-sector communities, and to some extent among the general public. This diffusion was facilitated by technical advancement in computer technology, reduction in the cost of acquiring hardware and software, and progress in spatial analysis. National and international standardization efforts resulted in easier sharing of data, helped by the Internet revolution, while the market consolidated around relatively few key players. The 1990s also saw the beginning of a critical assessment of the role of GIS in relation to traditional disciplines like geography.

The history of GIS is not very well documented, especially regarding software development. Even so, to even briefly report on this history requires making choices regarding the events, institutions, and people highlighted; omissions are inevitable. The early history of GIS during the 1960s and 1970s is particularly important to understand, as it was during these two decades that the technical and theoretical foundations at the basis of many core GIS software functionalities were conceived and implemented. The origin of GIS lies at the confluence of technical advances in computer technology in the 1950s and 1960s, cartographic needs of government agencies, and theoretical advances in geography and spatial analysis. Influential theoretical works include Waldo R. Tobler's 1959 paper on automation and cartography, Torsten Hägerstrand's 1967 paper on the computer and the geographer, and especially Ian L. McHarg's 1969 book describing how to overlay various data themes using transparent sheets to assist with locational decision making. These works were preceded in 1950 by Jacqueline Tyrwhitt's description of the process of overlaying data themes.

Advances in computer technology in the 1950s and 1960s made it possible to investigate the feasibility of making maps with the computer, and early projects like CGIS were motivated in large part by the need to minimize the costs associated with the creation and updating of large numbers of maps. As a consequence, early systems such as GIMMS (Geographic Information Mapping and Manipulation System) and SYMAP (synagraphic mapping) were heavily focused on cartographic operations like digitizing, plotting, transforming coordinates, and projecting maps. Of course, the financial resources needed at this time to make maps using the computer meant that government agencies like Canada's Agricultural Rehabilitation and Development Administration (ARDA), or well-endowed institutions like Harvard University through a Ford Foundation grant, were among the few institutions capable of meeting the challenges of developing computer cartography and GIS.

The impulse for what was to become CGIS dates back to the late 1950s, and was a direct consequence of the Canadian government's policy decision to start managing its natural resources. This required the creation of a large number of new or updated maps (about 1,500) at scales ranging from 1:20,000 to 1:250,000. Recognizing the financial magnitude of the enterprise, the government sought alternatives to manual data creation and analysis from the very beginning. What was to become CGIS arose from those needs and the leadership, vision, technical skills, and even chance encounters of a few individuals. The story is vividly recalled in a 1998 essay by Roger F. Tomlinson, one of the fathers of GIS. While an employee of Spartan Air Services in Ottawa in 1960, Tomlinson started experimenting with the use of computers to help locate forest plantations in East Africa. Encounters with John Sharp of IBM in 1960 and Lee Pratt of the Canada Land Inventory in 1962 laid the foundation for the technical and intellectual impulse to start CGIS. In a report written for the National Land Capability Inventory Seminar in Ottawa in November 1962, Tomlinson established the functional requirements for a geographic information system whose objective was "to analyze geographical data over any part of a continent-wide area" (Tomlinson 1998, 25). Lee Pratt, Al Davidson from the Department of Agriculture, IBM, and Spartan Air Services followed up on Tomlinson's report with an economic feasibility study and the beginning of the development work. Tomlinson joined ARDA to direct the development of the system, which took forty people and the rest of the decade to accomplish. CGIS became fully operational in 1971 and continued to be developed well into the 1980s.

According to Tomlinson's 1962 report, the new system ought to be able to perform a mix of cartographic and spatial analytical functions, including the output of analytical results in tabular or map form, the automatic edge matching of map sheets, the automatic recognition of several types of topological errors, and the handling of data from many maps in a seamless nationwide structure. Additionally, the system had to be able to convert existing paper maps to digital form via scanning for polygon boundaries, digitizing selected points inside polygons, and keypunch input of descriptors and statistical data (Tomlinson 1998, 25). The GIS that resulted—the staff of CGIS settled on the term geographic information system around 1964—possessed several revolutionary characteristics, including the spatial organization of the data in frames (near squares) composed of the largest units that could be processed by the computers available at the time. This data structure is a precursor of the raster data model used in GIS software packages today. (Raster-based systems use a grid composed of cells, usually square, of equal size on the ground; each cell in a certain data theme [e.g., land use] is assigned one and only one value or category [e.g., residential].)

In the CGIS, the arrangement of frames was crucial to ensuring the system's efficiency with the relatively slow computers available at the time. An arrangement was designed by Guy Morton in 1966 on the principle that frames near each other geographically should also be near each other in the sequence used by the computer to search data on a magnetic tape. Morton created an efficient search algorithm with these characteristics, the Morton Matrix, a structure known as the quadtree in later systems. Other principles from CGIS that were to become standard in future GIS software packages included the idea that data should be kept separate from its representation, which meant organizing data in tables that could be queried, with the results output to a printer or plotter. Another important characteristic of the system was its interface: users could interact with the computer through a series of easily understandable commands written in plain English. Data retrieval commands included such self-explanatory terms as *read*, *select*, *merge*, *classify*, and *plot*. The ability to overlay data themes to determine optimal locations was one of the reasons the Canadian government wanted a geographic information system, and CGIS included an *overlay* function that allowed users to lay one map on top of another (up to a maximum of eight) to create a composite map, technically described as a coverage.

CGIS efforts did not occur in a vacuum, of course, as efforts in Europe (Rhind 1998), the United States, and elsewhere contributed to advances in the field. The Swedish government started a program on geographical data processing in 1967 with funding from the National Swedish Council for Building Research—Staten råd för byggnadsforskning. The program produced the NORMAP system, which included functionalities for the calculation of optimal locations, the analysis of flow information, and the creation of several types of maps. By 1977, twelve geographic information systems, run by central government agencies, local governments, and universities, were implemented in Sweden (Rhind 1998, 295–96).

In Britain, early efforts were conducted in the 1950s by Franklyn Perring and S. M. Walters (with a mechanical rather than computer-based system) and by Coppock. According to Rhind (1988, 278), "arguably the most important single catalyst for computer-assisted cartography in the UK was the manually-produced *Atlas of Britain*," published in 1963 by Clarendon Press in Oxford and planned and directed by David P. Bickmore and Mary Alison Shaw. An early center in the United Kingdom was the Experimental Cartography Unit (ECU) founded by Bickmore in 1967 at the Royal College of Art in London, funded by the government's National Research Council, and active until 1975. Among the many outcomes of work conducted at the ECU were computer programs for converting digitized map coordinates to geographical coordinates, for projection change, for cartographic editing and generalization, and for automated contouring. Another British project was LINMAP (line printer mapping), which began in 1968 at the Ministry of Local Housing and Development. LINMAP included statistical mapping capabilities for the production of choropleth, isoline, and dot maps (Rhind 1998, 296–97).

In the late 1960s and early 1970s, while at the University of Edinburgh, Thomas C. Waugh, an alumnus of the Harvard Laboratory for Computer Graphics and Spatial Analysis, developed a vector-based mapping program called GIMMS. (A vector GIS is based on three fundamental objects—points, lines, and polygons—rather than the single object [the cell] in a raster GIS. Points are defined by a set of geographical coordinates, lines by a sequence of points, and polygons by a sequence of lines.) A fundamental concept in a vector GIS is topology, the encoding of the adjacency and connectivity of the features mapped. GIMMS included functionalities for data manipulation and analysis, and became available commercially starting in 1973. According to Rhind (1998, 297), GIMMS "can be considered the first globally-used GIS. It pioneered the use of topological data structures, user command languages for interactive operations, macro languages, and user control of high quality graphics. . . . [It] anticipated some key characteristics of the Harvard Odyssey system by nearly five years and ARC/INFO by a decade."

At the academic level, the most influential early GIS work was conducted at the Harvard Laboratory. The story of the laboratory is well documented and chronicled in several publications, most extensively by Nicholas R. Chrisman (2006). The Harvard Laboratory for Computer Graphics ("and Spatial Analysis" was added in 1968) was founded in 1965 with funding from a three-and-a-half-year grant from the Ford Foundation. Howard T. Fisher, the first director, became interested in computer cartography at Northwestern University in 1963, after attending a course taught by Edgar M. Horwood of the University of Washington on how to make maps with computers. Fisher set out to improve on the method he had learned, and within a year he and programmer Betty Benson had developed a functional prototype, SYMAP, capable of making contour and choropleth maps. At Harvard University, Fisher's work on computer mapping was complemented by William Warntz's focus on spatial analysis. Warntz was hired as associate director of the laboratory in the fall of 1966, and became its director in 1968 when Fisher retired. The laboratory staff had grown to more than forty in 1971, when the Ford Foundation grant ended and Warntz resigned. The laboratory continued with a much reduced staff (six members in 1972), supporting itself primarily through the sale of software (SYMAP and later ODYSSEY). After a period of acting directorship by Allan H. Schmidt, Brian J. L. Berry became director in 1975, with Schmidt the executive director. Under their tenure the laboratory increased its staff and developed another major software program, ODYSSEY. After Berry left in 1981, the laboratory continued for ten more years as a research center, ceasing its operations in 1991.

The Harvard Laboratory for Computer Graphics and Spatial Analysis had a long-lasting effect on the history of geographic information science. Many of the leading scholars of the late twentieth century worked at the laboratory, attended its conferences, or published their work in its publications series. In terms of GIS software, arguably the most important legacies of the laboratory were the principles and solutions that informed the design of SYMAP and ODYSSEY. SYMAP employed a vector data model, with thematic attributes attached to the points, lines, and polygons that constituted the map. Maps were printed on line printers, and although the cartography was rather crude compared to later displays, it was effective. SYMAP's main functionalities included the production of choropleth and contour maps, the latter created using nearest neighbor, inverse distance weighting, and trend surface interpolation algorithms. Later in the 1960s, David F. Sinton developed a raster-based program called GRID by modifying one of SYMAP's routines to perform overlay operations. GRID was later improved to overlay several data themes using map algebra functions. The new program was called IMGRID. In the late 1960s and 1970s, other offspring of SYMAP included SYMVU, for the 3-D representation of surfaces, and CALFORM, whose objective was to increase the quality of cartographic output, specifically of choropleth maps (fig. 903).

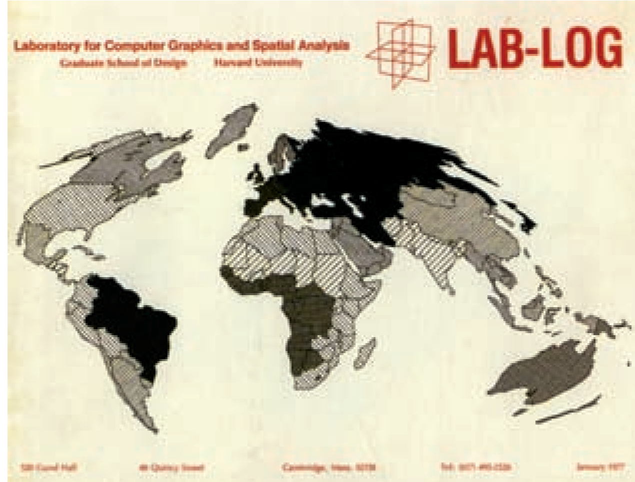


FIG. 903. MAP PRINTED USING CALFORM, 1977. Progress in the quality of cartographic output is evident in this choropleth map showing the per capita rate of gross national product growth, 1965–72.
From Chrisman 2006, 83. Permission courtesy of the Frances Loeb Library, Harvard University Graduate School of Design.

The second major achievement of the laboratory was ODYSSEY in the second half of the 1970s. ODYSSEY, a vector GIS originally conceived by Chrisman and Denis White, was the result of gradual and cumulative efforts by the laboratory staff, including POLYVRT, GEOGRAF, CYCLONE, and other programs. The most important characteristic of ODYSSEY was its fully topological data structure, an important advancement in GIS history. The overlay capability included a program called WHIRLPOOL to eliminate sliver polygons, which are produced when the shared boundaries of contiguous polygons do not match perfectly. This and other technical solutions were to be implemented in many GIS software products to come. One such example is ERDAS (Earth Resources Data Analysis Systems), first developed in 1978 as a streamlined version of IMGRID, integrated with Landsat remote sensing processing software, and adapted to run on a microcomputer. ERDAS was a successful product and entered the twenty-first century with a considerable user base. In 1997, ERDAS IMAGINE was installed in over ten thousand computers worldwide (Jordan and Rado 1998, 79–82).

A connection also exists between the Harvard Laboratory and the Environmental Systems Research Institute (ESRI), the dominent GIS software vendor by century's end. ESRI was founded in 1969 by Jack Dangermond, one of the Harvard Laboratory graduates. One of the earliest ESRI products was AUTOMAP II, created for "useful mapping functions with output on a line printer" (Dangermond and Smith 1988, 302), followed by GRID for raster overlay and GRID-TOPO for 3-D representation. ARC/INFO, first written in the mid-1980s, coupled the processing of vector cartographic data (points, lines, and polygons) by ARC with the processing of the associated attribute data by INFO. Also in the mid-1980s, ARC/INFO was complemented by the related programs NETWORK for network analysis, COGO for coordinate geometry, TIN for the representation of elevation via a triangulated irregular network, and the Arc Macro Language (AML) for writing macros.

A key characteristic of ARC/INFO was its use of the INFO relational database management system. (A relational database is a collection of tables corresponding to data themes in a GIS that can be linked to each other through a common key [a column in the table].) Relational databases allow faster processing of queries and are easy to manage and update, since each table can be created and edited separately from other tables. The relational database model dominated the GIS market in the 1990s, but toward the end of the decade a powerful alternative became available. Smallworld was the first company that made available to the general public a GIS software package based on the object-oriented data model. (As the name implies, an object-oriented data model uses objects to organize spatial data; objects can be grouped hierarchically and their properties can be inherited. Object-oriented databases are generally more complex than relational ones, but they more closely resemble the real world and are in principle easier to update than relational databases.) Another key development of the late 1980s and 1990s was the implementation of graphical user interface (GUI). Developed at Xerox PARC in the 1970s from earlier prototypes and popularized in the 1980s and 1990s in Apple- and Windows-based computer systems, GUIs allowed users to interact more naturally with the GIS compared with the command-line interface of the early systems (Lanter and Essinger 1991) and contributed greatly to the diffusion of GIS beyond the realm of the computer expert.

Harvard University was not the only academic institution involved in the design of GIS software. In the 1980s and 1990s, for example, CGRIES-GIS was created at Michigan State University, MacGIS at the University of Oregon, ILWIS (Integrated Land and Water Information System) at ITC in Enschede, Netherlands, and OSU MAP at Ohio State University. Most academically originated programs have since faded away, and those that are still available play only a marginal role in the GIS market. One exception is IDRISI, whose development started in 1987 at the Graduate School of Geography of Clark University under J. Ronald Eastman's direction. IDRISI retains a broad worldwide presence, especially in the developing world. The software is based on the raster data model and includes sophisticated analytical functions and the ability to integrate remote sensing data.

Early overviews of the GIS software market in general are found in Tomlinson, Hugh W. Calkins, and Duane F. Marble (1976), and in Marble (1980). In the late 1980s and 1990s, *GIS World* magazine published several extensive GIS directories. The first, for the year 1988, was published in 1989 and listed thirty-seven GIS software companies (see figs. 904–906 for examples of GIS software applications from the period). The 1990 directory included almost one hundred systems, with installations ranging in number from a single license to the tens of thousands (GIS World 1990, 20–24). MapInfo was the market leader in 1990 with over ten thousand installations, followed by ESRI (ARC/INFO) with over four thousand; ERDAS, IDRISI, and GRASS (Geographic Resources Analysis Support System)—among others—had more than a thousand installations each, with Intergraph's MGE (Modular GIS Environment) at less than five hundred. Software costs ranged widely, from a little under $100 to $200,000 for GeoSpectra's ATOM (Automatic Topographic Mapper). Five years later in 1995 (GIS World 1995, 26–28), almost half of the 486 products from the 278 companies included in the directory were GIS software packages, ranging in number of installations from just a handful to over 130,000 for Intergraph's MGE, MicroStation, and Framme suite of products. Over 75 percent of the GIS software packages listed had three hundred installations or less. Costs varied from less than $100 to tens of thousands (the average cost of GIS-related software was $5,848). Most companies listed had their first installations in the 1990s and have since gone out of business. By the early 2000s, GIS software market shares had consolidated around a relatively small number of major players.

From very early in the history of GIS, several institutions, in many cases publicly funded, made available to the general public open-source and free GIS software packages. One example with a considerable user base

FIG. 904. POLAR BEAR TRACKING WITH GIS, 1986–87. The U.S. Fish and Wildlife Service tracked polar bears and mapped their range and distribution using satellite telemetry.
From John C. Antenucci et al., *Geographic Information Systems: A Guide to the Technology* (New York: Van Nostrand Reinhold, 1991), between 82–83 (fig. C-23). Permission courtesy of John Wiley & Sons, Inc.

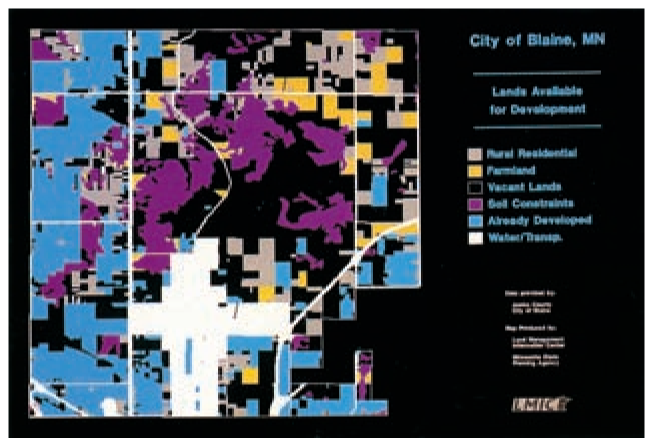


FIG. 905. MODELING LAND USE SUITABILITY AND DEVELOPMENT USING GIS, LATE 1980s.
From John C. Antenucci et al., *Geographic Information Systems: A Guide to the Technology* (New York: Van Nostrand Reinhold, 1991), between 82–83 (fig. C-24). Permission courtesy of John Wiley & Sons, Inc.

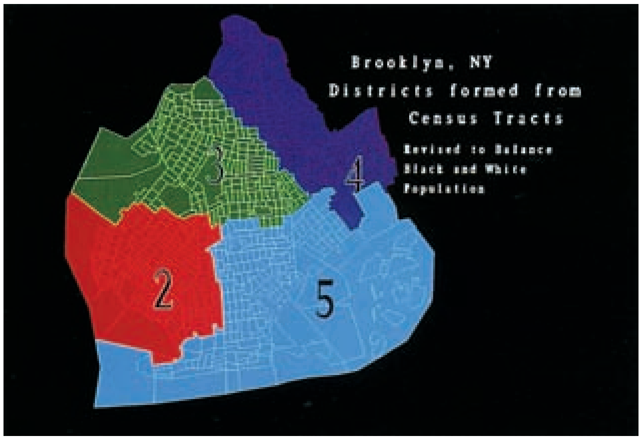


FIG. 906. GIS-SUPPORTED STATE-LEVEL REDISTRICTING, LATE 1980s. Following U.S. decennial censuses, local governments relied on GIS to map electoral and service districts.
From John C. Antenucci et al., *Geographic Information Systems: A Guide to the Technology* (New York: Van Nostrand Reinhold, 1991), between 82–83 (fig. C-25). Permission courtesy of John Wiley & Sons, Inc.

is GRASS, originally developed by the U.S. Army Corp of Engineers and available since the mid-1980s. GRASS supports both raster and vector data. The Open Geospatial Consortium (OGC), an organization of almost four hundred companies, government agencies, and universities that promote the creation of publicly available interface standards for GIS, originated as a user group for GRASS. An even earlier example is MOSS (Map Overlay and Statistical System), a vector GIS originally developed in 1978 for the U.S. Fish and Wildlife Service by the nonprofit Federation of Rocky Mountain States under the leadership of Larry Salmon (Reed 2004). MOSS was used by many federal agencies and several state and local governments. Among its design characteristics worth noting is the fact that the user interacted with the system through a simple command line.

In the first decade of the twenty-first century, GIS has matured into a technology used by urban planners and ecologists, historians, forensic scientists, and natural resources managers, among others. The field of geographic information science continued to thrive, and the GIS market remained a multibillion dollar industry.

ALBERTO GIORDANO

SEE ALSO: Environmental Systems Research Institute (U.S.) (ESRI); Geographic Information System (GIS)

BIBLIOGRAPHY:

Chrisman, Nicholas R. 2006. *Charting the Unknown: How Computer Mapping at Harvard Became GIS*. Redlands: ESRI Press.

Coppock, J. T. 1988. "The Analogue to Digital Revolution: A View from an Unreconstructed Geographer." *American Cartographer* 15:263–75.

Coppock, J. T., and David Rhind. 1991. "The History of GIS." In *Geographical Information Systems: Principles and Applications*, 2 vols., ed. D. J. Maguire, Michael F. Goodchild, and David Rhind, 1:21–43. New York: Longman Scientific & Technical.

Dangermond, Jack, and Lowell Kent Smith. 1988. "Geographic Information Systems and the Revolution in Cartography: The Nature of the Role Played by a Commercial Organization." *American Cartographer* 15:301–10.

Foresman, Timothy W., ed. 1998. *The History of Geographic Information Systems: Perspectives from the Pioneers*. Upper Saddle River: Prentice Hall PTR.

GIS World, Inc. 1990. *The 1990 GIS Sourcebook: Geographic Information System Technology in 1990*. Fort Collins: GIS World.

———. 1995. *GIS World Sourcebook 1996: Geographic Information System Technology*. Fort Collins: GIS World.

Hägerstrand, Torsten. 1967. "The Computer and the Geographer." *Transactions of the Institute of British Geographers* 42:1–19.

Jordan, Lawrie E., and Bruce Q. Rado. 1998. "Investments in Personal Computing." In *The History of Geographic Information Systems: Perspectives from the Pioneers*, ed. Timothy W. Foresman, 73–82. Upper Saddle River: Prentice Hall PTR.

Lanter, David P., and Rupert Essinger. 1991. *User-Centered Graphical User Interface Design for GIS*. N.p.: National Center for Geographic Information and Analysis.

Marble, Duane F., ed. 1980. *Computer Software for Spatial Data Handling*. 3 vols. Ottawa: International Geographical Union, Commission on Geographical Data Sensing and Processing.

McHarg, Ian L. 1969. *Design with Nature*. Garden City: For the American Museum of Natural History by the Natural History Press.

Reed, Carl. 2004. "MOSS—A Historical Perspective." *Scribd*. Online publication.

Rhind, David. 1988. "Personality as a Factor in the Development of a Discipline: The Example of Computer-Assisted Cartography." *American Cartographer* 15:277–89.

———. 1998. "The Incubation of GIS in Europe." In *The History of Geographic Information Systems: Perspectives from the Pioneers*, ed. Timothy W. Foresman, 293–306. Upper Saddle River: Prentice Hall PTR.

Tobler, Waldo R. 1959. "Automation and Cartography." *Geographical Review* 49:526–34.

Tomlinson, Roger F. 1998. "The Canada Geographic Information System." In *The History of Geographic Information Systems: Perspectives from the Pioneers*, ed. Timothy W. Foresman, 21–32. Upper Saddle River: Prentice Hall PTR.

Tomlinson, Roger F., Hugh W. Calkins, and Duane F. Marble. 1976. *Computer Handling of Geographical Data: An Examination of Selected Geographic Information Systems*. Paris: Unesco Press.

