F

Facilities Map. Public utility systems that distribute electricity, gas, and drinking water use maps both to plan and maintain their networks. Included in this category are sewer and storm drainage systems, which collect rather than distribute, and telecommunication systems, through which information flows in both directions. Many of these lines are buried, either to avoid visual blight or to protect the public as well as the infrastructure. Facilities maps, as they are called, are particularly important in avoiding inadvertent service interruptions by excavators or when a leaking gas or water line demands immediate attention. These maps played an essential but largely unsung role in the rise of the modern networked city in the late nineteenth and early twentieth centuries (Tarr and Dupuy 1988).

Despite their importance to society, facilities maps have been almost completely ignored by cartographic scholars. Typically produced as working drawings by drafters or engineers, they were of no interest to academic cartographers focused on the design or persuasive impact of maps intended for decision makers or the general public. Occasionally copied using one-off, on-demand reproduction technologies like blueprinting, they are not represented in map collections, public or private. When their information was converted to a digital format, principally in the 1970s and 1980s, the originals were rarely, if ever, archived for permanent preservation. Because utilities networks are vulnerable to terrorists and mischief makers, the maps have been treated as confidential, available principally to system employees who need their information for a specific purpose and shared reluctantly with fire prevention and emergency management officials. Privately owned public utilities in the United States not only feared litigation but considered their maps proprietary information, potentially useful to a competitor.

The sparse literature on facilities maps includes a modest but obligatory treatment in the few textbooks on urban surveying. An example from the first half of the century is *City Surveying* by George D. Whitmore, head of the Maps and Surveys Division of the Tennessee Valley Authority. Published in 1942, this short book addresses topics ranging from horizontal and vertical referencing systems to city planning and includes operational issues like card files and surveyors' time sheets. A single paragraph in a section on city maps (6–7) advises municipalities to develop an "underground map," drawn on "a number of sheets" but separate from cadastral or topographic maps, and showing "underground utility lines and all other underground structures, such as subways and tunnels; street and alley lines; and certain surface features, such as street railways, pavements, curbs, sidewalks, wire and light poles, and fire hydrants, that are located over or nearly over the underground lines." Toward the end of the book, a section on underground maps (92–94) discusses scales, drawing media, required fieldwork, and the importance of elevation.

An exemplar from the latter half of the century is *Urban Surveying and Mapping* by T. J. Blachut, Adam Chrzanowski, and Jouko H. Saastamoinen, a team of Canadian geodetic engineers who were encouraged to write a manual by the Commission on Cartography of the Pan American Institute of Geography and History/Instituto Panamerico de Geografía e Historia. Published in 1979, this lengthy book covers map projections, control networks, photogrammetry, and methods of computation and adjustment, and incorporates examples from North America and Europe. A chapter on utility surveys (221–34) discusses organizational and technical issues in converting existing maps to electronic format and the problems arising from maps showing the network as planned, rather than "as built."

Scattered reports in the survey engineering literature of the 1970s document the digital transition. A 1972 report by a task committee of the American Society of Civil Engineers recommended map scales and contour intervals for a range of engineering applications, including aerial and underground transmission lines, sewer systems, and water distribution systems. Commercial vendors offering inexpensive systems that integrated data capture and data display hardware with menu-driven, interactive mapping and engineering-design software were a strong incentive for automating facilities mapping (Aguilar 1975). A geographic information system (GIS) developed for Houston, Texas, included separate data layers for municipal water, waste water, and storm water systems; city owned rights-of-way; and historic details on the nature and locations of leaks (Hanigan 1979). Three decades later the handheld Global Positioning System (GPS) receiver posed an entirely new job security issue for licensed land surveyors: whether firefighters and other unlicensed city employees could lawfully map the locations of fire hydrants (Deakin 2008, 10).