Tyrwhitt, Jacqueline, comp. 1950. "Surveys for Planning." In *Town and Country Planning Textbook*, ed. Association for Planning and Regional Reconstruction, 146–78. London: Architectural Press.

Soils Map. This review of the recent history of soil mapping begins with two premises: (1) a taxonomy both reflects and shapes the current state of disciplinary knowledge, and (2) map construction and use usually reflect currently fashionable taxonomic concepts. Early taxonomies viewed soil as a rooting medium with observable place-to-place differences that had consequences for plants and animals (Liebig 1840; Yaalon 1989). The job of a soil scientist was to analyze soil samples from specific places in order to identify the chemicals that were in short supply there. Soil taxonomies were rare and consisted primarily of verbal descriptions of the texture and color of the earth in different parts of a field (for a modern example of this kind of classification, independently developed in a remote part of Peru, see Sandor and Furbee 1996).

By the mid-nineteenth century, people had accumulated enough observations to notice some soil-landscape relationships, and those observations led to simple theories of soil genesis. According to one popular early theory, each kind of rock produces a specific kind of soil (Fallou 1862). After some pilot projects, a systematic program of county-level soil surveying was started in the United States in 1899. A Bureau of Soils was established within the Department of Agriculture (USDA) to coordinate this survey, and ten years later it produced a color map titled *United States Soil Provinces* (Whitney 1909). This map used geologic techniques and nomenclature to divide the country into provinces and identify representative soil series within each province. A soil series was defined as the taxonomic equivalent of a biological species; it consists of all sampled soils that resemble a given prototype more closely than any other. Like the name of a geologic formation, the name of a soil series comes from the geographic location of its prototype.

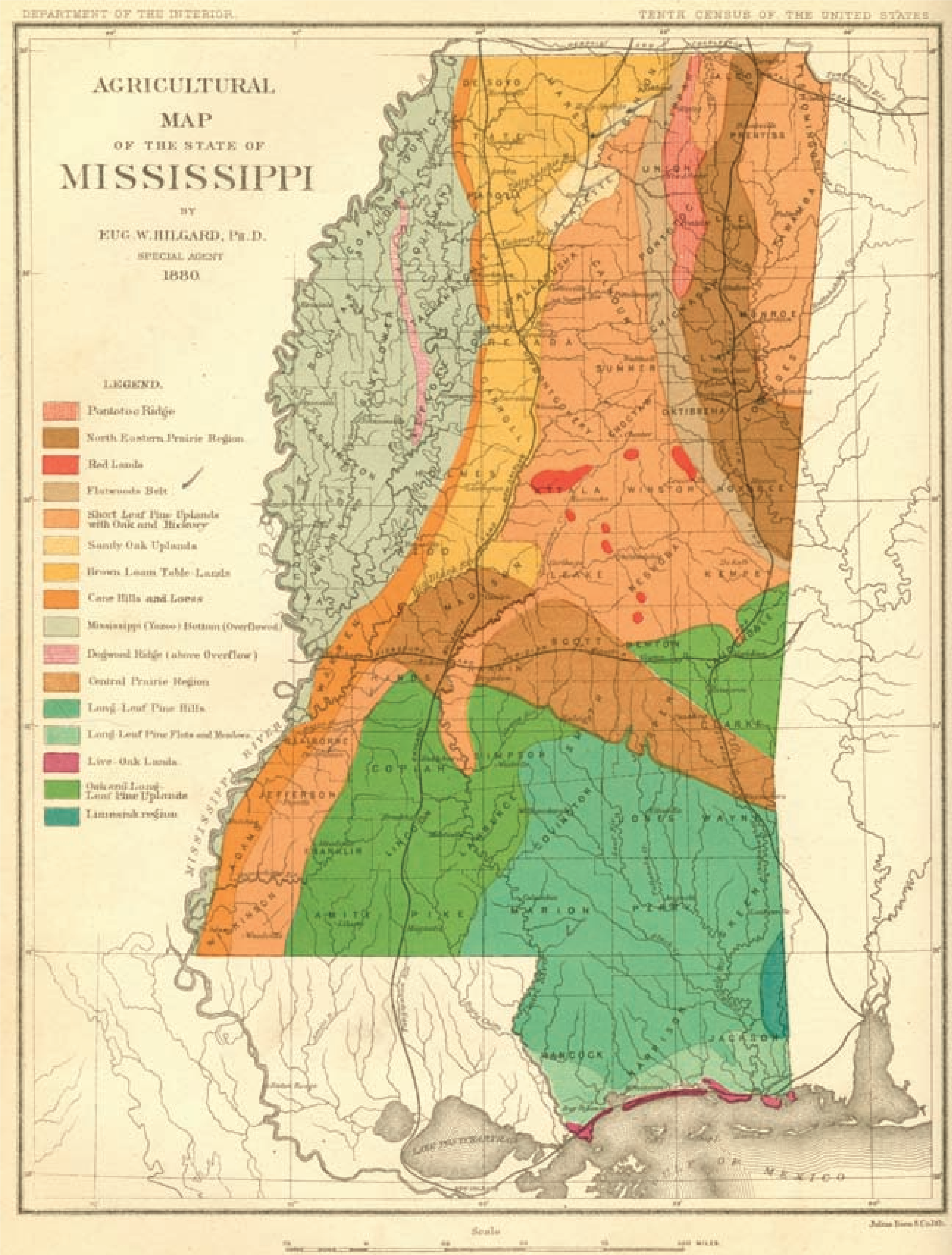
The first national soil map used a geology-based taxonomy because Eugene W. Hilgard was unwilling to make a third long-distance move late in his life. Hilgard's early life neatly reflects the history of soil science up to his time: degrees in geology and chemistry from several European universities and a dual position as professor of agricultural chemistry at the University of Mississippi and state geologist of Mississippi. After eighteen years of trying to devise chemical ways of coping with the acidity and infertility of typical Mississippi soils, Hilgard moved to California in 1875. There, he faced an almost diametrically opposite problem—how to counteract the chemical hostility of excessively alkaline soils. These soils were presumed to be the result of evaporation of a previous inland ocean (i.e., a consequence of geologic processes). To Hilgard, however, the California soils had many resemblances to soils he had seen in Mississippi, and he rightly ascribed the differences to the influence of climate. His observations and inferences came together in the U.S. Census of 1880, which included several state-scale maps of soil regions derived by generalization from thousands of soil samples collected by farmers, railroad engineers, and other interested parties and sent to the state lab for physical and chemical analysis (fig. 907). One common result of map generalization, unfortunately, is the loss of information about local variability, as well as the metadata that might allow further investigation of the causes for that variability.

Lacking a consensus on a taxonomic frame to help organize the rapidly growing mass of information, the nascent discipline of soil geography split and followed three different paths. Major John Wesley Powell, head of the U.S. Geological Survey (USGS), proposed to establish a new Division of Agricultural Geology within the USGS. He asked Hilgard about his willingness to head this division, if approved. Hilgard supported the idea, but was not interested in another cross-continental move. Marginalized by distance, his advocacy for an inductive, bottom-up approach to soil mapping and a multivariate concept of soil genesis was partially eclipsed by the USDA's top-down program to produce a national soil map based on geologic information. At the same time, more and more states were establishing soil chemistry laboratories to provide fertilizer recommendations to farmers who submitted soil samples for analysis. The separation of broad-scale soil mapping, county-scale soil surveying, and site-scale soil fertility analysis into different agencies at different levels of government led to a period of analytical and taxonomic stagnation.

Meanwhile, halfway around the globe, Russian scholars were developing a climate-based concept of soil formation, based on observations in the vast Asian expanses of forest and grassland (Dokuchaev 1893). In their view, a sufficient amount of time in a specific climatic environment (a natural zone) will eventually produce a specific kind of soil (a zonal soil) even from different rock materials. This view came to America when Curtis Fletcher Marbut found a German translation of a Russian soil book, translated it into English, and tried to apply its principles in the United States. The result was a classification that borrowed terms from several languages as it separated soils into broad climate-influenced zones with topographic exceptions (Marbut 1935). This classification had a short life expectancy because the ongoing program of county-level soil surveying was generating so much detailed information that the weaknesses of a top-down climate-based classification were becoming apparent even before it had completely displaced the even weaker geology-based classifications (Thorp and Smith 1949). This led to a concerted effort that generated a sequence of ever more refined approximations of a soil taxonomy based primarily on the presence or absence of distinctive surface or subsoil layers.

(*Facing page*)

FIG. 907. EUGENE W. HILGARD, *AGRICULTURAL MAP OF THE STATE OF MISSISSIPPI*, 1880. General soils map. Size of the original: 24.5 × 18.3 cm. From Eugene W. Hilgard, *Report on Cotton Production in the United States*, 2 vols. (Washington, D.C.: Government Printing Office, 1884), vol. 1, between 210–11.



DEPARTMENT OF THE INTERIOR.
TENTH CENSUS OF THE UNITED STATES
AGRICULTURAL
MAP
OF THE STATE OF
MISSISSIPPI
BY
EUG. W. HILGARD, PH. D.
SPECIAL AGENT
1880.
LEGEND.
Pontotoc Ridge
North Eastern Prairie Region
Red Lands
Flatwoods Belt
Short Leaf Pine Uplands with Oak and Hickory
Sandy Oak Uplands
Brown Loam Table Lands
Cane Hills and Loess
Mississippi (Yazoo) Bottom (Overflowed)
Dogwood Ridge (above Overflow)
Central Prairie Region
Long Leaf Pine Hills
Long Leaf Pine Flats and Meadows
Live-Oak Lands
Oak and Long-Leaf Pine Uplands
Limesink region
DE SOTO
TATE
UNION
PRENTISS
PONTOTOC
LEE
CALHOUN
CHICKASAW
MONROE
GRENADA
SUMNER
OKTIBBEHA
CHOCTAW
ATTALA
WINSTON
NOXUBEE
LEAKE
NESHOBA
KEMPER
SCOTT
NEWTON
RANKIN
HINDS
CLARKE
CLAIBORNE
COPIAH
JEFFERSON
FRANKLIN
ADAMS
AMITE
PIKE
MARION
PERRY
JONES
WAYNE
HANCOCK
JACKSON
MISSISSIPPI RIVER
MEXICO
Scale
Julius Bien & Co. Lith.

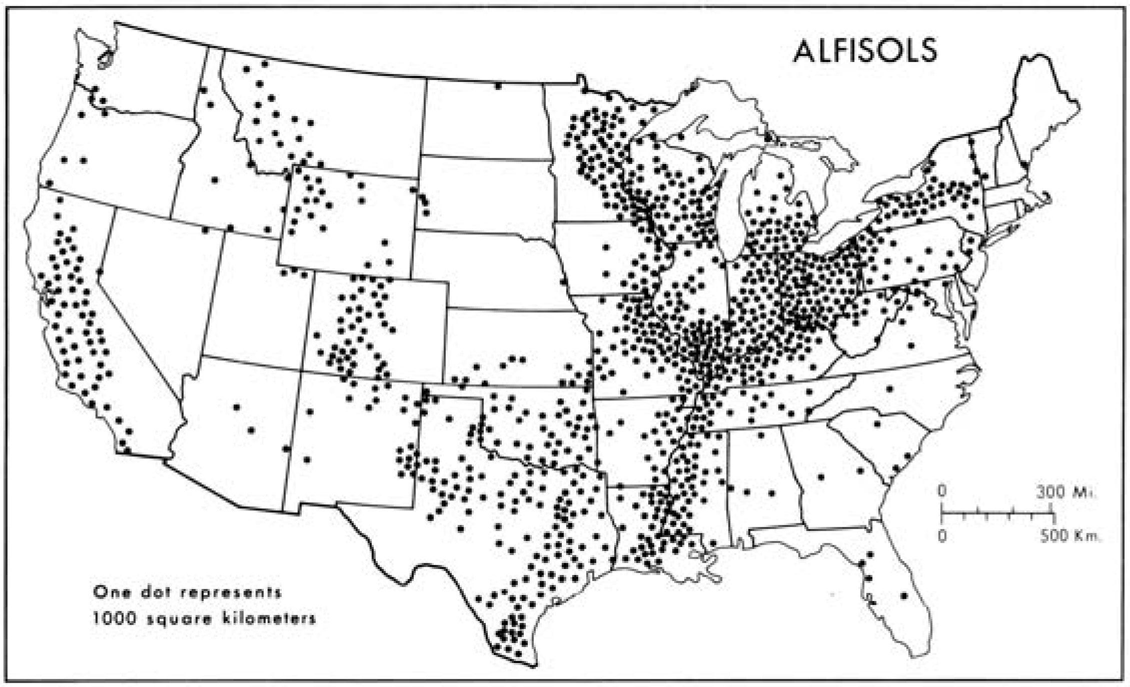


FIG. 908. LOCATIONS OF SOILS CLASSIFIED AS ALFISOLS. Depiction of soil patterns with dots allows comparison of maps for different soil orders, which in turn can reveal the extent of spatial overlap when soils are shown on national maps.

Size of the original: 8.9 × 14.7 cm. From Gersmehl 1977, 426 (fig. 7). Reproduced by permission of Taylor & Francis.

The adoption of the Soil Taxonomy (popularly known as the Seventh Approximation) by the USDA in 1960 posed a major cartographic dilemma: a classification that groups soils into categories from the bottom up is likely to produce a much more complicated-looking map than a taxonomy that assumes the inevitable development of a typical zonal soil within each broad climatic or geologic region. As a result, cartographers became dissatisfied with the colored-area soil maps of the early 1900s and began to experiment with dots and other graphic vocabularies for depicting global or continental patterns of soil (fig. 908; Gersmehl 1977).

Meanwhile, the work of making county soil surveys continued. Despite the arguments about soil genesis and classification, the field surveyor's concepts of soil individuals, series, and associations remained remarkably constant and in fact were extended to many other countries (Institut International d'Agriculture 1926). The physical form of published soil surveys, however, changed several times. These changes in publication form were not due to the dramatic changes in taxonomy. On the contrary, they occurred as a result of technological changes in data gathering and representation. In rough chronological order, county soil surveys in the United States have appeared as: an envelope of relatively large color maps, with or without accompanying explanatory text; a book with explanatory text bound together with a larger number of smaller color foldout maps; a book with text and foldout maps that had soil boundaries and identification codes overprinted on grayscale aerial photographs (fig. 909); a tripartite book with text, separate set of interpretation tables, and aerial photo-based maps; a similar book, but with state-level numeric codes instead of county-level mnemonic letter codes; a raster digital file made by scanning a printed soil map; and a vector digital file that allowed selective display of information.

This list is not comprehensive; other experiments in format included several attempts to produce maps that corresponded to USGS topographic quadrangles in both extent and scale. It would be convenient, for many reasons, to be able to cite a policy decision and date for each major format shift, but in fact the various publication eras had considerable overlap. For example, the soil survey for Quitman County, Mississippi, was finished in 1947 and issued in 1958 with aerial photo-based maps, while the one for Dakota County, Minnesota, was finished in 1955 and issued in 1960 with color maps. Since color maps were simultaneously more expensive to print and more difficult to use than the aerial photo format, Dakota County redid its survey in 1983. At that time, it used the newer system of numeric codes, which

FIG. 909. DETAIL FROM COUNTY SOIL SURVEY, STARK COUNTY, ILLINOIS. Poorly drained soil (dark color) and well-drained soil (light color) are visually quite distinct in this part of the United States, but it is also clear that soil surveyors have to make judgments in order to map soils at the desired level of generalization. As a result each delimited area tends to include smaller areas of different soil.
Size of the entire original: 24.6 × 41.2 cm; size of detail: 12.3 × 9.9 cm. From *Soil Survey of Stark County, Illinois* ([Washington, D.C.]: [Natural Resources Conservation Service], 1996), sheet no. 14.

made the maps easier to compare with other counties but more difficult to use within a county. This trade-off was unacceptable in other states, which continued to use mnemonic letter codes into the late 1990s.

The gradual extension of the soil survey to an additional ten to forty counties per year was derailed by the passage of the U.S. Food Security Act of 1985. This complex law transformed the U.S. Soil Conservation Service (SCS) from an advisory agency into a regulatory body, because it linked farm subsidies to SCS approval of an erosion-control plan for any field with more than a specified fraction of its area mapped as highly erodible land (HEL). This provision dramatically changed the role of the county soil survey from a source of technical information for advisory purposes into a source of spatial information for program administration.

That change, in turn, created a host of technical cartographic problems and administrative issues with cartographic overtones. At one extreme were some computer hardware salespeople extolling the benefits of scanning soil maps at 200 lines per inch rather than 40 or 50, an advantage that seemed absurd to soil surveyors, who knew that soil surveys were originally made with grease pencils on unrectified aerial photos by someone tired of walking over muddy fields in the rain. A related, more serious issue was raised by landowners threatening lawsuits when computerized measurements of soil areas on their fields resulted in a “HEL ratio” that missed the threshold by a few percent, thus denying them tens of thousands of dollars of federal subsidy. This also seemed absurd to anyone who knew that the areas delimited in a standard soil survey are seldom taxonomically pure enough to support the precise area measurements required by the law.

These issues, however, could not be adequately addressed because the resources of the SCS were stressed by a much larger problem: the absence of soil surveys in nearly half of the more than 3,000 counties in the United States. To meet the sudden demand for soil maps, the SCS hired additional surveyors and detailed people out of counties that already had surveys or where the law did not pose immediate problems. This had two consequences of concern for historians of cartography. First, many post-1985 soil surveys were done by people who had little experience in a given region. Second, even when soil maps were being compiled by people with extensive local knowledge, the rush to finish the survey often led to acceptance of lower standards of soil surveying. This can often be seen by comparing the visual complexity of survey maps made in the 1960s and 1970s with the maps in an adjacent county surveyed in the 1990s. Such comparisons usually show that the newer survey has fewer map delineations per square mile and more areas mapped as complexes of series that are taxonomically unrelated but often occur close to each other in an intricate landscape. The temporary solutions to the workload problem imposed long-term costs because soil surveys became less reliable for area measurements and less easy to use in planning for individual fields.

One short-lived solution was to try to create single-purpose maps—for example, prime farmland maps, land capability class maps, septic system hazard maps, or corn suitability rating maps. Hundreds of these projects appeared in different parts of the country, for different reasons, with different standards and graphic vocabularies. In time, knowledgeable people realized that the weaknesses of a soil survey were not likely to disappear if it was simply recoded into another form. In fact, these products could simultaneously magnify the landscape heterogeneity issues and hide them from casual users by scanning county soil association maps, transforming

FIG. 910. SOIL SURVEY MAP AND ASSOCIATION DIAGRAM, BREMER COUNTY, IOWA. Bassett (Be), Clyde (Ck), and Oran (Or) soils comprise about 60 percent of the association around Frederika. For areas that are not level or nearly level, a capital letter (A through F, least to greatest) indicates the slope. The relationship of slope, vegetation, and parent material is shown in the association diagram.
Size of the entire original (top): 26.6 × 39.5 cm; size of detail: 14.4 × 13.9 cm; size of the original (bottom): 12.3 × 18.8 cm.
From *Soil Survey: Bremer County, Iowa* ([Washington, D.C.]: U.S. Soil Conservation Service, 1967), sheet no. 13 and p. 4 (fig. 3).

them electronically, and delivering the information to users in the form of large colored areas identified according to a single criterion, such as the texture of the surface in just one of the soils in the association. This was a problem because a soil association, by definition, is a group of dissimilar soils that occur in different parts of an intricate landscape—e.g., hilltop, side slope, and valley bottom—and cannot be separated at the scale of a county map (fig. 910).

The wave of paper product development gradually ebbed as it became obvious that ever-increasing computer power would allow users to interrogate a detailed soil database and create a wide range of displays directly from soil survey information. That realization, in turn, led people to focus once again on the process of soil surveying. The late twentieth century was characterized by a flurry of journal articles that explore the applications of various logical and mathematical devices—expert systems, kriging, fractals, *k*-means, fuzzy sets, for example—as aids in trying to extend the knowledge gained from a limited number of field soil samples into a more comprehensive and accurate depiction of the local geography of soils on individual fields (Odeh, McBratney, and Chittleborough 1992; Dale, McBratney, and Russell 1989). The jury is still out on whether these ideas actually result in improvements in all environments, or whether they might require a costly period of calibration every time the idea is extended into a new environment.

Meanwhile, global-scale projects are trying to create valid databases of soil information that can be used as input into environmental models that deal with global climate change, animal migration, species extinction, and related issues. These projects reopen an old question that has never been satisfactorily answered: how does one describe the general kind of soil that tends to form in a particular climate and at the same time preserve a valid impression of the site-scale variability that occurs as a result of local geology, slope, internal drainage, vegetation cover, and prior land use? Here is a striking but hardly unique example: a USGS map of soil limitations (classification based primarily on the soils' capability to produce common cultivated crops and pasture plants without deteriorating over a long period of time) in the United States (fig. 911). It shows a broad dark-green swath of no-limitation soils extending west from Indiana through Iowa and then south to central Texas. Hutchinson County, Texas, is in this area, but its 1976 soil survey shows soils that fall into six different soil orders, three of the four land capability subclasses, and six of the eight land capability classes (II, III, IV, V, VI, and VII). Notably absent from the county soil survey, however, are any soils in land capability class I with no significant limitations. One should view with extreme suspicion, therefore, any assessment of "impact of urban sprawl on soil resources" that is based on electronically overlaying this soil map with any other database (Imhoff et al. 1998).

In short, local variability often makes a global soil map unsuitable for many of the uses to which it is being put by naïve users. That variability, moreover, cannot even be assessed until the entire world is surveyed to the

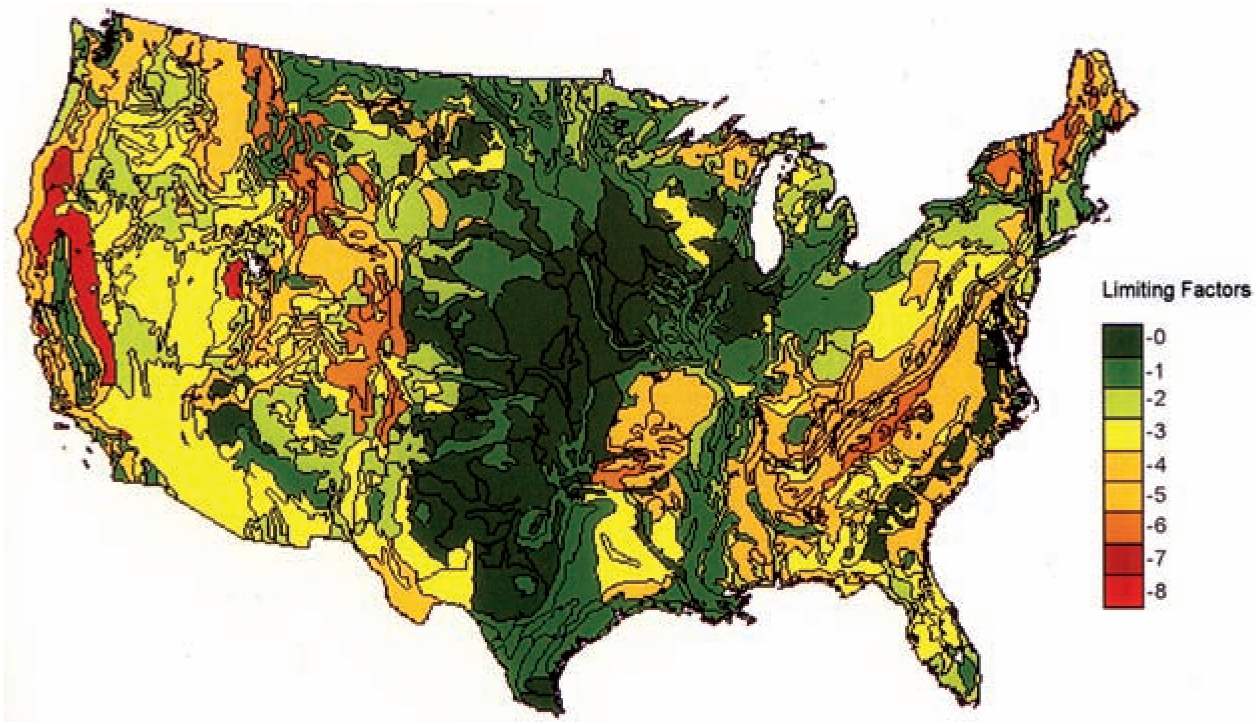


FIG. 911. SOIL LIMITATIONS IN THE UNITED STATES. Created from the United Nations Food and Agriculture Organization digital soils map of the world. Size of the original: 9.3 × 16.3 cm. From Imhoff et al. 1998, 17 (fig. 3–2).

same precision as is the rule in a few countries today. Until then, the existing generalized soil maps can "create apparently authoritative misinformation and perpetuate stereotypes about [unsurveyed areas such as] Africa" (Showers 2005, 314). One can reasonably expect that our ideas about soil taxonomy and mapping will continue to change as new information enters the decision arena. In the meantime, a soil survey map remains a remarkably powerful tool in the hands of a knowledgeable user, whose reading of the map is tempered by prior knowledge about the global influence of climate as well as the local influence of geology, topography, and land cover. Such a map reader is able to look at the lines and symbols on a soil survey map and make inferences that can help people make much better decisions about the use of land.

PHILIP J. GERSMEHL

SEE ALSO: Biogeography and Cartography; Forestry and Cartography; Scientific Discovery and Cartography

BIBLIOGRAPHY:

Buol, S. W., et al. 2003. *Soil Genesis and Classification*. 5th ed. Ames: Iowa State **[University?]** Press.

Dale, M. B., A. B. McBratney, and J. S. Russell. 1989. "On the Role of Expert Systems and Numerical Taxonomy in Soil Classification." *Journal of Soil Science* 40:223–34.

Dokuchaev, V. V. 1893. *The Russian Steppes: Study of the Soil in Russia, Its Past and Present*. St. Petersburg: Department of Agriculture, Ministry of Crown Domains, for the World's Columbian Exposition at Chicago.

Fallou, Friedrich Albert. 1862. *Pedologie oder allgemeine und besondere Bodenkunde*. Dresden: Schönfeld.

Gersmehl, Philip J. 1977. "Soil Taxonomy and Mapping." *Annals of the Association of American Geographers* 67:419–28.

Imhoff, M. L., et al. 1998. "Assessing the Impact of Urban Sprawl on Soil Resources in the United States Using Nighttime 'City Lights' Satellite Images and Digital Soils Maps." In *Perspectives on the Land Use History of North America: A Context for Understanding Our Changing Environment*, ed. Thomas D. Sisk, 13–22. [Reston]: U.S. Department of the Interior, U.S. Geological Survey, Biological Resources Division. Also published online with improved color illustrations.

Institut International d'Agriculture. 1926. *Actes de la IVème Conférence Internationale de Pédologie*. 3 vols. Rome: Imprimerie de l'Institut International d'Agriculture.

Liebig, Justus. 1840. *Organic Chemistry in Its Applications to Agriculture and Physiology*. London: Taylor and Walton.

Marbut, Curtis Fletcher. 1935. "Soils of the United States." In *Atlas of American Agriculture: Physical Basis Including Land Relief, Climate, Soils, and Natural Vegetation of the United States*, ed. O. E. Baker, pt. 3, 1–98. Washington, D.C.: United States Government Printing Office, 1936.

Odeh, I. O. A., A. B. McBratney, and D. J. Chittleborough. 1992. "Soil Pattern Recognition with Fuzzy-*c*-means: Application to Classification and Soil-Landform Interrelationships." *Soil Science Society of America Journal* 56:505–16.

Sandor, J. A., and L. Furbee. 1996. "Indigenous Knowledge and Classification of Soils in the Andes of Southern Peru." *Soil Science Society of America Journal* 60:1502–12.

Showers, Kate Barger. 2005. "On Mapping African Soils." *Environmental History* 10:314–20.
Thorp, James, and Guy D. Smith. 1949. "Higher Categories of Soil Classification: Order, Suborder, and Great Soil Groups." *Soil Science* 67:117–26.
Whitney, Milton. 1909. *Soils of the United States, Based upon the Work of the Bureau of Soils to January 1, 1908*. Washington, D.C.: Government Printing Office.
Yaalon, Dan H. 1989. "The Earliest Soil Maps and Their Logic." *Bulletin of the International Society of Soil Science* 76:24.

Sources of Cartographic Information. The twentieth century witnessed a huge increase in map production and use, which made it harder for map libraries to monitor and populate their collections with the ever-burgeoning corpus of printed maps and atlases. As the volume of mapping expanded, so too did the challenging task of collecting and making available the finished product. Initiatives to compile and disseminate information about current map publications were undertaken by map librarians seeking to benefit the professional community of map libraries and by map publishers seeking to increase sales. Driven by commercial expediency as well as by curatorial cooperation, those two distinct sectors of the cartographic community independently undertook to promote mapping availability, ensuring that map users and collections were provided with a succession of broad, although by no means comprehensive, guides to the state of mapping throughout the century and especially in its later years.

Nancy Jones Pruett (1990, 337) provides useful guidelines for monitoring map availability of earth science mapping. Her seven headings have been adapted here to reflect how map collections utilized readily available information to strengthen their holdings or to direct inquirers toward an appropriate cartographic answer. The list of sources of cartographic information discussed below includes: graphic indexes of national mapping, catalogs of maps published by government agencies, commercial map dealers' lists, map library accession lists, national bibliographies, cartobibliographies, and reviews in journals of new maps.

Index volumes are a strikingly graphic means of readily identifying the availability of maps, particularly series mapping. A number of national mapping agencies produced comprehensive booklets identifying their cartographic output with the aid of graphic indexes. Classic examples included those published by India (Tandy 1924), Australia/Papua New Guinea (1965), France (1968), Argentina (1973), and Italy (1977). Indexes typically consisted of outline maps with one or more grids superimposed to show different map scales as well as sheet boundaries and availability (fig. 912).

Defense agencies were also prolific mappers, and British map libraries benefited from the four-volume *Ministry of Defence Map Catalogue* prepared on a series-by-series basis along similar lines to those just described. By the 1990s, map publishers' catalogs were often issued monthly, and annual catalogs, usually produced by national mapping agencies, had also become the norm. In the case of Ordnance Survey mapping of Great Britain, a printed catalog was first published in 1862 and appeared sporadically until 1899, whereupon it became annual. An initial monthly listing was made available beginning in January 1883, running throughout most of the twentieth century until superseded by the electronic *Leisure Map Catalogue* offered on the Ordnance Survey's website and circulated by email to subscribers.

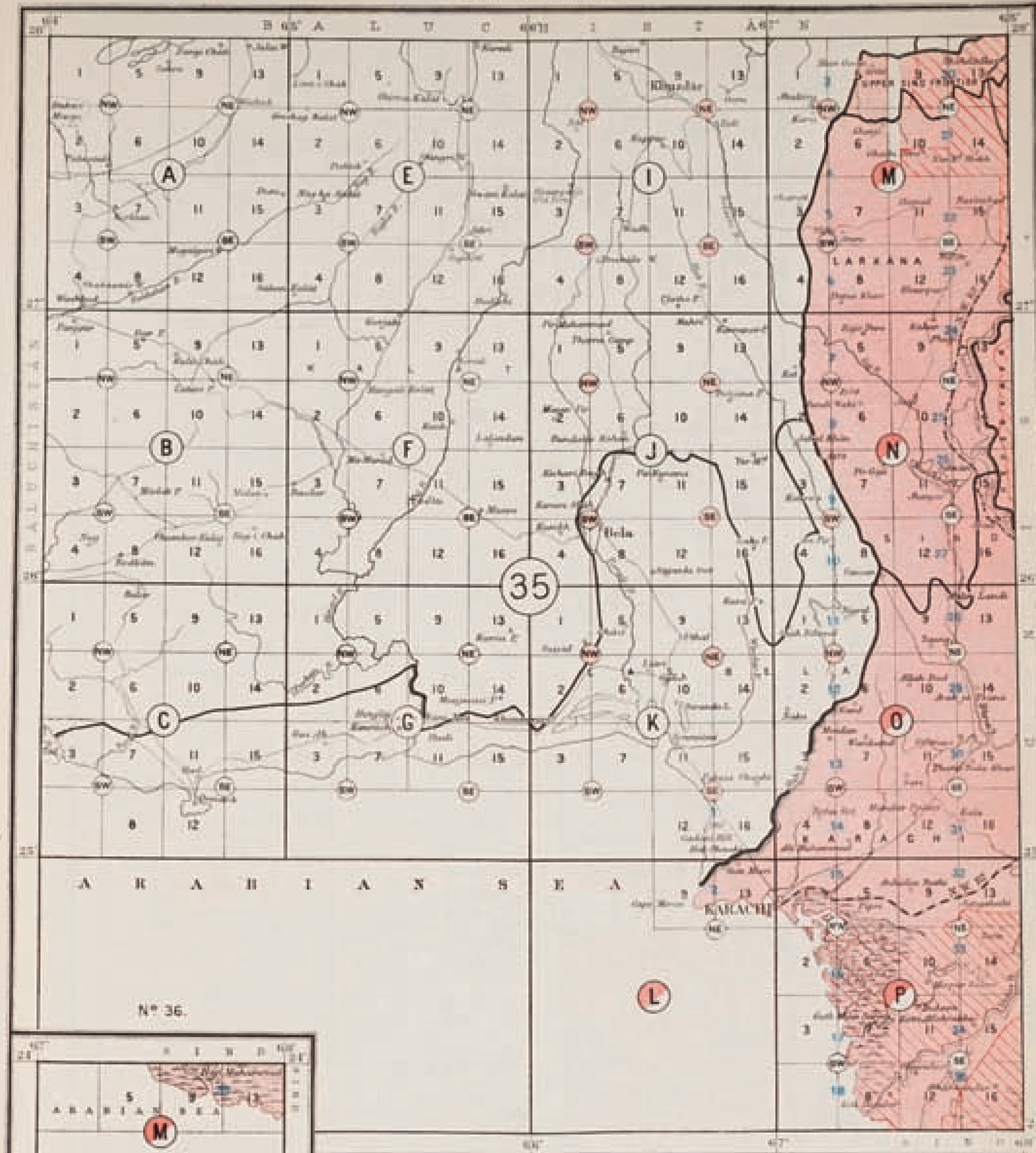
Particularly important were commercial dealers' listings, circulated via mailshots, at trade fairs, or by application. In 1975 international lists of maps available for sale began appearing in *GeoKartenbrief* (three issues per year) and the more substantial *GeoKatalog* (annual) distributed by GeoCenter Internationales Landkartenhaus, the Stuttgart-based map vendor founded in 1971 by the merger of Zumstein Kartenhaus and Reise- und Verkehrsverlag. Such listings, while overtly commercial in nature, had an international remit, identifying map titles worldwide. The drawback was that no matter how comprehensive the listing, the result was purely a priced-up inventory of the stock offered for sale by a particular company at a particular time.

Accessions lists produced by map libraries traditionally alerted other map libraries and map users to recent acquisitions. The lists identified not only maps produced by national agencies but also locally produced cartographic items otherwise unlikely to be publicized widely. Hence a broad assortment of internationally derived lists were of significant benefit to map libraries, especially as most were supplied free of charge. David A. Cobb (1973, 20–21) listed sixteen libraries with accessions lists, primarily created in Canada and the United States. The Bodleian Library in Oxford (a United Kingdom library of legal deposit) began distributing its monthly *Selected Map and Book Accessions* in 1958 and continued that free service to the international map library community into the twenty-first century. Other

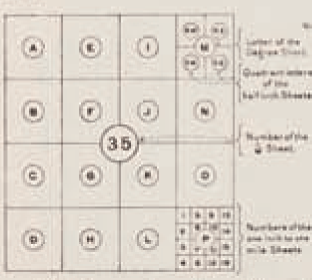
(*Facing page*)
FIG. 912. EXAMPLE OF GRAPHIC MAP INDEXING. This index shows a variety of mapping scales and their availability for the Karachi area. From Tandy 1924, nos. 35–36.
Size of the original: ca. 43.1 × 28.5 cm. Image courtesy of the Burke Library, Union Theological Seminary, New York.

Corrected to 1st July 1924.

INDEX Nos 35 & 36.



ENGD. & HELIO. S. I. O., CALCUTTA.



For a map on the ¼ Scale quote the number only, thus 35

For a Degree Sheet (¼ inch Scale) add the letter, thus 35 M

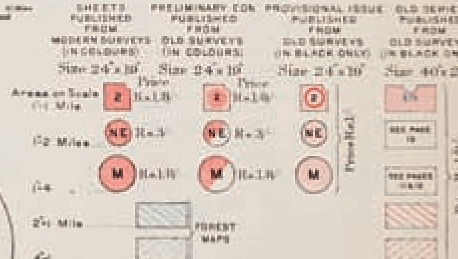
For a Half inch Sheet add letter & quadrant, thus 35 M NE

For a One inch Sheet add the letter & number, thus $35\frac{P}{16}$

APPLICATION FOR MAPS SHOULD BE MADE TO OFFICER IN CHARGE MAP RECORD & ISSUE OFFICE, 13, WOOD STREET, CALCUTTA.

FOREST MAPS ARE OBTAINABLE FROM THE O.C. FOREST MAP OFFICE, DEHRA DUN. (PRICES ON APPLICATION)

REFERENCE



For areas uncoloured, maps on the above mentioned scales are not available.

At Special request hand-colouring of boundaries and detail can be added to uncoloured Provisional Issues or old maps, at an extra charge of 8 Annas or 1 Rupee respectively. The hand-colouring of maps involves delay and is inadvisable for large or urgent demands.

notable examples included *Current Geographical Publications* (1938–2003) from the American Geographical Society, and *Akzessionsliste: Staatsbibliothek Preußischer Kulturbesitz, Kartenabteilung* (1972–91), produced in Berlin.

A model publication was the *Bibliographie cartographique de la France*, first compiled by the Bibliothèque nationale in Paris in the late 1930s and published as a supplement to the *Bulletin du Comité national français de géographie*. After World War II it rapidly evolved into the *Bibliographie cartographique internationale*. Armand Colin subsequently took over publication, although editorial control remained with the Bibliothèque nationale. It had begun as a listing of recently published French maps, yet by the time it ceased publication in 1975, its content was fully international, although including only a small percentage of overall global mapping output. In later years the *Bibliographie cartographique internationale* displayed great strength in its listing of Western European and Polish map publications, while its treatment of Asian maps was very limited.

A number of national bibliographies also played a key role (Larsgaard 1998, 79), by including maps within their pages, most notably those of Australia, Austria, the Federal Republic of Germany, the German Democratic Republic, New Zealand, Poland, Switzerland, and the United States. That of Australia even included full catalog records. The Library of Congress in Washington, D.C., issued its national union catalog *NUC: Cartographic Materials* for the United States from 1983 to 2002. Other U.S. examples included the annual *Bibliographic Guide to Maps and Atlases* (covering 1979–2003), which listed additions to the catalogs of the Library of Congress and the New York Public Library.

Cartobibliographical sources of mapping were highlighted first by C. B. Muriel Lock's *Modern Maps and Atlases* (1969) and in the following decade by Kenneth L. Winch's *International Maps and Atlases in Print*, a major development running to two editions in the mid-1970s. Winch listed around 8,000 entries from 700 publishers (Nichols 1976, 34). Again appearing in two issues was the ground-breaking *World Mapping Today* by Robert B. Parry and C. R. Perkins, published first in 1987 and then in a second edition in 2000. Both editions conveyed the state of the world of mapping of the time and were filled with graphic indexes and publishers' addresses, the latter of immense value to map collections aiming to deal direct with hitherto uncontactable map producers.

A number of international journals regularly featured reviews of maps or simply listed newly published maps of interest to their readership. In chronological order, some key titles that regularly and reliably concentrated on announcing details of new products were: *Petermanns Geographische Mitteilungen* (1856–); *Geographical Journal* (1893–); *Irish Geography* (1944–); *New Zealand Journal of Geography* (1946–); the quarterly *Bulletin*, Special Libraries Association, Geography and Map Division (1947–97); *World Cartography* (1951–94); *American Cartographer*, later *Cartography and Geographic Information Systems* (later *Science*) (1974–); *Cartographer*, later *Canadian Cartographer*, later *Cartographica* (1964–); *Cartographic Journal* (1964–); *Geographical Abstracts (Geo Abstracts)* (1966–); *Bulletin of the Society of University Cartographers* (1966–); *Western Association of Map Libraries Information Bulletin* (1970–); and *Cartinform* (1971–93).

To sum up this broad-brush approach to a complex issue, an all-encompassing listing of global cartographic production eluded map collections throughout the century, and not unreasonably so. Political sensitivities played a major role, and it was not until the 1990s that the huge range of mapping produced in the Soviet Union was revealed to the world in general. Other geopolitically sensitive areas, for example, Latin America, were also problematic when endeavoring to identify cartographic information. As the twentieth century progressed, the potential to harness mapping sources increased. By the turn of the millennium, the Internet was rendering the monitoring of current map publications much more accessible than earlier in the century.

NICK MILLEA

SEE ALSO: Geographic Names: Gazetteer; Journals, Cartographic; Libraries, Map; Libraries and Map Collections, National; Public Access to Cartographic Information; Societies, Cartographic; Societies, Map; Societies, Map Librarianship; Societies, Photogrammetric and Remote Sensing

BIBLIOGRAPHY:

Cobb, David A. 1973. "Selection and Acquisition of Materials for the Map Library." *Drexel Library Quarterly* 9, no. 4:15–25.

Larsgaard, Mary Lynette. 1998. *Map Librarianship: An Introduction*. 3d ed. Englewood: Libraries Unlimited.

Lock, C. B. Muriel. 1969. *Modern Maps and Atlases: An Outline Guide to Twentieth Century Production*. London: Clive Bingley.

Nichols, Harold. 1976. *Map Librarianship*. London: Clive Bingley.

Parry, Robert B., and C. R. Perkins. 2000. *World Mapping Today*. 2d ed. London: Bowker-Saur.

Pruett, Nancy Jones. 1990. "Earth Science Mapping." In *Information Sources in Cartography*, ed. C. R. Perkins and Robert B. Parry, 331–46. London: Bowker-Saur.

Stephenson, Richard W. 1970. "Published Sources of Information about Maps and Atlases." *Special Libraries* 61:87–98, 110–12.

Tandy, E. A. 1924. *Catalogue of Maps Published by the Survey of India, Corrected up to 1st July 1924*. Calcutta: Survey of India Offices.

Winch, Kenneth L., ed. 1976. *International Maps and Atlases in Print*. 2d ed. London: Bowker.

Space Oblique Mercator Projection. The Space Oblique Mercator (SOM) projection was developed in the 1970s in response to the need for a new map projection that could be used to conformally map remote sensing data received from the first Landsat satellite, originally named the Earth Resources Technology Satellite (ERTS 1). Alden P. Colvocoresses, cartographic coordinator for earth satellite mapping at the U.S. Geological Survey (USGS), first conceived of and described the projection geometrically in 1974. Because Landsat circled and scanned the earth continuously in a near polar orbit, the new projection needed to account for the motion of the satellite and the rotation of the earth, requiring that time be considered as a map projection parameter.

In order to produce a conformal map with a minimum of scale error, Colvocoresses (1974) envisioned the earth inscribed in a cylinder whose axis was perpendicular to that of the axis of the earth. The cylinder then oscillated back and forth at a compensatory rate to account for the earth-satellite motions. Although he was able to describe the projection geometrically, neither he nor anyone else at the time could discover the analytical equations for such a projection.

In April 1977, after attending a conference on the future of geodesy at which the lack of a mathematical solution was discussed, John Parr Snyder, a chemical engineer and part-time cartographic historian, began work on a solution. The difficulty that Snyder had to overcome was the derivation of a series of differential equations that described the complex geometry of the motion of the satellite relative to the earth so that the shape and position of the satellite's ground track could be calculated to high degree of accuracy.

In August 1977, Snyder produced a set of equations that, while not perfectly conformal and not realistically representing the satellite's orbit, nevertheless, produced scale errors sufficiently low for mapping applications (Hessler 2004, 8–9). Snyder (1981) took an empirical approach to the problem, deriving a series of nonlinear differential equations that he integrated numerically on an early Texas Instruments programmable calculator, the TI-56. In the months that followed he improved his derivations and obtained equations for the SOM that regard the earth as an ellipsoid and the satellite orbit as Keplerian.

The graticule for the SOM describes the ground track of the satellite as the centerline of the projection and as a nearly sinusoidal curve (fig. 913). The oscillations of the curve represent the vibrations of the cylinder in Colvocoresses' original conception and account for the earth-satellite motions.

At the same time that Snyder was deriving his results, John L. Junkins and a team at the University of Virginia proposed a different solution to the problem. Junkins's approach was more theoretical, working out the orbital relationships of the earth and the satellite in more detail, but it contained levels of distortion unacceptable to the USGS. A conformal solution was finally found by Yang Cheng (1996) and is known as the Conformal Space projection. The SOM, one of the most complex projections ever developed, continues to be used in most satellite earth mapping applications.

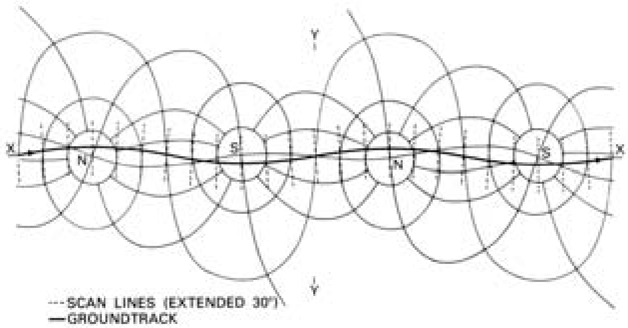


FIG. 913. GRATICULE FOR THE SPACE OBLIQUE MERCATOR PROJECTION.
Size of the original: 9.7 × 18.9 cm. From Snyder 1981, 14.

JOHN W. HESSLER

SEE ALSO: Conformality; Mercator Projection; Remote Sensing: Data Handling and Information Extraction from Remotely Sensed Imagery; Snyder, John P(arr)

BIBLIOGRAPHY:
Cheng, Yang. 1996. "The Conformal Space Projection." *Cartography and Geographic Information Systems* 23:37–50.
Colvocoresses, Alden P. 1974. "Space Oblique Mercator." *Photogrammetric Engineering* 40:921–26.
Hessler, John W. 2004. *Projecting Time: John Parr Snyder and the Development of the Space Oblique Mercator Projection*. Washington, D.C.: Geography and Map Division, Library of Congress.
Snyder, John Parr. 1981. *Space Oblique Mercator Projection: Mathematical Development*. Washington, D.C.: U.S. Geological Survey.

Standards for Cartographic Information. At the start of the century, most agencies that produced topographic maps, with a few notable exceptions, were controlled by the military of their respective countries. The notable exceptions were the Ordnance Survey in the United Kingdom and the U.S. Geological Survey (Collier 2002). Accuracy specifications were applied to particular map series produced by each organization.