Digital conversion was an incentive for the "one-call center," typically a local or regional consortium of private and public utilities (Monmonier 2010, 160–62). Companies pooled their data so that anyone planning to excavate could call a toll-free number, provide an address, and quickly determine potential interference with underground facilities. Companies or municipal departments with lines that might be breached would then visit the site and use small flags or spray paint to mark the location and depth of their lines. Although legislation sometimes mandated cooperation, the consequences of a broken line outweighed the cost of maintaining the center. As with earlier facilities maps, the public never actually saw the cartography.

MARK MONMONIER

SEE ALSO: Administrative Cartography; Travel, Tourism, and Place Marketing; Urban Mapping

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Figure of the Earth. In 1828 Carl Friedrich Gauss defined the mathematical figure of the earth as that equipotential surface of the earth's gravity field that corresponds on average to mean sea level. In 1873 Johann Benedict Listing gave to this surface the name geoid (Torge 2001, 3).

All mathematical representations of the earth's figure are approximations. The crudest is the sphere, followed by the reference ellipsoid. Paolo Pizzetti formulated the first formally exact theory of the rotating reference ellipsoid and its gravity field in 1894. John Fillmore Hayford estimated its geometrical parameters in 1909, and Carlo Somigliana developed the theory further in 1929 (Torge 2001, 103, 115). The International Union of Geodesy and Geophysics (IUGG) adopted the International ellipsoid in 1924, based on Hayford's parameters, and the corresponding International gravity formula in 1930, based on the 1928 work of Veikko Aleksanteri Heiskanen.

Improved knowledge of the earth's precise figure led to more accurate ellipsoid models called geodetic reference systems (GRS). The IUGG adopted the GRS67 in 1967 and the GRS80 in 1979. Both were defined by the geometrical ellipsoid parameters a (equatorial radius) and f (flattening), and the geophysical parameters GM (total mass), J_2 (dynamic flattening), and ω (angular velocity of rotation) (Torge 2001, 115–16).

A reference ellipsoid does not describe the real earth precisely, but rather is an approximation, or idealization, in the form of a simple mathematical model. It removes the irregular deviations of the true earth surface—and its gravity field—from such a simple figure, minimizing them overall according to the least-squares criterion. This allows the theory to model linearly the interrelations between these small deviations so that, for example, map projections remain mathematically tractable on a reference ellipsoid.

Each reference ellipsoid has a corresponding gravity field model called a normal gravity field, which has the ellipsoid surface as one of its equipotential surfaces. The true gravity field of the earth has a slightly different, undulating surface as its equipotential surface. The force of gravity is everywhere perpendicular to this surface in the same way that the model or normal gravity is perpendicular to the ellipsoid. The separation between these two equipotential surfaces, called the geoidal undulation, is directly related to the difference between the true gravity field—also called geopotential—and the mathematically defined smooth ellipsoidal or normal geopotential. As George Gabriel Stokes showed in 1849, determining geoidal undulations from global gravity measurements is equivalent to solving a boundary value problem that determines the geometric figure of a fluid earth from the acceleration of gravity given everywhere on its surface (Heiskanen and Moritz 1967, 94).

In the 1950s and 1960s the Soviet geophysicist M. S. Molodenskiy pioneered an alternative technique that would prove useful in connection with satellite geodesy. Instead of geoidal undulations, he determined vertical separations between corresponding true and ellipsoidal ("normal") equipotential surfaces at terrain level. These values represent the external geopotential directly, without the complication of having topographic masses of unknown density between the earth's physical surface and the chosen boundary surface (Molodenskiy, Eremeev, and Yurkina 1962).

An entirely different approach determines the geopotential (and thus geoidal undulations) from available gravimetric observations using a statistical least-squares estimation technique called collocation. Pioneered by the Danes Torben Krarup and Carl Christian Tscherning and the Austrian Helmut Moritz, this technique carefully accounts for the statistical behavior of various observations of gravity-related quantities on the earth's surface. In addition to allowing the use of arbitrarily distributed observations, collocation can combine observations of different types, like gravity anomalies, deflections of the vertical, and gravity gradient components (Moritz 1980).