The idea of an internationally agreed specification had been discussed in the mid-nineteenth century and revived in 1891 at the Fifth International Geographical Congress by the German geographer Albrecht Penck. Following a series of meetings at subsequent congresses, agreement was reached on a standard specification for the International Map of the World at 1:1,000,000 in 1909. However, as noted by Alastair W. Pearson et al. (2006), there were considerable problems in ensuring consistency, geographical coverage was never completed, and geopolitics ensured its goal was not accomplished. Given that there were two world wars during the first half of the century, with countries being partitioned and rearranged after each, map accuracy specifications that applied in one area before the war did not necessarily apply after the war. Generally, map specifications applied to particular series of maps. To this day map accuracy specifications or standards are not available for many countries in the world.

During this time many national mapping agencies in Europe and North America began moving toward specific accuracy specifications for their topographic maps that began to approach one-half millimeter error specification for the placement of points and lines on the hard copy map. The Swiss were one of the leaders in this kind of work. Elsewhere in the world, many former colonial countries in Africa and Asia looked to their former ruling powers for inspiration and leadership in map accuracy strategies. Latin American countries, having achieved independence earlier, typically looked to Spain or Portugal for leadership in map accuracy strategies.

During the 1930s, in some countries the concern for map accuracy specifications turned into an effort to develop a national map accuracy standard. As photogrammetric map compilation procedures became more prominent, the need for better map accuracy specifications became evident. The United States was such a case where a bottom-up process was taking place. Private-sector firms and federal agencies had used different map accuracy specifications that produced differing results (Marsden 1960). In 1937, the American Society of Photogrammetry set up a committee to develop better map accuracy specifications. After several years, and with the participation of several federal agencies, the U.S. Bureau of the Budget proposed a draft map accuracy standard in 1941, which after several revisions became the United States National Map Accuracy Standards (NMAS) in 1947. The horizontal accuracy standard stated that not more than 10 percent of tested well-defined points on the ground could be in error on the map by more than $\frac{1}{30}$ inch (0.85 mm) of their true map position for scales larger that 1:20,000, and $\frac{1}{50}$ inch (0.5 mm) for scales smaller than 1:20,000. For vertical accuracy NMAS stated that not more than 10 percent of tested elevation points could be in error by more than one half the map's contour interval (Thompson 1981, 102–4). This is an example of what Harold Moellering (1997, 5) has called a "surface structure" standard. The National Mapping Council of Australia approved a similar accuracy standard in 1953.

In the 1930s and the following decades a number of European countries had map accuracy specifications along the lines of 0.5 millimeter maximum positional error for tested points. In Switzerland, a feature on a map should not be more than 0.3 millimeter from the corresponding point seen in the photogrammetric model. The Russian specification in the 1950s called for average errors of 0.5 millimeter or less in flatter areas, while in high altitudes and deserts such errors must be 0.75 millimeter or less.

An international mapping conference was held by the British War Office in March 1943 to harmonize mapping standards between the Western Allies (Clough 1952, 44–48). The 1943 agreement was the forerunner of subsequent agreements on mapping standards between North Atlantic Treaty Organization (NATO) members. These standards agreements (STANAGs) covered all map and chart series used within the NATO command.

The U.S. Army (1963) began to examine maps from many sources and developed an accuracy classification scheme using the NMAS and other criteria to evaluate them. In the late 1980s the Pan American Institute for Geography and History/Instituto Panamericano de Geografía e Historia utilized a similar accuracy classification system for the countries of Latin America. During the same period some other countries, mainly in Europe and North America, were exploring the use of statistical methods to define accuracy standards. These usually involved the use of the root-mean-square error (RMSE) to look at the differences between map positions and true ground positions. A classic study employing the statistical concepts of error analysis and map accuracy is that by Clyde R. Greenwalt and Melvin E. Shultz (1962), which provided the theoretical grounding for a Linear Map Accuracy Standard (LMAS) as well as a Circular Map Accuracy Standard (CMAS).

Meanwhile, a number of countries updated their accuracy standards. Japan in 1986 updated the standard that specified horizontal position on large-scale maps as having a standard deviation (SD) of less than 0.7 millimeter on the map. Error for contour lines was specified as less than one-half of the intermediate contour line. Israel introduced a positional accuracy standard in 1987 along the lines of the U.S. NMAS standard: ordnance no. 36 specified "the difference between the position of well-defined points of detail and their position as established through field survey, shall not exceed 0.8 mm, at the map scale, with respect to at least 90% of the details checked" (Peled and Adler 1993, 427).

At the same time, researchers continued to apply the RMSE to analyze the differences between the locations on the map of "well defined points" and their true position on the ground. The American Society for Photogrammetry and Remote Sensing (ASPRS) developed an accuracy standard for large-scale maps in the 1980s using the RMSE and the associated SD. After much discussion and debate, it was accepted as an ASPRS standard in 1990.

This kind of thinking pushed many agencies in the world toward RMSE map accuracy standards based on ground accuracies, and many, such as the U.K. Ordnance Survey, began accuracy improvement programs. Many other countries, such as Australia (2009), South Africa (1997), Canada (1997), France (2003), and New Zealand (2003), issued new ground-based map accuracy standards that Moellering (1997, 5) has called "deep structure" standards. In 1998 the U.S. Federal Geographic Data Committee approved the National Standard for Spatial Data Accuracy. The status of map accuracy standards for many countries in the world has been summarized by Brazilian engineers Marcelo Antonio Nero and Jorge Pimentel Cintra (2005), who analyzed the relevant standards for eighteen countries. Some counties are credited with more than one standard, so the total analyzed is much larger.

In the latter part of the century, several organizations worked toward comprehensive world map coverage. In an effort reminiscent of the International Map of the World, the Digital Chart of the World was initiated by the United States, Canada, Australia, and the United Kingdom to create a digital navigation chart for the world, while the Global Mapping Project was initiated under the leadership of Japan to develop thematic data sets with world coverage, both intended for use at the 1:1,000,000 scale.

In the 1960s spatial data processing was largely an experimental undertaking with proof of concept systems. By the 1970s many organizations and agencies were developing freestanding spatial data and mapping systems, each with its own data structure, formats, and data codes. Over time, many groups tried to share data with other systems, with very mixed results because of the incompatibilities of formats and data codes. Many of the technologically advanced countries saw the need to develop national mapping transfer standards so spatial data could be moved between systems. This work was conducted in the spatial deep structure with "virtual 3" map files—virtual maps in neither hard copy nor directly viewable (Moellering 1997, 5).

One of the earlier efforts in the 1980s began when the U.S. Geological Survey authorized and funded the establishment of the American Congress on Surveying and Mapping (ACSM) National Committee for Digital Cartographic Data Standards (NCDCDS) to develop what became the Spatial Data Transfer Standard (SDTS) under the leadership of Moellering. This effort spurred many European agencies to establish their own national data transfer standards. Several European regional organizations, such as Comité Européen des Responsables de la Cartographie Officielle (CERCO), Comité Européen de normalisation—CEN/TC 287, NATO Digital Geographic Information Working Group (DGIWG), and the International Hydrographic Organization (IHO), also became interested in developing spatial data transfer standards for their stakeholders, as discussed by François Salgé (1999). Europe (Salgé 1997) and North America (Hogan and Sondheim 1997) led this work, with the Asia-Pacific region in close pursuit (Clarke 1997).

By the early 1990s, there were seventeen national transfer standards, four regional standards, and one international transfer standard approved or being developed, as shown in table 48. These transfer standards can be viewed in terms of their flexibility, as shown in figure 914. Most national standards are fixed transfer formats at the more rigid end with little flexibility and a transfer mechanism at the more flexible end. Somewhere in the middle is the British National Transfer Format (NTF), which has several different transfer levels. The U.S. SDTS gains its flexibility by defining the standard in terms of transfer modules. Because of its flexibility and transfer power, SDTS was adopted by Australia, New Zealand, and Korea and adapted to national conditions. Further, SDTS had a strong influence in the development of the DGIWG Digital Geographic Information Exchange Standard (DIGEST) standard and the IHO S-57 transfer standard. Other standards were influenced to a lesser degree. It was also influential because of its systematic definitions of data quality, the core of what later became known as spatial metadata.

With the widespread thinking and developments in spatial data transfer standards and possible data sharing, many individuals, agencies, and organizations began to realize that this raised a host of new questions as to how these new digital spatial data could be defined, used, and shared. Organizations in many countries deliberated on how these new opportunities could benefit their stakeholders. One of the most prominent was the Chorley Report from Great Britain (1987), which systematically addressed these new challenges and opportunities. From it came sixty-four recommendations on how to coordinate efforts to more effectively gather, utilize, distribute, and share geographic information.

In a wider domain, at the 1989 Budapest International Cartographic Association (ICA) meetings a group of cartographic data standards specialists organized what became the ICA Commission on Spatial Data Standards. Over twenty countries have been full members, with about a dozen corresponding members and another dozen international observers. The commission meets to discuss and understand spatial data standards under development in the various member countries/organizations, share ideas and conceptual perspectives, initially analyze spatial data transfer standards, and later spatial metadata standards. The commission published three books and many papers and journal articles in various venues. Two of those books (Moellering and Hogan

Table 48. National/Regional/International spatial data transfer standards (from Moellering and Hogan 1997).

Country/Region/Organization	Name of Spatial Data Transfer Standard (Acronym)
Australia and New Zealand	Spatial Data Transfer Standard (AS/NZS 4270)
Austria	Datenschnittstelle für den digitalen Austausch von Geo-Daten (A 2260)
Canada	Canadian Geomatics Interchange Standards—Spatial Archive and Interchange Format (SAIF)
China	Data Exchange Format for Information of Surveying and Mapping (DEFS)
Finland	EDI Based Geographic Information Service (JHS 111-119)
France	Traitement de l'information géographique numérique: Echange de données informatisé dans le domaine de l'information géographique (EDIGéO)
Germany	Einheitliche Datenbankschnittstelle (EDBS) für die Automatisierte Liegenschaftskarte (ALK) und das Amtliche Topographisch-Kartographische Informationssystem (ATKIS) (ALK/ ATKIS-EDBS)
Israel	Israel Exchange Format 1991 (IEF '91)
Japan	Standard Procedure and Data Format for Digital Mapping (SPDFDM)
Netherlands	Automatische gegevensverwerking. Uitwisselingsformat voor gegevens over de aan het aardoppervlak gerelateerde ruimtelijke objecten (NEN 1878)
Norway	Samordnet opplegg for stedfestet informasjon (SOSI)
Russian Federation	Digital and Electronic Maps Transfer Standard (DEMTS) GOST R 50828-95 Geoinformatic Mapping. Spatial Data, Digital and Electronic Maps. General Requirements
South Africa	National Standard for the Exchange of Digital Geo-Referenced Information (NES)
Spain	Norma de intercambio de cartografía catastral (NICCa)
Switzerland	INTERLIS
United Kingdom	Electronic Transfer of Geographic Information (NTF)
United States	Spatial Data Transfer Standard (SDTS)
CERCO	European Territorial Data Base (ETDB)
CEN/TC 287	Family of Standards (CEN/TC 287)
CEN TC 278 WG 7	Geographic Data File (GDF)
DGIWG	Digital Geographic Information Exchange Standard (DIGEST)
IHO	IHO Transfer Standard for Digital Hydrographic Data (S-57)

1997; Moellering, Aalders, and Crane 2005) served as a prime set of references into the twenty-first century.

In 1994 the International Organization for Standardization (ISO) Technical Committee 211 Geographic Information/Geomatics was organized under the leadership of Olaf Østensen of Norway. This is the world standards authority for geographic information on a de jure basis and as such interacts with all of the national standards bodies throughout the world. ISO/TC 211 has thirty-two participating country members, thirty-one observer countries, and about thirty external liaison organizations. ISO/TC 211 is providing the lead for official geographic information standards throughout the world (Østensen 1997; Østensen and Danko 2005). To date ISO/TC 211 has developed about sixty spatial data standards and specifications. Some of the more significant ones are shown in table 49.

About the same time the Open GIS Consortium (OGC) was founded as an organization that provides de facto publicly available interface standards. As such it serves its constituency base and cooperates with ISO/TC 211.

Once one has the ability to transfer spatial data between diverse systems, then the challenge is to understand the data's characteristics and qualities. Thus emerge metadata, which are data about the data set. This need was recognized in the 1980s as spatial data systems and transfer standards were emerging. Many countries that developed transfer standards went on to develop their own spatial metadata standards in the 1990s, such as

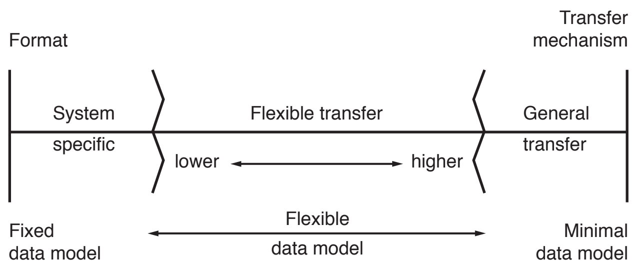


FIG. 914. THE FLEXIBILITY OF CARTOGRAPHIC DATABASE TRANSFER PROCESSES.
After Moellering and Hogan 1997, 7.

TABLE 49. Sample of ISO/TC 211 significant standards and specifications (from ISO/TC 211 website; Østensen and Danko 2005, 146).

ISO #	Name of Standard/Specification
6709	Standard Representation of Geographic Point Location by Coordinates
19101	Reference Model
19107	Spatial Schema
19108	Temporal Schema
19111	Spatial Referencing by Coordinates
19113	Quality Principles
19115	Metadata
19116	Positioning Services
19121	Imagery and Gridded Data
19125	Simple Feature Access
19127	Geodetic Codes and Parameters
19128	Web Map Server Interface
19136	Geography Markup Language
19141	Schema for Moving Features
19142	Web Feature Service
19150	Ontology
19152	Land Administration Domain Model
19157	Data Quality

those in North America (Fadaie et al. 2005). In the Asia-Pacific region activity was mixed. Australia and New Zealand had already developed their metadata standard in the late 1990s, Japan a little later, with Korea and China a few years later (Macauley et al. 2005). Some European countries could see that ISO/TC 211 was developing a world spatial metadata standard and did not want to duplicate that effort, and hence joined in with ISO/TC 211 to directly work on the world standard (Aalders, Salgé, and Martynenko 2005). Some continued to use the CEN/TC 287 draft metadata standard. Meanwhile, a number of Latin American countries became very interested in spatial metadata standards (described by Delgado-Fernández, Rey-Martinez, and Chaparro-Dominguez 2005). In Africa and the Middle East, South Africa and Israel have led the way in developing spatial metadata standards (Cooper and Gavin 2005), while other countries in those regions contemplated their situation. Table 50 shows the various metadata standards that had been developed by the end of the century.

The ISO/TC 211 ISO 19115 world metadata standard was in its final stages at the end of the century. Member countries could then take their national metadata standard and harmonize it by making it a profile of ISO 19115. This meant revising their national metadata standard so its metadata items were a subset of the metadata items in ISO 19115 world standard.

In the closing years of the century ISO/TC 211 and its national affiliate members continued to flesh out the de jure spatial data standards framework. Most nations were harmonizing their standards with this new world spatial data standards framework. Organizations like OGC and DGIWG continued to develop de facto spatial standards for their stakeholders. At the same time, many saw the potential for the spatial data infrastructure (SDI), and several organizations such as Global Spatial Data Infrastructure, Digital Earth, Global Mapping, and various regional SDI organizations were being formed and working toward various SDI goals.

In the beginning of the century map accuracy was measured on hard copy maps in the surface structure. As the century progressed, accuracy began to be thought of as related to the ground in the deep structure, but still present in hard copy maps. About midcentury computer processing of digital map data resulted in processing the data in a virtual 3 map environment in the deep structure. Thus the necessity for spatial data standards emerged. Hard copy maps are still made, especially as output, but almost all data gathering and processing of cartographic data is conducted in a virtual 3 deep structure setting using spatial data standards to characterize the data.

HAROLD MOELLERING

SEE ALSO: Analytical Cartography; Conventions, Cartographic; Geographic Information System (GIS): Metadata; Metric System; Uncertainty and Reliability

BIBLIOGRAPHY:

Aalders, Henri J. G. L., François Salgé, and Alexander I. Martynenko. 2005. "European Efforts in the Field of Geographic Metadata and Related SDI Activities." In *World Spatial Metadata Standards: Scientific and Technical Descriptions, and Full Descriptions with Crosstable*, ed. Harold Moellering, Henri J. G. L. Aalders, and Aaron Crane, 31–62. Amsterdam: Elsevier.

Clarke, Andrew L. 1997. "Developing a Geographic Data Infrastructure: An Asia-Pacific Perspective." In *Spatial Database Transfer Stan-*

Table 50. Spatial metadata standards as of the close of the twentieth century (from Moellering, Aalders, and Crane 2005, cross-table insert)

Country/Organization	Name of Spatial Metadata Standard
Australia and New Zealand	ANZLIC Metadata Guidelines
Canada	Directory Information Describing Digital Geo-Referenced Data Sets/Information de repetoire décrivand les ensembles de données numériques à référence spatial
China	Geographic Information Metadata Standard (地理信息元数据标准 Dili xinxi yuanshuju biaozhun)
Czech Republic	Standard ISVS pro strukturu a vymenny format metadat informacnich zdroju/Standard for Structure and Transfer Format of Metadata on Geo-data Sets
Denmark	Infodatabase om Geodata/National Danish GI Metadata Service
Finland	JHS 137 Tietotuoteseloste; JHS 137A Tietotuoteseloste–Paikkatiedot/JHS 137 Data Product Description; JHA 137A Data Product Description–Geographic Information
Hungary	KIKERES Terinformatikai Profil/KIKERES Spatial Metadata Profile
Israel	Israel Metadata Standard 2000
Japan	Japanese Metadata Profile (日本メタデータプロファイル Nihon metade-ta purofairu)
Korea	National Geographic Information System Metadata: Interim Standard (국가지리정보체계 [NGIS]의 자료 이력서 [메타데이터] 잠정표준 Kukka jiri jŏngbo ch'egye [NGIS] ŭi jaryo iryŏksŏ [Met'a deit'ŏ] Chapchŏngp'yojun)
Netherlands	NCGI Metadata
Russian Federation	Gosudarstvennyy standart Rossiyskoy Federatsii GOST R 51353-99 "Geoinformatsionnoye kartografirovaniye. Metadannyye zlektronnykh kart. Sostav i soderzhaniye"/State Standard of the Russian Federation GOST R 51353-99 "Geoinformatic Mapping. Metadata of the Electronic Maps. Composition and Content"
South Africa	Content Standard for Digital Geospatial Data
Spain	MIGRA (Mecanismo de intercambio de información geográfica relacional formado por agregación)/Aggregated Relational Geographic Information Interchange Mechanism
United States	Content Standard for Digital Geospatial Metadata
Dublin Core	The Dublin Core Metadata Element Set
CEN/TC 287	Geographic Information—Data Description—Metadata
ISO/TC 211	ISO 19115 Geographic Information—Metadata

dards 2: Characteristics for Assessing Standards and Full Descriptions of the National and International Standards in the World, ed. Harold Moellering and Richard Hogan, 39–50. Oxford: Elsevier Science.

Clough, A. B., comp. 1952. *Maps and Survey*. London: War Office.

Collier, Peter. 2002. "The Impact on Topographic Mapping of Developments in Land and Air Survey: 1900–1939." *Cartography and Geographic Information Science* 29:155–74.

Cooper, Antony, and Elizabeth J. O. Gavin. 2005. "Spatial Metadata in Africa and the Middle East." In *World Spatial Metadata Standards: Scientific and Technical Descriptions, and Full Descriptions with Crosstable*, ed. Harold Moellering, Henri J. G. L. Aalders, and Aaron Crane, 123–39. Amsterdam: Elsevier.

Delgado-Fernández, Tatiana, Dora Inés Rey-Martinez, and Martha Ivette Chaparro-Dominguez. 2005. "Metadata Standards Development Activities in Central and South America and the Caribbean." In *World Spatial Metadata Standards: Scientific and Technical Descriptions, and Full Descriptions with Crosstable*, ed. Harold Moellering, Henri J. G. L. Aalders, and Aaron Crane, 103–21. Amsterdam: Elsevier

Fadaie, Kian, et al. 2005. "North American Metadata Standards Developments in Canada and the United States of America." In *World Spatial Metadata Standards: Scientific and Technical Descriptions, and Full Descriptions with Crosstable*, ed. Harold Moellering, Henri J. G. L. Aalders, and Aaron Crane, 63–82. Amsterdam: Elsevier.

Great Britain. Committee of Enquiry into the Handling of Geographic Information. 1987. *Handling of Geographic Information: Report to the Secretary of State for the Environment of the Committee of Enquiry into the Handling of Geographic Information*. Lord Chorley, chairman. London: Her Majesty's Stationery Office.

Greenwalt, Clyde R., and Melvin E. Shultz. 1962. *Principles of Error Theory and Cartographic Applications*. St. Louis: Aeronautical Chart and Information Center.

Hogan, Richard, and Mark Sondheim. 1997. "Spatial Data Transfer Standards Activities in North America." In *Spatial Database Transfer Standards 2: Characteristics for Assessing Standards and Full Descriptions of the National and International Standards in the World*, ed. Harold Moellering and Richard Hogan, 31–38. Oxford: Elsevier Science.

Macauley, Craig, et al. 2005. "Metadata Standards Development Activities in the Asia-Pacific Region." In *World Spatial Metadata Standards: Scientific and Technical Descriptions, and Full Descriptions with Crosstable*, ed. Harold Moellering, Henri J. G. L. Aalders, and Aaron Crane, 83–101. Amsterdam: Elsevier.
Marsden, Lloyd E.. 1960. "How the National Map Accuracy Standards Were Developed." *Surveying and Mapping* 20:427–39.
Moellering, Harold. 1997. "An Introduction to World Database Transfer Standards." In *Spatial Database Transfer Standards 2: Characteristics for Assessing Standards and Full Descriptions of the National and International Standards in the World*, ed. Harold Moellering and Richard Hogan, 3–13. Oxford: Elsevier Science.
Moellering, Harold, Henri J. G. L. Aalders, and Aaron Crane, eds. 2005. *World Spatial Metadata Standards: Scientific and Technical Descriptions, and Full Descriptions with Crosstable*. Amsterdam: Elsevier.
Moellering, Harold, and Richard Hogan, eds. 1997. *Spatial Database Transfer Standards 2: Characteristics for Assessing Standards and Full Descriptions of the National and International Standards in the World*. Oxford: Elsevier Science.
Nero, Marcelo Antonio, and Jorge Pimentel Cintra. 2005. "Controle de qualidade de mapeamento: Visão geral das normas de diversos países." *Proceedings, XXII Congresso Brasileiro de Cartografia*.
Østensen, Olaf. 1997. "ISO Standardization in the Field of Geographic Information: The Global Perspective." In *Spatial Database Transfer Standards 2: Characteristics for Assessing Standards and Full Descriptions of the National and International Standards in the World*, ed. Harold Moellering and Richard Hogan, 51–60. Oxford: Elsevier Science.
Østensen, Olaf, and David M. Danko. 2005. "Global Spatial Metadata Activities in the ISO/TC211 Geographic Information Domain." In *World Spatial Metadata Standards: Scientific and Technical Descriptions, and Full Descriptions with Crosstable*, ed. Harold Moellering, Henri J. G. L. Aalders, and Aaron Crane, 141–65. Amsterdam: Elsevier.
Pearson, Alastair W., et al. 2006. "Cartographic Ideals and Geopolitical Realities: International Maps of the World from the 1890s to the Present." *Canadian Geographer* 50:149–76.
Peled, Ammatzia, and Ron Adler. 1993. "A Common Database for Digital Mapping and GIS." *International Journal of Geographical Information Systems* 7:425–34.
Salgé, François. 1997. "Standardization in the Field of Geographic Information: The European Efforts." In *Spatial Database Transfer Standards 2: Characteristics for Assessing Standards and Full Descriptions of the National and International Standards in the World*, ed. Harold Moellering and Richard Hogan, 17–30. Oxford: Elsevier Science.
———. 1999. "National and International Data Standards." In *Geographical Information Systems*, 2d ed., 2 vols., ed. Paul A. Longley et al., 2:693–706. New York: John Wiley & Sons.
Thompson, Morris M. 1981. *Maps for America*. 2d ed. Reston: U.S. Department of Interior, Geological Survey National Center.
United States. Department of the Army. 1963. *Foreign Maps*. Washington, D.C.: Headquarters, Department of the Army.

Star Chart. During the twentieth century, star charts ceded their historic role in navigation and surveying to electronic measurement, overhead imaging, and constellations of GPS (Global Positioning System) satellites. However, advances in astronomy, technological developments, and increased global cooperation among astronomers have resulted in maps—even those intended for amateur skywatchers—that lack the ornate pictorial elements of earlier charts but are far richer in information about the cosmos than historic star maps.

By 1900, photography was becoming the preferred means of recording telescopic observations, a position it would hold until nearly the end of the twentieth century. Because of its improvements on human vision, astronomers could observe many more stars and with greater accuracy. The possibility of photographically mapping the sky drew the interest of several scientists, and the director of the Paris Observatory, Admiral Ernest Amédée Barthlémy Mouchez, became the project's greatest advocate. In April 1887, the *Astrographic Catalogue* and *Carte du Ciel* were launched at an international gathering of astronomers hosted in Paris by the Académie des sciences. The catalog was intended to include stars to the eleventh magnitude, and the star map would go even fainter, capturing stars to the fourteenth magnitude. Each of the participating observatories was assigned different zones of the sky and instructed to make two sets of plates, one for the catalog and a second, with longer exposure times, for the map plates (Turner 1912). To compile the catalog, workers who were called "computers" (often women employed for this purpose) made careful measurements of stars' locations. Unfortunately, the scale of the project taxed the resources of several observatories for decades to such an extent that the complete catalog was not published until 1964 and the star map was never finished.

Despite the difficulty of the task, the *Astrographic Catalogue* and *Carte du Ciel* provided a model for international cooperation among astronomers. The International Astronomical Union (IAU), which was formed in 1919, grew out of the photographic mapping project, and the organization took responsibility for it as well as several other international projects (Blaauw 1994). The IAU also became the international authority for identifying and naming celestial bodies and their surface features. This role had a direct effect on star charts when, in 1930, the organization established a standard list of eighty-eight constellations as well as their boundaries (Delporte 1930). Rather than the pictorial forms that had dominated older star maps, it described rectangular boundaries for each constellation. This practice had appeared in earlier astronomical maps, but the IAU's decision standardized their locations and the stars that comprised each constellation.

Other developments in astronomy also changed humanity's understanding of the cosmos in the late nineteenth and early twentieth centuries. Large telescopes, many situated on mountaintop observatories, increased the visibility of faint objects such as dark nebulae. Spectrographic analysis identified binary stars previously be-

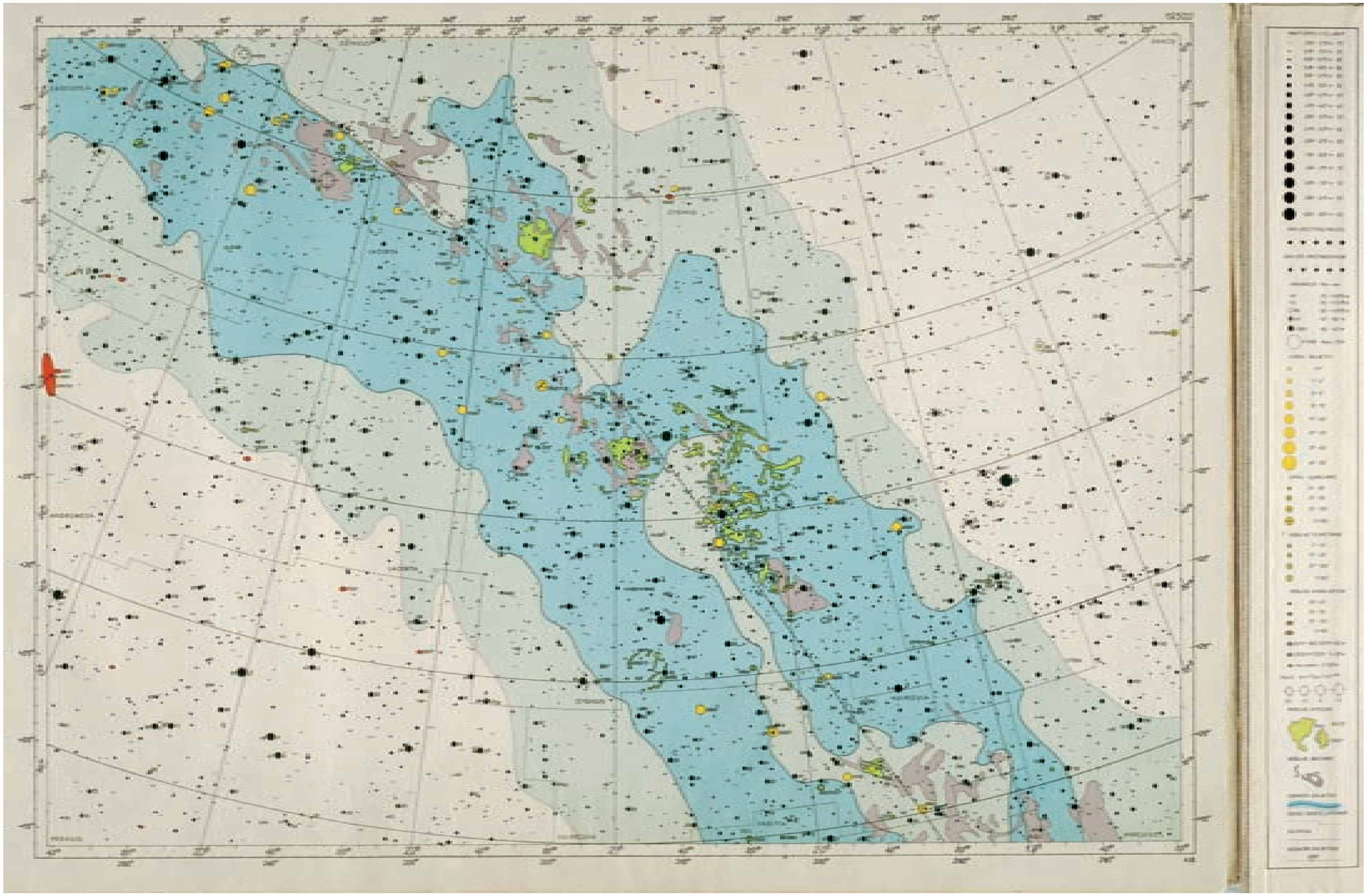


FIG. 915. STAR CHART FROM ANTONÍN BEČVÁŘ'S *ATLAS COELI*. Czechoslovakian astronomer Antonín Bečvář combined data from numerous catalogs for his atlas, and its format influenced several later star charts.

Size of the original: ca. 39.6 × 62.1 cm. From Antonín Bečvář, *Atlas of the Heavens, Atlas coeli, 1950.0* (Prague: Nakladatelství Československé Akademie Věd; Cambridge: Sky Publishing, 1958), pl. 5. Permission courtesy of Sky Publishing Corporation, Cambridge, Mass.

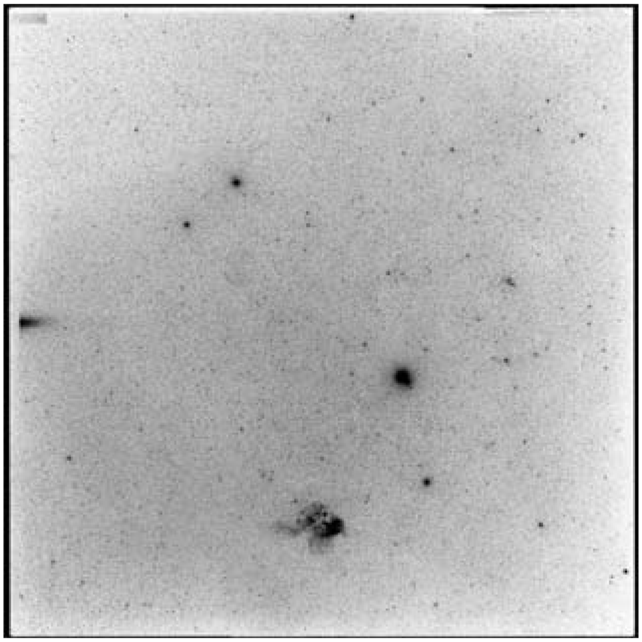


FIG. 916. PHOTOGRAPHIC MAP FROM THE NATIONAL GEOGRAPHIC SOCIETY–PALOMAR OBSERVATORY SKY SURVEY 1, 1951. Photograph taken 8/9 November 1951; image POSS no. E-420. The photographic survey of the Northern Hemisphere and small portion of the Southern Hemisphere conducted at Palomar Observatory in southern California inspired comprehensive surveys of the Southern Hemisphere and was the basis for numerous other mapping projects.
Size of the original photograph: 34.7 × 34.4 cm.

lieved to be single bodies. Perhaps the most radical shift came in 1924, when Edwin Powell Hubble announced that he had determined the distance to the Andromeda Nebula, settling a debate within astronomy as to whether some nebulae lay outside the Milky Way Galaxy. Through these advances, the scale of the universe increased dramatically as did the diversity of objects recognized and charted.

In 1948, Antonín Bečvář, director of the Skalnate Pleso Observatory in Czechoslovakia, published *Atlas coeli*, a modern atlas that represented the advances made in astronomy (Bečvář 1948). The sixteen maps, which covered the entire sky, were based on catalogs of star clusters, planetary nebulae, galaxies, binary and multiple stars, variable stars, and novae from the first half of the century. Different colors and shapes identify the phenomena, and the maps also show the boundaries of the IAU constellations. In addition to the ecliptic, Bečvář plotted the galactic equator, situating the maps in relationship to the larger universe confirmed by Hubble's observations. Although originally published in a limited run in Czechoslovakia, the international rights for publication were purchased by Sky Publishing, best known for its popular monthly *Sky and Telescope*. Under its guidance, numerous editions were printed and widely circulated with the title *Atlas of the Heavens* (fig. 915).

An era of successful photographic surveys began in

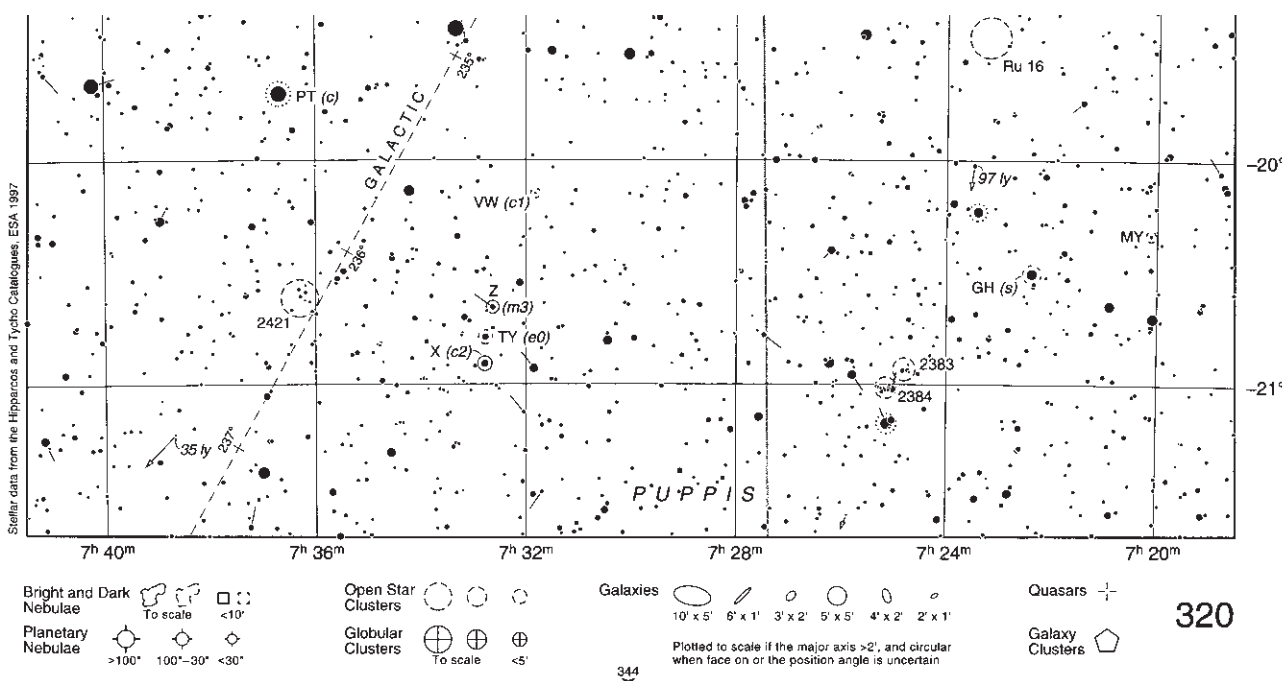


FIG. 917. DETAIL FROM GRAPHIC STAR CHART, 1997. By using data from the Hipparcos orbiting satellite telescope, the *Millennium Star Atlas* incorporated an unprecedented number of stars and other astronomical objects. Size of the entire original: 30.4 × 20.5 cm; size of detail: 10.7 × 20.5 cm. From Sinnott and Perryman 1997, vol. 1, chart 320. Permission courtesy of Sky Publishing Corporation, Cambridge, Mass.

1949 with the National Geographic Society–Palomar Observatory Sky Survey. Using the forty-eight-inch Schmidt telescope at Palomar Observatory, an instrument designed for wide-field views, astronomers created a photographic map of the Northern Hemisphere (and a small portion of the Southern Hemisphere), completing the observations in 1957 (fig. 916). From these plates, photographic sky atlases of 1,870 prints were made and distributed to observatories and research centers throughout the world (Strand 1963, 481–87). Beginning in 1973, surveys of the southern hemisphere were conducted at the European Southern Observatory in La Silla, Chile, and the Siding Spring Observatory in New South Wales, Australia, resulting in a similarly detailed photographic chart. The vast improvements in camera and photographic quality during the intervening years led to a second survey of the northern sky, the National Geographic Society–Palomar Observatory Sky Survey II (POSS II) (Reid 1988), which was initiated around 1984 and completed in 2000.

The surveys greatly expanded the number of known stars and other astronomical objects, but an even more comprehensive mapping project was developed from data collected by the Hipparcos Space Astrometry Mission, a satellite telescope launched by the European Space Agency (ESA) in 1989. While other survey results were available primarily as photographs, the data from Hipparcos were made into graphic charts and published (Sinnott and Perryman 1997). The positions of one million stars and several thousand galaxies with their correct orientations as well as numerous nebulae and globular clusters were plotted (fig. 917). Proper motion of fast-moving stars was also indicated.

With the increased availability of digital data, star charts also migrated from printed forms to the computer. Many digital atlases compiled data from the surveys conducted during the second half of the century, and they were valuable tools for both the amateur observer and the professional astronomer.

ELIZABETH A. KESSLER

SEE ALSO: Astrophysics and Cartography

BIBLIOGRAPHY:

Bečvář, Antonín. 1948. *Atlas coeli, Skalnaté Pleso, 1950.0*. Prague: Československá Společnost Astronomická v Praze.

Blaauw, Adriaan. 1994. *History of the IAU: The Birth and First Half-Century of the International Astronomical Union*. Dordrecht: Kluwer.

Débarbat, Suzanne, et al., eds. 1988. *Mapping the Sky, Past Heritage and Future Directions: Proceedings of the 133rd Symposium of the International Astronomical Union*. Dordrecht: Kluwer.

Delporte, E. 1930. *Délimitation scientifique des constellations*. Cambridge: Cambridge University Press.

Reid, Neill. 1988. "The Second Palomar Sky Survey." In *Mapping the Sky, Past Heritage and Future Directions: Proceedings of the 133rd Symposium of the International Astronomical Union*, ed. Suzanne Débarbat et al., 331–36. Dordrecht: Kluwer.

Sinnott, Roger W., and M. A. C. Perryman. 1997. *Millennium Star Atlas: An All-Sky Atlas Comprising One Million Stars to Visual Magnitude Eleven from the Hipparcos and Tycho Catalogues and Ten Thousand Nonstellar Objects*. 3 vols. Cambridge, Mass.: Sky Publishing; Noordwijk, Netherlands: European Space Agency.

Strand, K. Aage, ed. 1963. *Basic Astronomical Data*. Chicago: University of Chicago Press.

Turner, H. H. 1912. *The Great Star Map, Being a Brief General Account of the International Project Known as the Astrographic Chart*. New York: E. P. Dutton.

State Formation and Cartography. See Nation-State Formation and Cartography

Statistical Map. The word "statistics" was introduced in the mid-eighteenth century to refer to the collection and tabulation of numbers about the state (Friendly 2008, 504). The term reflected a mostly European interest in data about human populations that had earlier made its debut in the political arithmetic of the European nation-states of the seventeenth century. State statistics collected on population, land, and agricultural production for the purpose of taxation became an essential political component of imperial power (Beniger and Robyn 1978, 2). Whether the results helped to raise an army, extract taxes, or analyze age-related mortality, the collection of statistics facilitated political change, wealth, and expansion with each tabular summary of population, health, or economic indicators (Friendly 2008).

Statistical thinking was a component of the U.S. Constitution. In 1790 the U.S. became the first nation in the history of the world to take a population census and use it to allocate seats in a national assembly according to population (Anderson 2010, 154). The diversity of the U.S. population, combined with a decennial mechanism to adjust power and resources, made the census count and the federal statistical system truly central to the functioning of the society and the state (Anderson 2010, 155). As the diversity of data grew alongside a flourishing intellectual history of statistical thinking, a new urgency to portray these data visually as maps and diagrams was born (Friendly 2008).

In its earliest inception, statistical mapping was a subset of statistical graphics, a branch of statistics (Friendly 2008). "Moral statistics" introduced by European statisticians appeared on shaded maps with human and social topics of crime, suicide, and other social issues (Friendly 2007). The French typically referred to maps with isopleths, maps with diagrams, and maps with bands (flow maps) as *cartes figuratives*, or *cartogrammes*; in the United States, the term "statistical map" was more frequently used and included the cross-hatch map and dot or spot map (Funkhouser 1938, 301, 364–65).

FIG. 918. *DISTRIBUTION OF THE POPULATION: 1900*, IN THE UNITED STATES.
Size of the original: 22 × 33 cm. From *Statistical Atlas: Prepared under the Supervision of Henry Gannett, Geographer of the Twelfth Census* (Washington, D.C.: United States Census Office, 1903), pl. 13. Image courtesy of the David Rumsey Map Collection.

The early innovators of these basic map types set the stage for the lexicon of visual language and graphic ingenuity that made its dramatic debut in the national mapping programs and statistical bureaus of Europe and the United States in the late nineteenth century. These new forms of statistical graphics introduced statisticians, administrators, planners, and social scientists to the important geographic revelations hidden within numerical census tables and text-laden reports. Within a relatively short time, graphic statistics became a universal language (Funkhouser 1938, 331).

At the beginning of the twentieth century, statistical thinking in the United States began to change, and there was an obvious shift both in appearance and enthusiasm for statistical graphics from 1900 to 1930. There was a pronounced shift toward theoretical models and experimentation in statistical graphics, yet results were generally inconclusive and contradictory and yielded few innovations (Fienberg 1979, 176; Beniger and Robyn 1978, 6–9).

Cartography as an academic discipline was taught at some institutions in Europe by 1902, but was not a commonly taught discipline in the United States at the time. The high cost of statistical atlas production reduced national programs in the United States and in Europe. U.S. statistical atlases produced by the Census Bureau between 1900 and 1920 were reduced in size and color folios (fig. 918). The last major statistical atlases in Europe were the Swiss contributions in 1897 and 1914.

A transition was also taking place in the national statistical agencies. In the United States, several statistical agencies grew and prospered, and data poured out of federal statistical offices, guiding developments in tariffs and taxation, immigration policy, disabilities, labor relations, and many more areas (Anderson 2010, 157). Yet there were problems in consistency, standardization, and coordination, as well as manpower shortages. Statistical systems worldwide needed to address explosive issues such as immigration and the dramatic growth of cities. Federal mapping efforts introduced the dot map in U.S. Department of Agriculture publications in 1903, reflecting a new concern with the productivity of American farms and industry in the early twentieth century (Funkhouser 1938, 328). Compared to mathematical modeling, the graphs and maps that appeared in official publications at that time were viewed by statisticians as simplistic and limited in efficacy.

There were several unsuccessful efforts to centralize the U.S. federal statistical system prior to 1930. The economic crisis of the 1930s suspended publication of statistical maps for the decennial census, but the demand for official statistical information remained high. The Department of Agriculture was able to maintain a *Graphic Summary of American Agriculture* series, based on census data, that began in 1915 and was revised in 1921 and 1931 (Baker 1931). During the 1920s and 1930s statistical mapping at the U.S. Census Bureau became secondary to the unofficial mandate to accurately delineate geographic areas for the American public to create their own statistical maps (Klove 1967). The massive preparation of outline maps showing counties, minor civil divisions, incorporated cities, boroughs, towns, and villages created a huge volume of map resources to be updated for the next four decades (Klove 1967, 191–92). By 1940, outline maps of small statistical areas such as census tracts were added to this inventory.

Most histories of statistical graphics skip over the period from 1930 to 1960 and consider this the "modern dark ages" (Friendly and Denis 2000, 53). The dark ages really weren't so dark; the voluminous mapping efforts at the U.S. Census Bureau and other statistical agencies as well as other statistical maps were produced during these intervening years. Academic researchers at the University of Pennsylvania as well as research analysts from the U.S. Works Progress Administration resurrected Charles Joseph Minard's nineteenth-century flow maps for their human migration studies conducted in the early 1930s. C. W. Thornthwaite referenced the development of a mathematical model to quantify the width of the arrow as proportionate to the number of migrants (Thornthwaite 1934). Evidence of his mathematical theory was not published, but the map that accompanies his report (fig. 919) is an impressive summary of the data derived from place-of-birth to place-of-current-residence tables from the census (Tobler 1995, 329–33).