Until the late twentieth century, different reference ellipsoids were employed for individual countries or continents. A regional ellipsoid provides a single, well-defined mathematical framework for adjusting angles and distances, measured at or between points in a triangulation network covering a large area. This adjustment, necessary because of the curvature of the earth, requires knowledge of the heights of the geodetic points above the reference surface. Because geodetic heights are traditionally referred to sea level—that is, to the geoid—a geoidal undulation map or model is needed to make this reduction precise. A precise national, continental, or (more recently) global network thus established is further enhanced by adding lower-order networks with denser sets of reference points in the terrain progressively closer to various local user communities.

Large, classical geodetic projects aimed at establishing a continental datum like ED50 (European Datum 1950) and NAD27 (North American Datum 1927) adjusted their extensive triangulation networks on a regionally defined "best fitting" (and thus nongeocentric) reference ellipsoid. In those days, global unification of these networks was still unimaginable. The same was the case for vertical datums, typically referenced to mean sea level at a specific coastal location like Amsterdam. Their global unification at better than one-meter precision was hindered by the poorly known stationary sea surface topography (SSST), the permanent separation between the geoid and mean sea surface arising from, among other factors, ocean currents (Torge 2001, 78).

The idea of a precise geodetic mapping of large areas using very high targets is generally attributed to Yrjö Väisälä, who, in 1945, inspired by antiaircraft shells bursting over his home city of Turku, Finland, proposed using artificial satellites as geodetic targets (Väisälä 1946). The technique, called stellar triangulation, was perfected in Finland and Hungary using high balloon-borne flash lamps, and first applied in space on the U.S. ANNA 1B flash lamp satellite (COSPAR number 1962-060A, launch 1962), photographed by a global Minitrack Optical Tracking System (MOTS) camera network. The Global Positioning System (GPS) made these optical technologies, like also the Doppler-Transit satellite radio positioning system, obsolete around 1990. The American GPS and its Russian counterpart GLONASS (Global'naya Navigatsionnaya Sputnikovaya Sistema) provided precise geodetic positions almost anywhere on earth in a geocentric system, including heights above a geometrically defined reference ellipsoid. This allowed global unification of the existing continental geodetic reference networks and promises ever greater precision as global positioning technology develops. In 1987 the International Astronomical Union (IAU) and the IUGG jointly entrusted maintenance of these new global datums, collectively known as the International Terrestrial Reference System/Frame (ITRS/ITRF), to the Central Bureau of the International Earth Rotation and Reference Systems Service (IERS), a coordinating agency located at Frankfurt, Germany.

Mapping the geoid is comparatively easy over the oceans, where the water surface closely approximates (± 1 m) the shape of an equipotential surface of earth's gravity field. Mapping the marine geoid with downward-looking radar from orbit was first attempted during the National Aeronautics and Space Administration (NASA) Skylab (1973-027A) mission. The first dedicated (but notably inaccurate) satellite altimetry mission was NASA's GEOS-3 (1975-027A). Accuracy improved dramatically when radar altimetric satellites equipped with on-board GPS started mapping the mean ocean surface geocentrically to within a few centimeters, but the resulting map did not depict the geoid, which is separated from the mean ocean surface by the aforementioned SSST.

National defense was a prime impetus for precisely mapping the marine geoid: submarine-launched ballistic missiles navigating with inertial guidance systems need a precise initial direction of the vertical, that is, the horizontal gradient of geoidal undulation.

While the figure of the earth can be graphically depicted as a geoid map, it is physically more meaningful to describe the geopotential field as a spherical harmonic expansion. This resembles Fourier analysis, which expresses a function as a summation of wave-like constituents of different wavelengths:

$$V(\theta, \lambda, r) = \frac{GM}{r}\left\{1 - \sum_{n=1}^{\infty}\sum_{m=0}^{n}\left(\frac{a}{r}\right)^n [J_{nm}R_{nm}(\theta, \lambda) + K_{nm}S_{nm}(\theta, \lambda)]\right\}$$