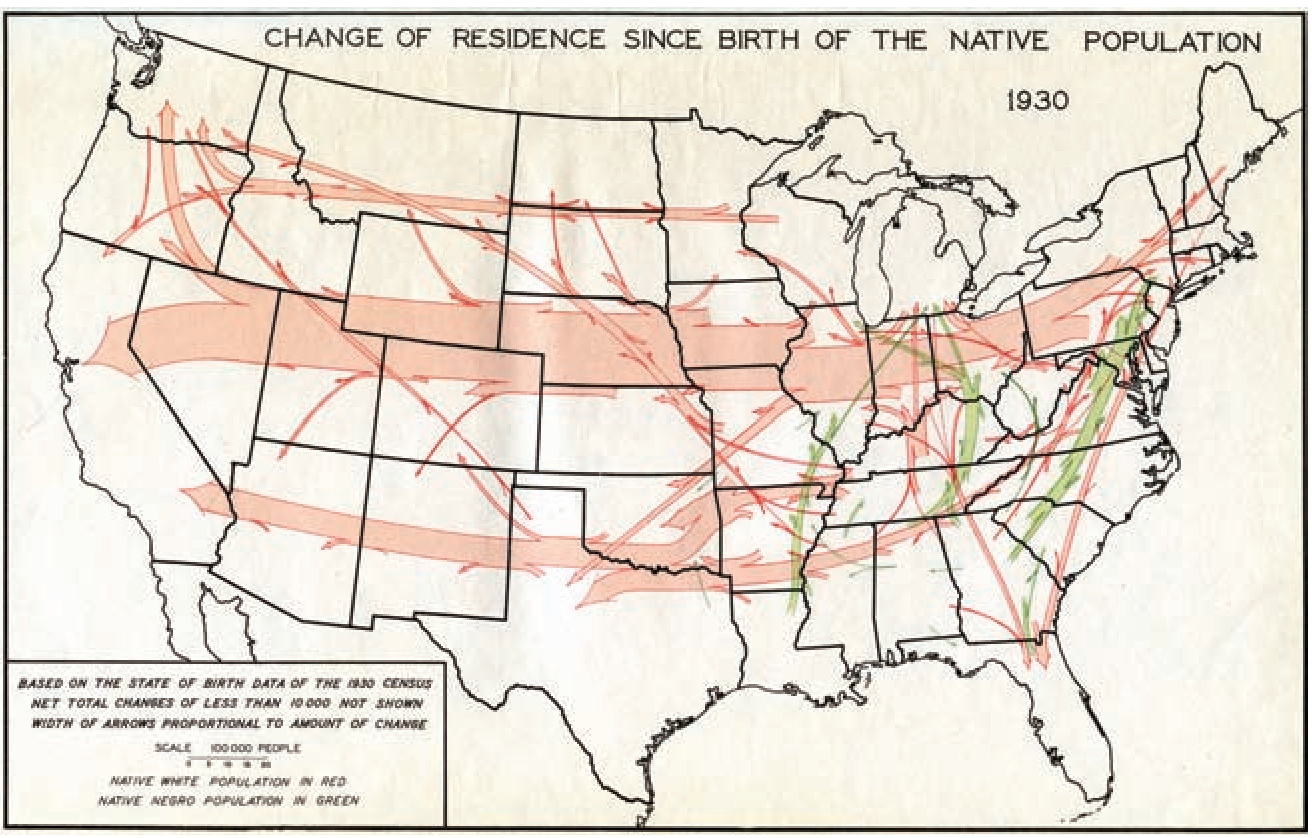


FIG. 919. *CHANGE OF RESIDENCE SINCE BIRTH OF THE NATIVE POPULATION, 1930*, IN THE UNITED STATES.

Size of the original: 13.5 × 21.6 cm. From Thornthwaite 1934, pl. 5 (following 16).

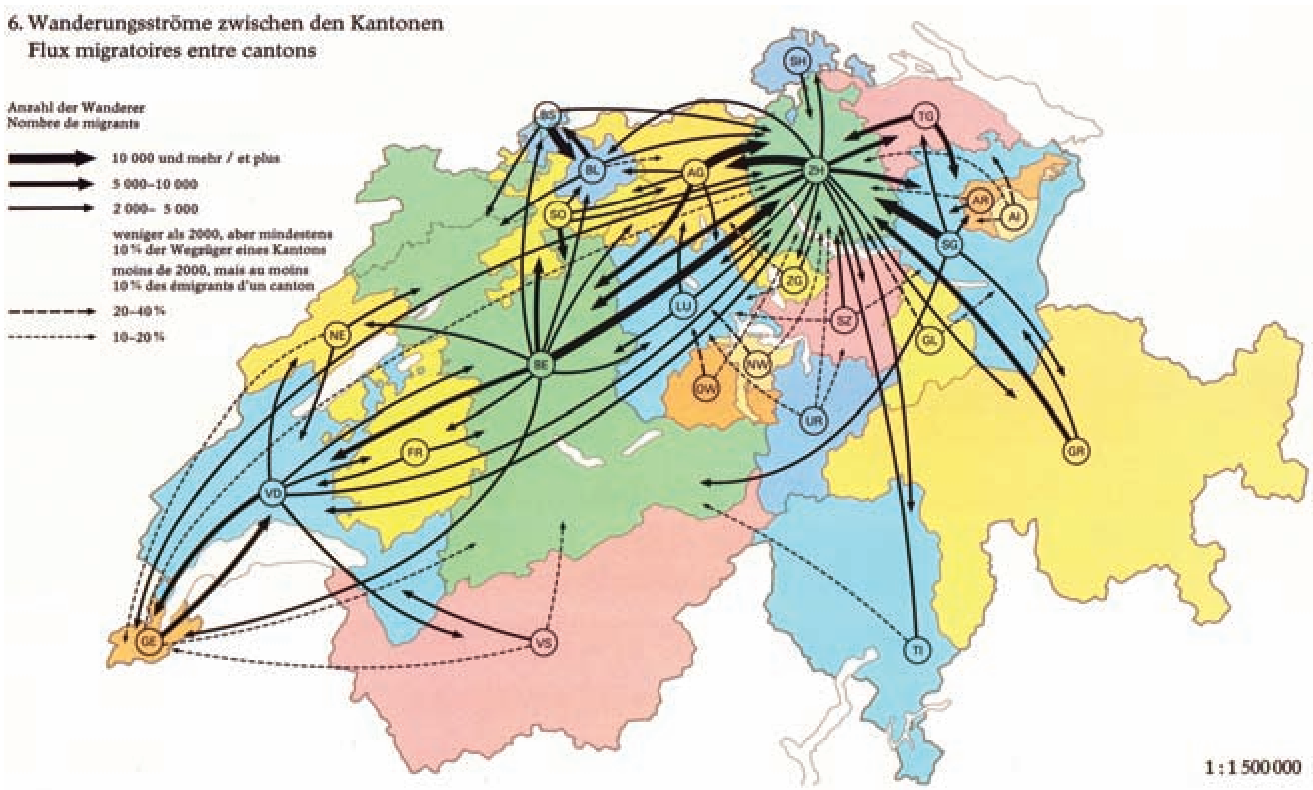


FIG. 920. MAP OF MIGRATION FLOWS BETWEEN SWISS CANTONS, 1965–70. Detail from the internal migration plate (2d ed., 1981) in Imhof's atlas of Switzerland.
Size of the map: 14.8 × 23.1 cm. From *Atlas der Schweiz = Atlas de la Suisse = Atlante della Svizzera*, ed. Eduard Imhof (Wabern-Bern: Verlag der Eidgenössischen Landestopographie, 1965–), pl. 24a (6). © swisstopo. Reproduced by permission of swisstopo (BA13119).

In the 1930s global warfare shifted the attention of statistical mapping from the internal concerns of nations to the world outside national borders. This shift in political and social awareness that followed the period of warfare in the 1940s was evident in Erwin Raisz's publication of the *Atlas of Global Geography* (1944), which included world themes of geopolitics, disease, hunger, poverty, and overpopulation (Schulten 2007, 200). During this time Raisz was one of a handful of academic cartographers in the United States who actively pursued thematic mapping.

Wartime impacted statistical mapping in Europe, but advances in academic cartography, statistical mapping, and national atlas programs in the 1920s continued with the wide-ranging efforts of a few mappers, such as Max Eckert and Eduard Imhof. Imhof's school atlases published from 1927 to 1934 set the stage for his later statistical mapping innovations in *Atlas der Schweiz = Atlas de la Suisse = Atlante della Svizzera* (fig. 920), which he edited from 1961 to 1978, as well as his textbook on thematic cartography published in 1972. Hannes Gebhard's social-statistical atlas of Finland first appeared in 1901 and inspired J. G. Granö's editorial work on revised editions of the national atlas of Finland (1899–) to incorporate new methods of statistical and geographical analysis (Jaatinen 1982). Economic cartography in Russia and Germany was also influenced by Nikolay N. Baranskiy's cartographic principles featured in Soviet atlas publications as early as 1929–31 based on the central statistical agency's official statistics.

Cartography as an academic discipline in the United States received international attention with Raisz's textbook *General Cartography* in 1938. The second edition (1948) featured discussions of isarithms, choropleth maps, and proportional symbols, yet did not delve deeply into statistical analysis. His value-by-area cartograms introduced a new graphic device to show the relational concept of a map with the statistical measurement of a diagram (Schulten 2007, 202). Inspired by Raisz's global view, a spate of atlases were produced in Europe and Asia in the early 1950s that were fundamentally statistical, relevant, and broad-reaching in thematic content. The *Oxford Economic Atlas of the World*, published in 1954 by the Oxford University Press, is one of the first multiedition atlases to use statistical mapping methods to illustrate global economic trends.

Prior to this, a noticeable dormancy had descended upon statistical mapping worldwide following World War II, particularly in Europe. Traditional methods of quantitative analysis no longer sufficed in an era of data overload. The supply of innovative statistical maps and graphics lagged behind an ever-increasing demand for new and diverse sources of statistical information across all disciplines (Friendly and Denis 2000, 53–54).

For American statistical agencies, the 1940s was a time of recovery. President Franklin D. Roosevelt appointed a director of statistical standards, later called the chief statistician, with the authority to coordinate the diverse federal statistics system. Statistical mapping at the U.S. Census Bureau expanded to a larger format with a manually produced two-sheet color map of population density by minor civil divisions after the 1940 census (Jenkins 1985). In addition, the Census Bureau began publishing agricultural statistical maps in 1945 to expand upon the earlier *Graphic Summary of American Agriculture* series produced by the U.S. Department of Agriculture.

By the 1950s the ENIAC (Electronic Numerical Integrator and Computer) and UNIVAC (Universal Automatic Computer) had revolutionized completely the collection, analysis, and presentation of statistics for the 1950 U.S. census and ushered in the computer era at the U.S. Census Bureau (Anderson, 2010, 159). Statistical mapping, however, was not fully automated for at least another three decades. The summary volume of the census of population for 1950 continued to feature black-and-white statistical maps. A large single-sheet population distribution map of the United States in color was published using manual cartographic methods (Klove 1975, 176). The census of manufactures in 1958 also included statistical maps derived from census data.

Arthur H. Robinson's *Elements of Cartography*, first published in 1953, summarized the state and development of American cartography and the incorporation of computer technology. In later editions, Robinson further developed ideas about the combination of statistics and cartography. By the time the third edition was published in 1969, the quantitative revolution in geography was in full force. Geography and computer technology had created new opportunities for experimentation and innovation in representing and disseminating statistical data.

In England, Francis John Monkhouse and Henry Robert Wilkinson's *Maps and Diagrams* (1952) as well as G. C. Dickinson's *Statistical Mapping* (1963) presented detailed descriptions of the diverse map types in use. The work of French cartographer Jacques Bertin provided a theoretical framework to statistical maps in his book *Sémiologie graphique* (1967). With an emphasis on order, structure, and interpretation of signs and grammatical rules for matching features and data, he introduced a graphical strategy for presenting meaningful maps and analyzing multivariate statistics. At the same time, the technological foundations were built for organizing statistical data in a central numerical library, foreshadowing the development of geographic information systems (GIS) (Aumen 1968, 223). Meanwhile, international dialog on statistical graphics and statistical mapping continued with establishment of the International Cartographic Association in 1959 and cartographic societies founded in Germany (1950), Switzerland (1960) and Austria (1961). After a long period of dormancy, the International Statistical Institute was reinstated by statistician Roberto Bachi in 1975 (Biderman 1978, 79).

Empowered by the innovations of an emerging digital mapping process, cartographers explored the uniqueness of the distribution of tabular data linked to a specific geographic area (Klove 1967, 192). Meanwhile, rapid improvement of the critical mass of statistical maps was essential to support the exponential growth and diversity of statistics. Automated statistical cartography was the most obvious solution. At the U.S. Census Bureau, Robert C. Klove, who was in 1967 assistant division chief, Geography Division, wanted to increase the number of maps produced for any one census from a handful to hundreds. In the 1960s, statistical mapping at the U.S. Census Bureau burst into color again with the publication of the GE-50 series consisting of large separate U.S. maps in color showing various demographic and economic data. Computer assistance for the wide diversity of maps that were planned for the GE-50 series consisted of analyzing the data to arrive at the best class intervals and plotting the county codes. Automated statistical cartography shortened the laborious task of transferring the county codes that link the statistical (class interval) data to over 3,000 U.S. counties but still involved manual production methods (Klove 1967). SYMAP appeared after 1966 and productivity increased even further, but this system was quickly replaced by newer software. The Census Bureau's 1969 and 1974 *Graphic Summaries of Agriculture* were also examples of computer-assisted statistical mapping (Broome and Witiuk 1980, 207).

The Census Bureau's *Urban Atlas* was a printed series of large-format soft-cover statistical atlases developed in the early 1970s that used automated methods to produce tract-level choropleth maps of twelve mapping variables for sixty-five computer-generated Standard Metropolitan Statistical Areas (SMSAs). Also in the 1970s, the U.S. Census Bureau and its field offices developed and disseminated the technology to digitize geographic boundaries and features for a GBF/DIME (Geographic Base File/Dual Independent Map Encoding) system. These files now cover much of the world and contain a vast amount of geographic information. This automated system was designed to be used by hundreds of governmental agencies to facilitate the conversion of administrative records into statistical data (Barabba 1975, 23).

The continuing information explosion in the 1960s and 1970s occurring alongside these new mapping technologies prompted new experimentation with map types and new opportunities for international cooperation. At this time, four types of statistical maps were frequently used in the United States and Europe: (1) point symbol maps with dots and graduated circles, (2) choropleth maps with data areas shaded, (3) isopleth maps with contour lines, and (4) flow maps with proportioned lines and arrows (Klove 1975, 179). In 1976, Bachi called for additional graphical symbols to present many important types of statistical data, including multivariate observations (Bachi 1978, 23).

Vincent P. Barabba (1977, 25) suggested that the Census Bureau serve as a depository of empirical evidence demonstrating the utility of different forms of automated graphic presentations. To that end, the Census Bureau later sponsored research by geographer Judy M. Olson on the spectrally encoded two-variable maps. Multivariate maps were just one of many on the growing list of statistical map types now possible in the new age of automated cartography (see fig. 85). Olson's focus on the user and the interpretation of the multivariate map showed that no matter how sophisticated the statistical method shown, the resulting interpretation was ultimately dependent on the user's ability to obtain measurable information. Olson's research also opened the door to new statistical thinking and gave rise to an enlivened interdisciplinary approach to statistical mapping in the 1980s and 1990s.

By 1982 there were over ninety federal agencies in the United States that collected, tabulated, and disseminated statistical data (Duncan 1982, 364). An interagency Domestic Information Display System (DIDS) was initiated in 1978 to provide statistical mapping services to the White House, but this program was short-lived (Broome and Witiuk 1980, 207–8). Beginning with the 1990 census, the U.S. Census Bureau designed and created the Topologically Integrated Geographic Encoding and Referencing (TIGER) system, making it possible to produce statistical maps on demand using GIS technology (Anderson 2010, 159). This new development fostered a nationwide statistical mapping network of GIS users who access geographic files over the internet (Morrison 1999).

In its early stages, GIS technology was particularly relevant to statistics because it enabled users to represent numbers cartographically. The ease of visualizing multiple layers and creating maps instantaneously created new challenges in the analysis of multidimensional data sets. Statistical mapping became more accessible with personal computing and access to the Internet. With its hidden perils, the most obvious result of new mapping software applications was the tremendous diversity of statistical map types.

In the last two decades of the twentieth century, some traditional methods of statistical mapping were given new names such as proportional symbol mapping, previously called point symbol mapping. New methods for data exploration and animation, electronic atlases, framed-rectangle symbols, and Daniel Dorling's cartograms (see figs. 123, 959, and 960) were some of the many visualization tools developed for spatial data on a statistical map.

The success or failure of these cartographic representations still relied on a sophisticated level of understanding by the user, but the primary innovation in statistical maps was accessibility. No longer were maps constrained by the volume of data and the centralization of statistical systems. Consequently, there was a dramatic increase in the number of statistical maps that were being produced worldwide for a multitude of topics ranging from global warming and environmental change to epidemiology, World Cup soccer, and election results. Thousands of maps have been created by these newer visualization tools. Automation, visualization, and globalization of the statistical map continued to inspire individual innovation and progress in mapping agencies worldwide.

TIMOTHY F. TRAINOR AND D. BEVINGTON-ATTARDI

SEE ALSO: Bivariate Map; Census Mapping; Centrography; Choropleth Map; Demographic Map; Exploratory Data Analysis; Projections: Projections Used for Statistical Maps; Statistics and Cartography; Thematic Mapping

BIBLIOGRAPHY:

Anderson, Margo J. 2010. "The Census and the Federal Statistical System: Historical Perspectives." *Annals of the American Academy of Political and Social Science* 631:152–62.

Aumen, William C. 1968. "Mapping in the Computer Age." *Papers, National Fall Convention. American Congress on Surveying and Mapping*, 221–26.

Bachi, Roberto. 1978. "Proposals for the Development of Selected Graphical Methods." In *Graphic Presentation of Statistical Information: Papers Presented at the 136th Annual Meeting of the American Statistical Association*, 23–67. Washington, D.C.: U.S. Department of Commerce, Bureau of Census.

Baker, O. E., comp. 1931. *A Graphic Summary of American Agriculture Based Largely on the Census*. Washington, D.C.: United States Department of Agriculture.

Barabba, Vincent P. 1975. "GBF/DIME, Dollars, and Sense: How Cities Can Improve Their Planning & Management Capacity Using a Bureau of the Census Geographic Data System." *Nation's Cities* 13, no. 11:21–36.

———. 1977. "A Challenge to Cartographers." In *Proceedings of the International Symposium on Computer-Assisted Cartography: Au-*

to-Carto II, ed. John C. Kavaliunas, 15–26. [Suitland]: U.S. Dept. of Commerce, Bureau of the Census; [Falls Church]: American Congress on Surveying and Mapping, Cartography Division.

———. 1978. "Automating Statistical Graphics: A Tool for Communication." In *Graphic Presentation of Statistical Information: Papers Presented at the 136th Annual Meeting of the American Statistical Association*, 7–13. Washington, D.C.: U.S. Department of Commerce, Bureau of the Census.

Beniger, James R., and Dorothy L. Robyn. 1978. "Quantitative Graphics in Statistics: A Brief History." *American Statistician* 32:1–11.

Biderman, Albert D. 1978. "Discussion: Innovation, Standardization, and Testing in Statistical Graphics." In *Graphic Presentation of Statistical Information: Papers Presented at the 136th Annual Meeting of the American Statistical Association*, 79–82. Washington, D.C.: U.S. Department of Commerce, Bureau of the Census.

Broome, Frederick R., and Sidney W. Witiuk. 1980. "Census Mapping by Computer." In *The Computer in Contemporary Cartography*, ed. D. R. F. Taylor, 191–217. New York: John Wiley & Sons.

Duncan, Joseph W. 1982. "Accessing Social Statistics." *Library Trends* 30:363–76.

Fienberg, Stephen E. 1979. "Graphical Methods in Statistics." *American Statistician* 33:165–78.

Friendly, Michael. 2007. "A.-M. Guerry's *Moral Statistics of France*: Challenges for Multivariable Spatial Analysis." *Statistical Science* 22:368–99.

———. 2008. "The Golden Age of Statistical Graphics." *Statistical Science* 23:502–35.

Friendly, Michael, and Daniel Denis. 2000. "The Roots and Branches of Modern Statistical Graphics." *Journal de la Société Française de Statistique* 141, no. 4:51–60.

Funkhouser, H. Gray. 1937. "Historical Development of the Graphical Representation of Statistical Data." *Osiris* 3:269–404.

Jaatinen, Stig. 1982. "The National Atlases of Finland: The Fifth Edition, Its Background and Structure." *GeoJournal* 6:201–8.

Jenkins, Robert M. 1985. *Procedural History of the 1940 Census of Population and Housing*. Madison: University of Wisconsin Press.

Klove, Robert C. 1967. "Statistical Cartography at the U.S. Bureau of the Census." *International Yearbook of Cartography* 7:191–99.

———. 1975. "Census Statistical Mapping and the Users." *Proceedings of the International Symposium on Computer-Assisted Cartography: Auto-Carto II*, ed. John C. Kavaliunas, 175–82. [Suitland]: U.S. Dept. of Commerce, Bureau of the Census; [Falls Church]: American Congress on Surveying and Mapping, Cartography Division.

Morrison, Joel L. 1999. "The State of Government Cartography in 1998." *Cartography and Geographic Information Science* 26: 167–99.

Schulten, Susan. 2007. "Mapping American History." In *Maps: Finding Our Place in the World*, ed. James R. Akerman and Robert W. Karrow, 159–205. Chicago: University of Chicago Press.

Thornthwaite, C. W. 1934. *Internal Migration in the United States*. Philadelphia: University of Pennsylvania Press.

Tobler, Waldo R. 1995. "Migration: Ravenstein, Thornthwaite, and Beyond." *Urban Geography* 16:327–43.

Statistics and Cartography. The fields of cartography and statistics experienced rapid growth in the twentieth century, and for both the century opened with an opportunity to expand in new directions. Cartography was moving from a goal of expanding the mapped fraction of the earth's surface to increasing positional accuracy, adding detailed information in known locations and adapting to new observation and measurement technologies. At the same time, the field of statistics was growing from its roots in mathematical probability to the development of an empirical science of data analysis. Available tools included families of distributions (e.g., normal, binomial) primarily associated with models of games of chance. The statistical toolbox also included linear regression, least-squares estimation, and indices of correlation between nonspatial variables. As the twentieth century began, statisticians such as Karl Pearson were deriving new families of distributions associated with summary statistics derived from finite numbers of observations. Such distributions required adjustment for the sample size and its association with the number of parameters to be estimated (degrees of freedom), a concept that lead to often-heated interactions between Pearson and his upstart contemporary Ronald Aylmer Fisher.

This focus of statistical development was largely in the framework of a controlled experiment with statistically independent observations, repeated observations under identical conditions, and control of potentially complicating variables. This framework provided a mathematical foundation allowing rapid evolution of empirical techniques and also formed the basis for frequency-based statistics wherein inferences are based on the long-term frequency of an event over an infinite set of independent and identical replications of an experiment. Spatial variation and association typically were viewed as complications to be controlled for in the experimental setting rather than intrinsic elements of a system to be accounted for in the quantitative techniques.

During the 1930s there was an explosion of development in statistical methods and experimental design, particularly from Fisher's work with the Rothamsted Experimental Station in the United Kingdom (Fisher 1935). Here, randomization (selection of subjects based on chance alone) provided the key to eliminating bias due to uncontrollable externalities. In particular, randomization provided a mechanism for ignoring spatial variations within field experiments.

The 1930s also contained glimpses from different sources that the "independent, identically distributed" paradigm of inferential statistics might not be fully sufficient for the analysis of spatially referenced data. Hints of the effect of the selection of areal units on spatial analysis—what we now refer to as the modifiable areal unit problem (MAUP)—appeared in a series of abstracts in a 1934 supplement of the *Journal of the American Statistical Association*. In particular, sociologists C. E. Gehlke and Katherine Biehl provided a very early report of the instability of the Pearson correlation coefficient as one moves from one level of census aggregation to another.