where r is distance from the geocenter, θ spherical colatitude, λ longitude, GM the earth's total mass multiplied by the universal gravitational constant, and a the earth ellipsoid's equatorial radius (Heiskanen and Moritz 1967, 59). Each constituent, or spherical harmonic, R_{nm} or S_{nm} has two integer "wave numbers": the degree n and the order m. Its wavelengths in the directions of longitude and latitude are 40,000 km/m and 40,000 km/$(n - m)$, respectively. The earth's oblateness is described by $R_{2,0}(\theta, \lambda)$, the coefficient of which is $J_{2,0} = J_2 = 1082.63 \cdot 10^{-6}$. This, the largest coefficient by far, causes the orbital plane of nonpolar near-earth satellites to rotate, or precess, around the earth's axis at several degrees per day.

Higher coefficients are all much smaller. Those for which $m = 0$ are called zonal, whereas those for which $m = n$ are known as sectorial harmonics. The remaining coefficients are called tesseral (from the Latin *tessera*, meaning a mosaic tile). The average magnitude of the coefficients J_{nm} and K_{nm} depends almost entirely upon n, and decays with increasing n according to the so-called Kaula's rule (Kaula 1966). Theoretically the expansion goes to infinity but is conveniently truncated at a limiting degree, $n = n_{max}$, corresponding to a spatial resolution at the earth's surface of 20,000 km/n_{max}.

The first useable spherical harmonic expansions produced for the whole earth were of low degree and based entirely on satellite orbit perturbation studies. As additional terrestrial and satellite data accumulated, geodesists pursued higher degrees of expansion. In 1951, Ohio State University's Veikko Aleksanteri Heiskanen started the Global Gravimetric Mapping Project to collect gravimetric data from around the globe in order to determine a global geoidal undulation map—or equivalently, to describe the earth's exterior geopotential—by solving the Stokes gravimetric boundary value problem. Richard H. Rapp continued Heiskanen's work, but until the dissolution of the Soviet Union, huge areas in Eurasia were poorly represented in these models because security restrictions during the Cold War prohibited the use of modern gravimetric survey data from these countries.

EGM96 (Earth Gravity Model 1996), the latest global model available in 2000, was published by a consortium led jointly by NASA's Goddard Space Flight Center and the U.S. National Imagery and Mapping Agency (as it was then called). Based on a combination of satellite and terrestrial data, EGM96 attained a maximum degree and order of 360, corresponding to a 55 km resolution. Over parts of the earth with comparatively accurate gravimetric mapping, the precision of this model, expressed as geoidal undulation, is measured in decimeters, mostly due to the "smearing-out effect" of its limited resolution. Precise and detailed geopotential models, or equivalently, global geoidal undulation maps, helped unify vertical datums on different continents by means of GPS, thereby establishing a single global vertical datum useful for studying sea level variations.

Decades of planning and preparation during the second half of the twentieth century culminated in three satellite gravity missions. The first two, one German and the other jointly U.S.-German, were the Challenging Minisatellite Payload (CHAMP; launched 2000) and the Gravity Recovery and Climate Experiment (GRACE; launched 2002). While CHAMP mapped the earth's gravitational field by tracking its own free-falling orbit motion using on-board GPS, GRACE employed a pair of satellites flying in tandem with a microwave beam measuring variations in their separation. In focusing on temporal gravity variations such as the annual ground water cycle in tropical river basins and the counterphase of dry and wet monsoons on opposite hemispheres, the GRACE mission also supported climate research.

A third mission, the Gravity Field and Steady-State Ocean Circulation Explorer (GOCE), was launched in March 2009. GOCE included a sensitive on-board gravitational gradiometer (Rummel 1986) designed to measure slight spatial variations in gravitation in order to determine a geopotential model so precise and detailed, that, when subtracted from the altimetrically obtained mean ocean surface, it provides a realistic picture of the SSST. Measurement of this topography, a disequilibrium phenomenon resulting largely from the effect of earth rotation (Coriolis force) on ocean currents, supports reliable modeling of the heat transported by these currents and its likely impact on climate (Wunsch 1993).