An interest in spatial elements within statistics began in the late 1940s, particularly with the work of Australian statistician P. A. P. "Pat" Moran and associates. In 1948 Moran introduced his *I* statistic, a measure of spatial correlation based on similarity between an observation at one location and the observations of the same quantity at neighboring locations. Moran's introduction of space into basic concepts of statistics provided a diagnostic test for spatial correlation, allowing a check of the basic assumption of independence underlying most statistical approaches. In the early 1950s, researchers expanded on Moran's work in addressing correlation among observations, still in the framework of a test of basic assumptions, rather than one allowing inference to acknowledge and adjust for correlation among observations.

This growing toolbox for detection of correlation fostered an intense interest in developing methods to analyze correlated data. This work catalyzed a rapid development of statistical methods for time series analysis and refined methods and mathematical models of temporally lagged autoregressions using weighted samples of past data to predict future results. In 1954, Peter Whittle proposed a spatial version of such models, namely his simultaneous autoregression (SAR) model.

The extension of approaches helpful for temporal correlations to those helpful for spatial correlations proved less straightforward than initially hoped, primarily due to the loss of a natural ordering of observations when moving from time to space. In addition, researchers noted that the introduction of correlation removes the mathematical separation of estimation of variation and expectation. In time series and spatial regressions, the temporal or spatial pattern observed in the outcome could arise from the impact of covariates on the mean outcome, correlations between outcome values, or some combination of both.

During the 1950s, several areas of science, including mining geology and meteorology, recognized a need to use spatial similarity between nearby observations to predict values at new locations. In 1951, South African mining engineer D. G. Krige empirically defined the kriging approach for surface interpolation based on a weighted average of observed values where the weights are based on spatial proximity and similarity, thereby triggering the development of the field of geostatistics for spatial prediction.

The advent of research computing in the 1960s provided a platform for these new methods that often did not reduce to summary formulae as readily as had those based on independent observations a generation before within the analysis of variance (ANOVA) framework. However, as computational power increased, it quickly found a use within the development of spatial statistical methods and their application. The new computers enabled the new methods and expanded the options for linking spatially referenced data across different sources.

The availability of data, computational resources, and rapidly developing mathematical tools and models provided the necessary framework for the formulation of a geographic information system (GIS) in Canada as well as the seeds of the quantitative revolution in geography. The quantitative revolution, representing a rapid incorporation of mathematics, statistics, and computation into cartography and geography, was led by individuals such as geographer William Louis Garrison and his "space cadets" at the University of Washington. Garrison's work led directly to the introduction of statistical training within academic geography units. A member of this group, Waldo R. Tobler, was well known both for his development of research and curricula in analytical cartography and for his advocacy of computer simulation. His famous First Law of Geography—"Everything is related to everything else, but near things are more related than distant things" (Tobler 1970, 236)—firmly established the fundamental importance of spatial dependence to research questions in geography and cartography. Tobler's law was a central assumption to be incorporated in the methodology, not a data feature to be randomized away.

The initial euphoria within the quantitative revolution did not extend to the entire field and resulted in what perhaps can best be described as fairly substantial backlash within the geographic community that grew throughout the 1970s and exists in some areas to this day. There was also a recognition among quantitative geographers that standard statistical approaches (e.g., regression, time series) revealed some aspects of interest, but were not sufficient to fully address questions central to geographical analysis. This is not to say that the quantitative geographers and analytical cartographers of this time entirely abandoned empirical research. Rather they recognized that considerable methodological development remained to be done before an adequate toolbox existed to address directly the issues of concern.

Central in the ongoing statistical development was the collaboration between geographer A. D. Cliff and statistician J. K. Ord in their seminal text on spatial autocorrelation (1973), providing a robust statistical theory for the distribution of indices of autocorrelation and the use of correlation within regression models. The work of Cliff and Ord represents an essential element linking standard aspatial statistical techniques to questions of primary interest in geography and cartography.

Point pattern analysis represents another area of spatial analysis that developed rapidly in this same time period, motivated by applications from areas such as ecology, archaeology, and criminology. The goal was to quantify observed patterns of point locations in order to draw inferences regarding the process generating the pattern. Much of the early research in point pattern analysis involved the derivation of distributional properties of various indices summarizing quadrat counts (e.g., comparisons of observed counts to those expected under certain processes) or distances between observed event locations within the study region. Distributions defined for complete spatial randomness (a lack of pattern wherein events occur independently of one another and are equally likely to occur anywhere) provided the null hypothesis for statistical tests but often required mathematically convenient but unrealistic assumptions.

Although attractive, the goal of inferring process from pattern remains elusive, as pattern is a difficult concept to uniquely quantify. In the 1960s, statisticians such as M. S. Bartlett provided justification for the claim that, without additional information, one cannot mathematically distinguish between a pattern of mutually independent events observed in a study area with spatial variations in event occurrence (e.g., trees growing from seeds scattered at random on a field with spatially varying soil fertility) and a pattern of interrelated events across a homogeneous study area (e.g., trees growing from seeds dropped by parent trees in soil of constant fertility). Determining what sort of additional information would allow statistical distinction of processes driving observed spatial patterns remains an active area of research. Related research in the 1970s and 1980s is summarized in geography texts including Peter Haggett, A. D. Cliff, and Allan E. Frey's *Locational Analysis in Human Geography* (2d ed., 1977) and Cliff and Ord's *Spatial Processes: Models & Applications* (1981). Statistics texts included Bartlett's *The Statistical Analysis of Spatial Pattern* (1975) and Peter Diggle's *Statistical Analysis of Spatial Point Patterns* (1983). More recent work builds on computationally intensive simulation methods and seeks to incorporate additional information such as demographics and land use into descriptive point pattern models.

As a result of the backlash against quantitative geography in the late 1960s to early 1970s, communication between the cartographic and statistical research communities decreased to the point of impacting the transfer of methods between the two. The statistical community quickly adopted the family of generalized linear models (GLMs) introduced in 1972 by statisticians John A. Nelder and R. W. M. Wedderburn. The GLM family includes logistic regression and Poisson regression models, which quickly became the standard approach in the statistical community for the analysis of census and other count data. In addition to the development of GLM approaches, statistician Julian Besag's foundational paper (1974) defined the mathematical framework of the conditional autoregressive (CAR) probability structure on spatial lattices (square grids), wherein the conditional distribution of observations at one location depends on the observed quantities of its neighboring values. The reduced communication limited both the development of spatial variants of GLMs and the early adoption of GLM and CAR approaches within geography and cartography.

During this time period, the geography community largely continued to focus on spatial variants of linear regression and the use of transformations to address nonlinear relationships or outcomes following distributions other than the familiar Gaussian (normal) distribution. Building on developments in geophysics and geology from the 1950s, Tobler, Haggett, and colleagues popularized regression-based trend surface analysis in the 1960s wherein geographic coordinates and their polynomial combinations are included in the regression model, allowing analysts to fit smooth, polynomial surfaces of spatial trends. While trend surfaces are linear regressions at heart, their applications to complex surfaces proved problematic due to the inherent correlation between increasing powers of the same covariates and the resulting numerical instability in the methods. As a result, most applications were limited to cubic or lower-order trend surfaces.

In addition to trend surface analysis, there was a growing literature in the 1970s on the analysis of spatial correlation in regression model residuals, extending Moran's *I* and other indices of spatial correlation from descriptors of associations between spatially referenced measurements to descriptors of association in error terms in regression models of spatially referenced observations. The indices motivated the development of linear regression methods allowing spatially correlated error terms, and these methods saw wide application especially in quantitative geography (Cliff and Ord, *Spatial Processes* [1981]) and spatial econometrics (Luc Anselin, *Spatial Econometrics: Methods and Models* [1988]).

During the 1970s there was an increased interest in possible solutions to the MAUP, most notably by geographer Stan Openshaw and colleagues. In an impressive 1979 demonstration involving a million or so correlation coefficients, Openshaw and Peter J. Taylor illustrated the extreme impact of the issue. As subsequent work revealed, the MAUP proved not so much a problem to be solved, but another complicating feature of spatial data that provides a context for development, application, and interpretation of statistical methods.

The use of computers continued to enhance both cartography and statistics through the 1980s and 1990s. Geographic information systems (GIS) expanded from mainframe to desktop applications with an increasingly rich set of analytical tools. Some tools included spatial statistical methods of analysis such as geostatistical prediction.

A rapid growth in the consolidation of spatial statistics into textbooks occurred in the 1980s, thereby identifying spatial statistics as a field of inquiry in its own right. Most of the statistical texts, however, treated space as a two-dimensional context for data without discussions or considerations of basic cartographic principles such as scale, projection, and geodesy.

A formalization of the classical statistical framework underlying the areas of geostatistics, spatial regression of area-referenced data, and spatial point processes, culminated in 1991 with Noel A. C. Cressie's comprehensive *Statistics for Spatial Data*. This work included revision of several basic assumptions underlying many classical, nonspatial statistical methods and development and evaluation of methods for data analysis in a spatial setting.

An interest in the development of analytical techniques for exploring local spatial impacts was evident in the last decade of the twentieth century. Luc Anselin's decomposition of global indices of spatial autocorrelation (e.g., Moran's *I*) into local indicators of spatial autocorrelation (1995) and Chris Brunsdon, A. Stewart Fotheringham, and Martin Charlton's introduction of geographically weighted regression (1996) both represent novel families of quantitative tools for exploring spatial variations in statistical associations, both correlations and regression parameters.

In summary, mathematical formalism provided a framework for the rapid development of modern statistical methods, but one must recognize that these methods typically are based on underlying principles that often do not hold for geographically referenced data. As a result, such statistical methods may not translate to the cartographic setting without careful modification, often requiring redevelopment under alternative paradigms. Both the statistical and cartographic communities must recognize this central element in their past experiences in order to best benefit from their future relationship and collaboration.

LANCE A. WALLER

SEE ALSO: Centrography; Demographic Map; Exploratory Data Analysis; Geographic Information System (GIS): (1) Computational Geography as a New Modality, (2) GIS as a Tool for Map Analysis and Spatial Modeling; Mathematics and Cartography; Statistical Map; Thematic Mapping; Uncertainty and Reliability

BIBLIOGRAPHY:

Anselin, Luc. 1995. "Local Indicators of Spatial Association—LISA." *Geographical Analysis* 27:93–115.

Besag, Julian. 1974. "Spatial Interaction and the Statistical Analysis of Lattice Systems." *Journal of the Royal Statistical Society, Series B* 36:192–236.

Besag, Julian, Jeremy York, and Annie Mollié. 1991. "Bayesian Image Restoration, with Two Applications in Spatial Statistics." *Annals of the Institute of Statistical Mathematics* 43:1–59.

Brunsdon, Chris, A. Stewart Fotheringham, and Martin Charlton. 1996. "Geographically Weighted Regression: A Method for Exploring Spatial Nonstationarity." *Geographical Analysis* 28:281–98.

Clayton, David, and John Kaldor. 1987. "Empirical Bayes Estimates of Age-Standardized Relative Risks for Use in Disease Mapping." *Biometrics* 43:671–81.

Cliff, A. D., and J. K. Ord. 1973. *Spatial Autocorrelation*. London: Pion Limited.

Cressie, Noel A. C. 1991. *Statistics for Spatial Data*. New York: John Wiley & Sons.

Fisher, Ronald Aylmer. 1935. *The Design of Experiments*. Edinburgh: Oliver and Boyd.

Gehlke, C. E., and Katherine Biehl. 1934. "Certain Effects of Grouping upon the Size of the Correlation Coefficient in Census Tract Material." *Journal of the American Statistical Association* 29 (supplement):169–70.

Krige, D. G. 1951. "A Statistical Approach to Some Basic Mine Valuation Problems on the Witwatersrand." *Journal of the Chemical, Metallurgical & Mining Society of South Africa* 52:119–39.

Moran, P. A. P. 1948. "The Interpretation of Statistical Maps." *Journal of the Royal Statistical Society, Series B* 10:243–51.

Nelder, John A., and R. W. M. Wedderburn. 1972. "Generalized Linear Models." *Journal of the Royal Statistical Society, Series A* 135:370–84.

Openshaw, Stan, and Peter J. Taylor. 1979. "A Million or So Correlation Coefficients: Three Experiments on the Modifiable Areal Unit Problem." In *Statistical Applications in the Spatial Sciences*, ed. Neil Wrigley, 127–44. London: Pion Limited.

Tobler, Waldo R. 1970. "A Computer Movie Simulating Urban Growth in the Detroit Region." *Economic Geography* 46:234–40.

Whittle, Peter. 1954. "On Stationary Processes in the Plane." *Biometrika* 41:434–49.

Street Map. See Wayfinding and Travel Maps: Indexed Street Map

Styles, Cartographic. The twentieth century witnessed an unprecedented abundance of cartographic styles, largely a consequence of rapidly evolving mapmaking technologies and an explosion of new or newly flowering cartographic genres. As *style* implies, these innovations were apparent in diverse ways, with some more widespread or more enduring than others. They fall conveniently into three categories: fads, signatures, and standards, with a few cartographic genres having their own distinctive styles.

As the dictionary implies, a cartographic fad was adopted quickly by a distinct group of mapmakers, used for a while, and then abandoned or transformed into something less conspicuous. A classic example is the drop shadow, which swept journalistic cartography during the revolution in newspaper design of the late 1970s and early 1980s, when specialists in news graphics realized they could make an individual symbol or even the entire map appear to rise above its surroundings by adding a thick, dark line along the right and bottom edge, thereby mimicking the shadow cast by a light source at the upper left. Drop shadows were easily produced by illustration software like MacDraw, which treated a drawing as a series of layers: a polygon representing a state or county could be duplicated, filled with solid black or dark gray, and placed on a new layer directly below the original layer but slightly to the right and bottom of the drawing. For a while at least, the drop shadow contributed to the distinctive look of many newspaper maps in much the same way that hand-sketched vegetation and related stylistic flourishes identified a map's author as a landscape architect. Although the drop shadow had become a graphic cliché by the late 1980s (Monmonier 1989, 236), some journalistic cartographers used thinner, lighter, subtler shadows as part of a more aesthetically pleasing design. Other cartographic fads include elaborate north arrows resembling rocket ships, which were common on large-scale architectural plans for much of the latter part of the century, and the zigzag line symbols resembling a flattened upper-case N in the standard legends of maps drawn with ARC/INFO and other Environmental Systems Research Institute (ESRI) software. Although some map authors discovered how to use ESRI software to produce a more traditional map key, these zigzag samples of a map's boundaries or roads remained a distinctive element of geographic information system maps into the twenty-first century.

Another type of cartographic style is the signature, so called because its distinctive form immediately identifies a map's author, or perhaps the innovator whose style the author was attempting to imitate. Signature styles introduced in the twentieth century include the revealing depictions of landforms on physiographic drawings by Erwin Raisz, the rich hues and oblique earth-from-space perspective of Richard Edes Harrison, and the dense naming of places and features on maps by the National Geographic Society. These three examples were introduced well before cartographic software and websites like MapQuest.com and Google Maps fostered a ready promulgation of standardized symbols. Although the National Geographic Society adopted dense labeling in response to positive feedback from members (Schulten 2001, 180–84; Woodward 1987, 210), Raisz and Harrison developed their styles idiosyncratically, as any artist or cartoonist might. By contrast, large newspapers like the *New York Times*, wire services like the Associated Press, road map and atlas publishers like Rand McNally, and other organizations employing multiple mapmakers typically adopted a standardized style sheet to simplify decision making by staff artists, minimize confusion among users, and provide a distinctive product with an instantly recognized house style, or trade dress, which might enjoy legal protection as intellectual property if properly registered and the owner was prepared to sue imitators.

Symbols devised by national mapping organizations as part of a larger standardization effort constitute a third kind of cartographic style, which includes precise definitions of mapped features and highly regulated projections, sheet lines, and content. In a sense these standardized styles were a larger-scale version, institutionally and geometrically, of the cartographic signature, with a distinctiveness sometimes apparent in international differences, as with the topographic symbols for railway lines (Monmonier 1996, 127–30). Change was rare, typically occurring when a new map series or product was introduced, often with new typefaces. When the U.S. Geological Survey (USGS) introduced its 1:100,000 topographic series in the 1970s, features were labeled in Souvenir, a typeface used by the restaurant chain Pizza Hut on its menus, and thus an inadvertent departure from the typical authoritative formality of government cartography (Woodward 1987, 207–8; Monmonier 1996, 133–35). USGS implemented an even less authoritative style in the early 1980s, when it lowered the cost of map finishing for some of its provisional 1:24,000 topographic maps by scratching out labels, letter by letter, on a reproduction negative (Monmonier 1996, 133–34).

Cartographic genres that arose in response to new phenomena often developed distinctive styles. Starting in the latter half of the nineteenth century, for instance, railroad maps that distorted geometry to accommodate a dense linear sequence of station names were labeled using wax engraving, which gave them a shared look (Woodward 1977, 31–36), and in the latter part of the twentieth century maps produced by statistical estimation or numerical modeling used the green-yellow-red traffic-light color sequence or its more cautious yellow-orange-red alterative to describe relative risk for environmental hazards (see fig. 363). In some instances, a specialized cartographic genre with a committed audience spawned a complex set of standard symbols, off-putting to casual map readers perhaps and occasionally at odds with cartographic textbooks, but readily understood by those who understood the code. Examples include geologic maps, aeronautical charts designed to be read in a poorly illuminated cockpit, and weather radar maps representing a dozen or more levels of precipitable moisture or wind velocity. The functional goals of cartographic styles often eclipsed their aesthetics.

MARK MONMONIER

SEE ALSO: Art and Cartography; Bertin, Jacques; Customization of Maps; Reproduction of Maps: Reproduction, Design, and Aesthetics; Wayfinding and Travel Maps: Road Symbols

BIBLIOGRAPHY:

Monmonier, Mark. 1989. *Maps with the News: The Development of American Journalistic Cartography*. Chicago: University of Chicago Press.

———. 1996. *How to Lie with Maps*. 2d ed. Chicago: University of Chicago Press.

Schulten, Susan. 2001. *The Geographical Imagination in America, 1880–1950*. Chicago: University of Chicago Press.

Woodward, David. 1977. *The All-American Map: Wax Engraving and Its Influence on Cartography*. Chicago: University of Chicago Press.

———. 1987. "The Manuscript, Engraved, and Typographic Traditions of Map Lettering." In *Art and Cartography: Six Historical Essays*, ed. David Woodward, 174–212. Chicago: University of Chicago Press.

Subject Testing in Cartography. See Perception and Cognition of Maps: Subject-Testing in Cartography

Subscription Atlas. See Atlas: Subscription Atlas

Survey of India. Claiming its inception from the appointment of James Rennell as surveyor general of Bengal in 1767, the Survey of India is one of the world's oldest national mapping organizations. During the nineteenth century it completed measurement of the Great Arc of the Meridian over 1,500 miles in length and covering 1,200 miles in breadth, and undertook the triangulation survey of the subcontinent, starting from a seven-mile base line in Madras in 1802, and extending north to the Himalayas by the end of the century. Maps based on the trigonometrical survey formed the basis of the *Indian Atlas*, planned as 177 sheets extending from Karachi to Singapore on a scale of four miles to the inch, which were printed first in London and from 1867 in Calcutta. In 1852 Mount Everest was measured at 29,002 feet (8,840 m), and found to be the highest peak in the world. This measurement was corrected by the Chinese in 1975 to 8,848 meters.

In 1900, in response to Albrecht Penck's proposal for a map of the world on a scale of 1:1,000,000 (the Millionth Map, soon to become the International Map of the World [IMW]), the surveyor general of India proposed a projection for such a map. The Survey had already begun to prepare sheets for the "India and Adjacent Countries" series with each sheet measuring 4° of longitude and 4° of latitude, numbered sequentially from 1 to 136 in north-south strips beginning at the northwest corner at 44°E 40°N and extending from the western frontier of Persia to the east of China (Gore 1900). Each sheet was further subdivided into 1-inch and ¼-inch sheets. New surveys had become increasingly necessary as the maps for the *Indian Atlas* became ever more outdated; revisions to the plates were not easy, and the projection and scale were inaccurate and not suited to extension westward into Persia or eastward into Burma. This system of numbering continued in use in India, Pakistan, Burma, and Bangladesh for the 1:253,440 series and was carried over after metrification for the 1:250,000 series. It was used in Iraq, Iran, and Afghanistan until 1940 and by the military wing of the Survey in mainland Southeast Asia from 1942 to 1946, although during World War II the international numbering was occasionally used elsewhere (Cook 1987).

When the IMW was formalized at the International Geographical Congresses of 1909 and 1913, it was decided that each sheet should cover 4° of latitude and 6° of longitude, and that contours should be shown in meters. Consequently the Survey of India produced both series concurrently, in addition to producing countless other maps for differing requirements. India led most other countries in survey work and publishing of the finished sheets. By 1987, of the twenty-six sheets for which the Survey was responsible, twenty-three were already available. Revision of all topographical sheets continued throughout the century, but publication was never sufficiently fast to satisfy military and development requirements.

The triangulation survey of India was linked to that of Russia in 1913 (Burrard 1914) by an Indian survey team in the Pamirs, thus connecting the triangulation from Ireland in the west to Cape Comorin in the south and Burma on the east (Madan 1997, 127). Covering previously unexplored territory of about 28,000 square miles, this was one of the most rugged and remote areas ever surveyed.

During the two world wars, the Survey undertook major tasks both within and beyond national frontiers. Between 1914 and 1920 surveys were conducted in Mesopotamia, Kurdistan, Macedonia, Arabia, Persia, Palestine, East Africa, and Afghanistan (Tandy 1925). At the start of World War II, despite a personnel shortage that arose when officers assigned to the Survey returned to their military duties, the work increased, and the Survey was expanded. At the Cairo Survey Conference in 1940 the Survey was again given the task of preparing maps in Iraq and Iran, and later in Afghanistan, Burma, Siam, Indochina, western and southern China, Malaya, and Sumatra, although for the duration most services were under direct military command. After the war, responsibility for Burma, so long a part of Indian government, ceased—except for assistance in establishing the Survey of Burma. Assistance was similarly given to Malaya. Map publication multiplied from 750,000 copies annually (of 1,580 different maps) before the war to about 22 million copies (of 2,483 different maps) in 1945. Use of air survey increased, with photographic aircraft under full control of the Survey. Rotary offset printing machines were installed at Dehra Dun (Wheeler 1955).

After Indian independence (1947), the Survey of India was urgently required to undertake surveys for the many projects and developmental works needed to modernize the country and make it self-reliant. All-purpose topographical maps were required for defense, civil

FIG. 921. INDIA AND ADJACENT COUNTRIES, 1954. The first official map of India and adjacent countries in Hindi to be published by the Survey of India appeared in 1952; this is the second edition. Showing political divisions within the country, it was printed in nine colors and was on a scale of 1 inch to 128 miles.
Size of the original: 54 × 63 cm. Image courtesy of the Texas A&M University Libraries, College Station.

administration, internal security, developmental needs, irrigation, watershed and resource management, and various types of engineering projects (fig. 921). The revenue surveys, begun in the late eighteenth century, had long been handed over to provincial control. By 1947 about 60 percent of the country had been mapped on a scale of 1 inch to 1 mile (Nag 2003). Training for the Survey had formerly been at Abbottabad (now in Pakistan), so a new establishment was opened in Hyderabad in 1962, and with help from United Nations Development Programme (UNDP) this became a premier institution in Asia. Officers and personnel who opted to move to Pakistan had been transferred to the Frontier Circle at Muree in 1947, and this formed the nucleus of a survey department for Pakistan. In 1956 all measurements were changed to the metric system (fig. 922). The first digital mapping centers were established in Dehra Dun and Hyderabad, and in 1990 the Global Positioning System was introduced. The Survey of India was part of the Ministry of Food and Agriculture until 1952, when it was transferred to the Ministry of Natural Resources and Scientific Research, and later renamed the

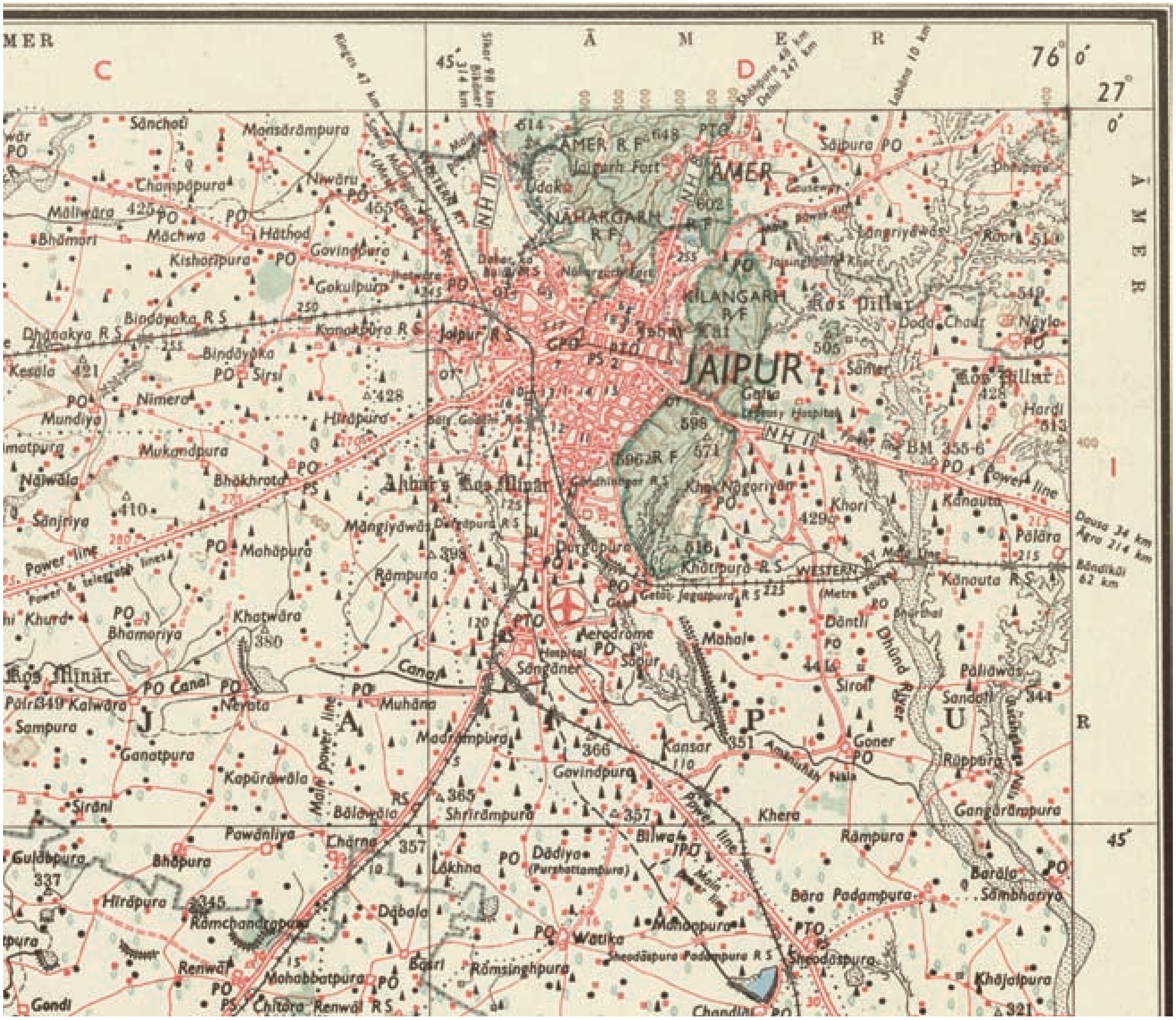


FIG. 922. DETAIL FROM *JAIPUR*, SURVEY OF INDIA 1:250,000 SERIES. Sheet 45N showing Jaipur in Rajasthan (first metric edition, 1977). Size of the entire original: ca. 58.5 × 64 cm; size of detail: 15.7 × 18.1 cm. Image courtesy of the National Library of Scotland, Edinburgh.

Department of Science and Technology. The first Indian surveyor general was appointed in 1955.

When the United Nations recommended in 1948 that governments of member states should stimulate surveying and mapping of their national territories, the Survey of India offered to host the first regional conference for Asia and the Far East, held in 1955 at Mussoorie. Eighteen countries were represented. The following year India joined the International Hydrographic Bureau (later the International Hydrographic Organization). Surveys of India's shore and coastal waters were conducted by the Hydrographic Department of the Indian Navy.

In 1950 the Survey consisted of five directorates, which mainly looked after the mapping requirements of defense forces in the northwest and northeast of the country. By the end of the twentieth century, it was much enlarged, and consisted of ten regional circles and eight specialized circles. Each regional circle is responsible for all topographical and developmental surveys of a state (province) or a group of small states. The specialized directorates are the Geodetic and Research Branch, the Map Publication Directorate, the Directorate of Survey (Air), the Survey Training Institute, the Research and Development Directorate, the Modern Cartographic Centre, the Digital Mapping Centre, and the Flood Plain Zoning Surveys (Chadha 1990). India has kept pace with modern developments in other parts of the world; at the end of the century it was one of the best-mapped countries and had given assistance to other nations in the region. It is responsible for all geodetic control (horizontal and vertical) and geodetic and geophysical surveys; all topographical control, surveys, and mapping within India; the mapping and projection of geographical maps and aeronautical charts; surveys for developmental projects; large-scale city and guide maps as well as cadastral surveys; the surveying and mapping for special-purpose maps; the spelling of geographical names; the demarcation of the external boundaries of the Republic of India and their depiction on maps published in the country; and the advising on demarcation of interstate boundaries. It is also responsible for the training of its own officers and staff as well as personnel from central and state government departments requiring survey training and trainees from foreign countries.

A major task of the modern Survey is to scrutinize and correct external boundaries and coastlines on maps published by other agencies and private publishers. As early as the late eighteenth century, instructions were being sent from London that manuscript maps prepared by the East India Company should exist only in two copies, one to be sent by ship to London and a second retained in India in case the first was lost at sea. Maps were recognized as potentially dangerous items that might aid an enemy. That policy persisted even after Independence, and the Survey jealously guards its right to grant or withhold permission to publish any map drawn after 1905. The instructions for publishers are lengthy and detailed. Its own maps on a scale of 1:250,000 or larger were for a long time not permitted to be exported from the country. In 1945 R. H. Phillimore prepared the first of what was to be a five-volume set of *Historical Records of the Survey of India*, published by the Survey at Dehra Dun. This was a comprehensive work, giving biographical details of the (mostly) British people who had served in the Survey of India and detailed accounts of the surveys themselves. However, the government of India never permitted the final volume to be released (chronologically it described surveys up to 1861) on the grounds of border security, and it later ordered the remaining copies of the first four volumes destroyed.

At the time of Indian independence, about 40 percent of the country remained to be resurveyed using modern methods, mainly in the difficult terrain of the high Himalayas, the northeast region, and the deserts. In 1962, after a brief territorial war with China, it became essential that the northern borders be accurately surveyed, and the Survey was duly expanded to achieve this. Only by keeping pace with modern developments was this aim possible. An initial phase of new primary and secondary triangulation networks at a spacing of 4° (250 miles) had been completed in 1956, and a second-level network consisting of ninety-nine lines totaling about 16,500 miles with Bombay port forming the basis was undertaken by 1977. This revealed that the east coast mean sea level (MSL) at Madras is higher by one foot than the west coast MSL at Mangalore. Tidal observations undertaken by the Survey show that the average trend of sea level rise agrees with world findings. The Survey also initiated comprehensive monitoring of sea levels in 1992 and 1993. Satellite geodesy was introduced in 1982, enabling outlying islands to be connected to mainland surveys. When India began sending expeditions to Antarctica, the Survey was requested to carry out various scientific experiments and observations (Chadha 1990).

Many cartographic records of the Survey of India were transferred from Dehra Dun to the National Archives in New Delhi. They comprise: historical maps; miscellaneous maps from the former India Office; consolidated village plans and traverse records (revenue); plane table survey sheets covering parts of Bengal, the Central Provinces, Madras, and Orissa; and Survey of India correspondence records, memoirs, general reports, diaries, and journals of the surveyors and explorers (Madan 1971).

Since 1956 a parallel organization, renamed in 1978 the National Atlas and Thematic Mapping Organisation and under the country's Department of Science and Technology, but located in Calcutta, has been preparing maps based on research studies in environmental and associated projects and their impact on social and economic development, as well as maps in regional languages.

In the words of a former surveyor general, "The Department, built on solid foundations, strong traditions and deep roots, keeps striving to keep India among the best surveyed countries in the world, adopting the latest technologies to meet new challenges—always living up to its motto: 'A setu Himachalam'" (fig. 923) (Chadha 1990).

SUSAN GOLE

SEE ALSO: Directorate of Overseas Surveys (U.K.); Military Mapping of Geographic Areas: Southeast Asia; Topographic Mapping: Overview

BIBLIOGRAPHY:

Burrard, Sidney Gerald. 1914. *Completion of the Link Connecting the Triangulations of India and Russia, 1913*. Vol. 6 of *Records of the Survey of India*. Dehra Dun: Survey of India.

Chadha, S. M. 1990. *Survey of India through the Ages*. Dehra Dun: Survey of India.

Cook, Andrew, 1987. Introduction to catalog "Survey of India Quarter-Inch (1:253,440) Topographical Map Series, c.1905–c.1950." In Oriental and India Office Library, British Library, London.

Gore, St. G. C. 1900. *On the Projection for a Map of India and Adjacent Countries on the Scale of 1:1,000,000*. Dehra Dun: Survey of India. 2d ed. 1903.

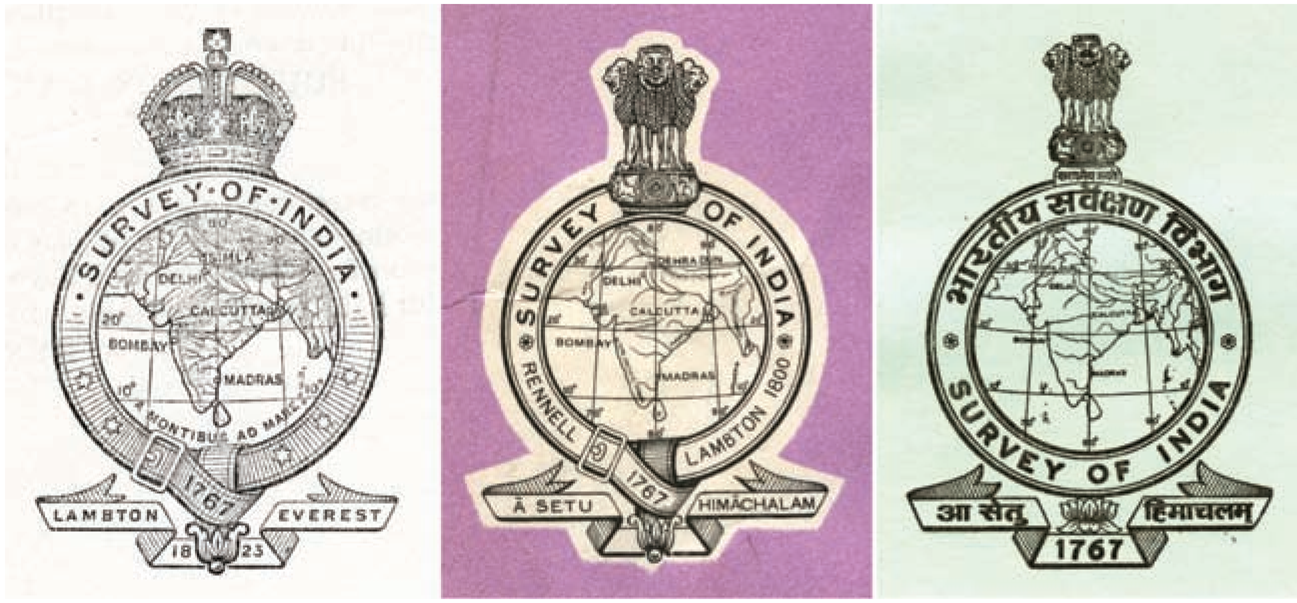


FIG. 923. SURVEY OF INDIA CRESTS 1945, 1956, AND 1979. A new crest for the Survey of India was approved in 1950. The earlier one (left), dating from 1883, showed the names of Lambton and Everest surmounted by the British crown. After independence (center), William Lambton's name was retained as the originator of the geodetic survey in India, but that of James Rennell replaced George Everest, and the date 1823, when Everest was appointed surveyor general, was removed. The Tudor crown was replaced by the Asoka lions, and the Sanskrit motto "Ā setu Himāchalam" (from Comorin to the Himalayas) replaced the Latin "A montibus ad mare." On the map, Dehra Dun, the headquarters of the Survey, replaced Simla, the former British government summer headquarters. The current crest (right) has been further simplified by the removal of personal names, the addition of the title Survey of India in Hindi as well as English, and the motto now in Devanagari script.

Madan, P. L. 1971. "Cartographic Records in the National Archives of India (1700–1900)." *Imago Mundi* 25:79–80.

———. 1997. *Indian Cartography: A Historical Perspective*. New Delhi: Manohar.

Nag, Prithvish. 2003. "Survey of India: An Introduction." In *The Great Arc 200 Years: Celebrating the Quest*, 25–56. [New Delhi]: Department of Science and Technology.

Tandy, E. A. 1925. *The War Record, 1914–1920*. Vol. 20 of *Records of the Survey of India*. Dehra Dun: Survey of India.

Wheeler, Oliver. 1955. *The Survey of India, during War and Early Reconstruction, 1939–1946*. Dehra Dun: Survey of India.

swisstopo (Switzerland). See Bundesamt für Landestopographie

SYMAP (software). The name "SYMAP" was derived from the phrase "synagraphic mapping"; "synagraphic," in turn combines the Greek root *syn* ("together," as in *synthesis*) with "graphic" and means "seeing things together." Howard T. Fisher at Northwestern University's Technological Institute, working with Betty Benson, a programmer, designed and produced SYMAP in 1964. SYMAP software and correspondence course materials were widely distributed by Fisher before and after he moved to Harvard University and established the Laboratory for Computer Graphics in 1965.

SYMAP displayed thematic data according to their locations on a reference map. Fisher realized that a page of printer output could be viewed as a coordinate space with row and column print locations analogous to *y* and *x* geographic coordinates. He conceptualized the process of area symbolization as filling the cells within user-defined areas of printer output with one or more print characters. Lighter tones were represented with individual symbols such as the period, the hyphen (which was typically used as a minus sign), the plus sign, the zero, or the capital letter X. Overprinting the letter O and the plus sign in a print cell produced a darker symbol, and overprinting the letters O, X, A, and V filled an even greater portion of the cell.

SYMAP used a standard line printer to display three basic kinds of thematic map images: conformant (choropleth), contour (isarithmic), and proximal (Thiessen polygon) (fig. 924). Other types included trend surface, residual, and dot maps. Conformant maps displayed each data zone as a predefined area, such as a census tract, which was filled with a gray tone representing the class level for its data value. Contour maps showed the variation of data values over the whole study area using

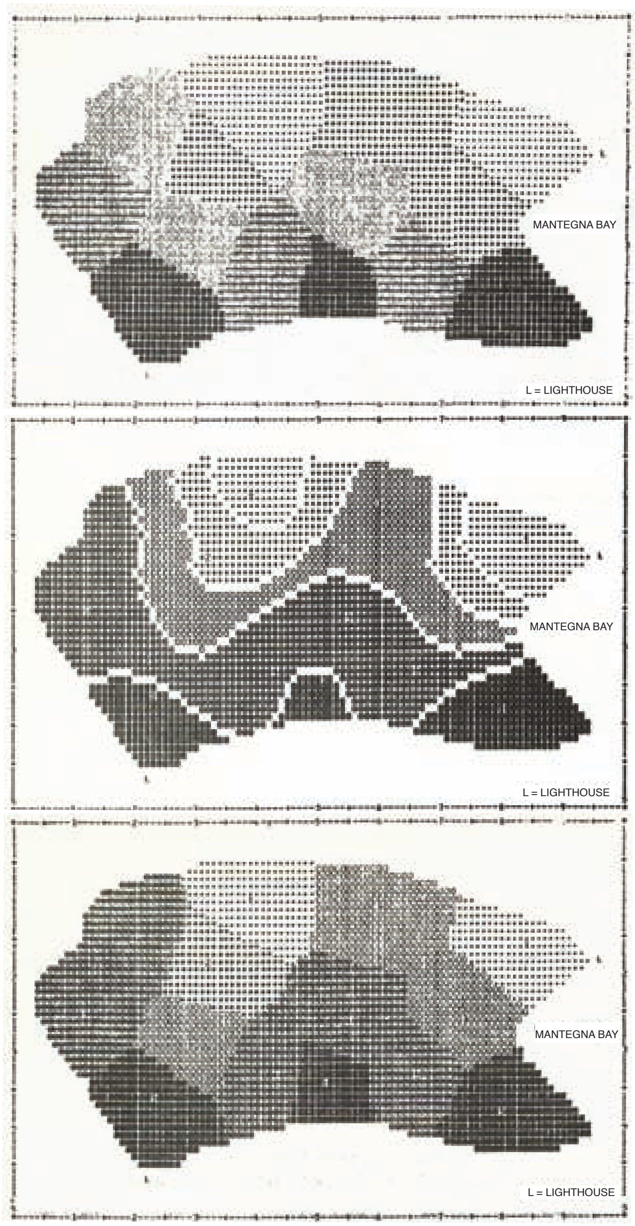


FIG. 924. TYPES OF SYMAP OUTPUT. Conformant map (top), contour map with contour lines (middle), and proximal map (bottom).

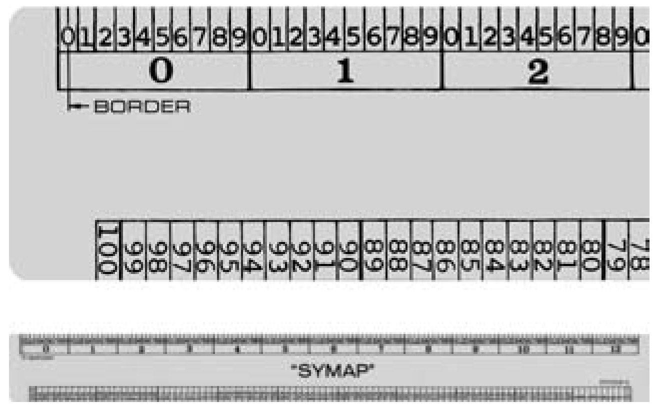


FIG. 925. SYMAP RULER. Upper section is at scale.

contour bands similar to the elevation zone on topographic maps. SYMAP made contour mapping available for use by geographers and planning professionals concerned with population, housing, and other statistics that describe spatially continuous phenomena. The speed and flexibility of SYMAP's computer-assisted map creation increased the opportunity for maps to be used as both analytic and descriptive tools. Proximal maps, which are similar to the Voronoi diagrams used in geophysics and meteorology, apply the nearest-neighbor principle to assign nondata positions the data value of the closest data point.

SYMAP users keypunched three types of information to describe the map's locational, attribute, and procedural data; data input was structured in packages. A user requesting a conformant map had to provide a list of the *x, y* coordinates defining each zone to be mapped. For example, a map based on census tracts required that the vertices of each tract's polygon be recoded in terms of row and column positions on the printer output. A user would identify and record these *x, y* coordinates on a coding form after superimposing a sheet of transparent SYMAP graph paper over an existing reference map. Alternatively, Fisher's correspondence course provided a SYMAP ruler with separate scales for estimating row and column positions on the printed sheet: a ten-columns-to-the-inch scale for measuring position from the map's left edge provided the *x*-coordinate, and an eight-rows-to-the-inch scale for measuring position downward from the top border provided the *y*-coordinate (fig. 925) (Chrisman 2006, 25–26). Coordinates were recorded in a clockwise direction around each data zone and entered onto a SYMAP coding form, and the information was then keyed onto punch cards. A second data package contained the value(s) to be associated with each data zone or data point. An option known as "Subroutine FLEXIN" allowed a FORTRAN FORMAT statement to define the locations of fields containing input data. In addition, FLEXIN allowed users to read data from tapes, disc files, and other sources, and also to manipulate the data prior to mapping.

A third data package indicated the size of the printed map, the title to appear below the map, the number and range of data value classes, the symbol(s) assigned to each class, and various specifications, including the map border, the map scale, maximum and minimum data values, and instructions for dealing with missing data. Various cosmetic options allowed the user to add a graphic scale, a north arrow, place-names, rivers, bodies of water, transport routes, city locations, and other point, line, or area symbols. A minor software-controlled modification to IBM line printers allowed printing at eight lines per inch rather than the standard six lines per inch used for normal printer output. Maps were printed in strips thirteen inches wide (130 print columns) at any requested length, and large, wallpaper-size maps could be assembled from multiple strips. A user requesting a contour map could specify that the resulting contoured surface be written onto a data file for input to SYMVU or ASPEX, which could draw perspective views of three-dimensional surfaces.

Contour maps required a set of *x, y* coordinates to define the perimeter of the mapped area as well as a set of *x, y* data points. To prepare a contour map based on areal units such as census tracts, the user specified a centroid within each data zone. Early versions of SYMAP based placement of contours on linear interpolation, whereby the interpolated value (surface elevation) for a point was calculated from nearby data values, each weighted according to the inverse of its horizontal distance from that point. Later versions used a comparatively sophisticated algorithm by Donald Shepard (1968) that weighted data values by the inverse of their squared distance to the interpolated point. Among other enhancements, the Shepard algorithm let users designate local barriers to interpolation, control the number of points used for interpolation, and control the extent of extrapolation along the edge of the map (Monmonier 1982, 50–65).

SYMAP was written in the FORTRAN IV language. Although initially developed on an IBM 7094, subsequent versions were produced for the Control Data Corporation (CDC) 3600, the IBM 360, and twenty-two other types of computer known to the Harvard Laboratory for Computer Graphics and Spatial Analysis as of 1973. In 1978 the laboratory's records listed 469 paid users in twenty-six countries (Chrisman 2006, 29).

ALLAN H. SCHMIDT

SEE ALSO: Harvard Laboratory for Computer Graphics and Spatial Analysis (U.S.); Interpolation; Software: Mapping Software

BIBLIOGRAPHY:

Chrisman, Nicholas R. 2006. *Charting the Unknown: How Computer Mapping at Harvard became GIS*. Redlands: ESRI Press.

Liebenberg, Elri. 1976. "Symap: Its Uses and Abuses." *Cartographic Journal* 13:26–36.

Monmonier, Mark. 1982. *Computer-Assisted Cartography: Principles and Prospects*. Englewood Cliffs: Prentice-Hall.

Shepard, Donald. 1968. "A Two-Dimensional Interpolation Function for Irregularly-Spaced Data." *Proceedings of 23rd National Conference, Association for Computing Machinery*, 517–24. Princeton: Brandon/Systems Press.

Smith, Richard M. 1980. "Improved Areal Symbols for Computer Line-Printed Maps." *American Cartographer* 7:51–57.