In much the same way that military security fostered the study of the figure of the earth during the beginning and middle of the twentieth century, earth systems science became the key impetus toward the century's end.

MARTIN VERMEER

SEE ALSO: Coordinate Systems; Geodesy: Geodesy and Military Planning; Geophysics and Cartography; Heiskanen, Veikko Aleksanteri; Projections: Projections Defined for the Ellipsoid

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Fire Insurance Map. Fire insurance maps are large-scale urban maps that were originally designed as graphic reference tools for insurance companies in analyzing risk and recording policies. They provided detailed information concerning the potential fire risks of individual commercial, residential, and industrial structures within a city, so that personal inspection of individual properties by underwriters was not necessary. These plans typically showed a building's footprint or shape; height or number of stories; construction materials, such as wood, brick, stone, iron facade, or adobe; location of fire walls, elevators, doors, and windows; proximity to water mains, fire hydrants, and fire alarm boxes; names of commercial establishments and public buildings; house numbers; and street widths (fig. 268). By annotating insured properties on their copies, insurance companies quickly created a visual record of the distribution and concentration of their potential liabilities.

Although a few single-sheet urban maps created specifically for fire insurance purposes were published as early as the 1790s, the multisheet, large-scale format that characterizes the twentieth-century fire insurance map had its origins in the 1860s. During the latter half of the nineteenth century, a number of competing companies produced fire insurance maps, each for their respective urban regions. However, one company (the Sanborn Map Company located in New York City) rapidly expanded its coverage to include cities throughout the United States. Some of the competitors ceased publication after brief productive periods, while others were absorbed by Sanborn.

The production of fire insurance maps continued and expanded throughout the first two-thirds of the twentieth century but ended in the 1960s and 1970s. During this time, two companies dominated production—Charles E. Goad and Sanborn Map. The former, originally located in Montreal, moved its headquarters to London in 1910. By then it had become the dominant publisher of fire insurance maps for cities and towns in Canada and the British Isles. In addition, the company produced plans for a few cities in other European countries, as well as selected Latin American and African cities, primarily in former British colonies (Hayward 1977; Rowley 1984).

Early in the twentieth century, the Sanborn Map Company gained a virtual monopoly on the production of fire insurance maps in the United States. However, the company was subject to the critical observation and evaluation by national and regional underwriting associations, including the National Board of Fire Insurance Underwriters. Sanborn's map production reached its peak in the early 1930s, but production was reduced drastically during the economic depression of the 1930s and World War II. For a variety of economic and technological reasons, the production of fire insurance maps did not improve after the war, and after 1961 the Sanborn Map Company ceased publication of new large-scale fire insurance maps. During almost one hundred years of activity, the company published maps for more than 12,000 cities and towns, most in multiple editions of five or more (Library of Congress 1981).

In the United States, the terms "Sanborn maps" and "fire insurance maps" are often used interchangeably, reflecting the dominance gained by this one company. The typical Sanborn maps, which were hand-colored lithographs, measured 21 × 25 inches (53.3 × 63.5 cm) and were published at a scale of 1 inch to 50 feet (fig. 269). Because production runs were small, the maps were expensive. Consequently, the maps were leased to individual insurance companies using a long-term subscription service. Cost-saving measures that were introduced included paste-on corrections for updating changes, loose-leaf atlases facilitating the replacement of single outdated sheets, subscription discounts, and reduced scales and sizes. The Goad maps followed a similar format but often utilized a scale of 1 inch to 40 feet.

Although the utility of these maps for fire insurance purposes was greatly diminished by the middle of the century, their value for historical and environmental research was realized during the last third of the century. They are resources for architectural historians, economic and urban historians, historical geographers, genealogists, and local historians (Karrow and Grim 1990, 215). In addition, environmentalists and urban planners began using them to examine prior land use as concerns for noxious land uses became more pressing. Consequently, libraries with major collections of these maps have prepared bibliographies of their hold-

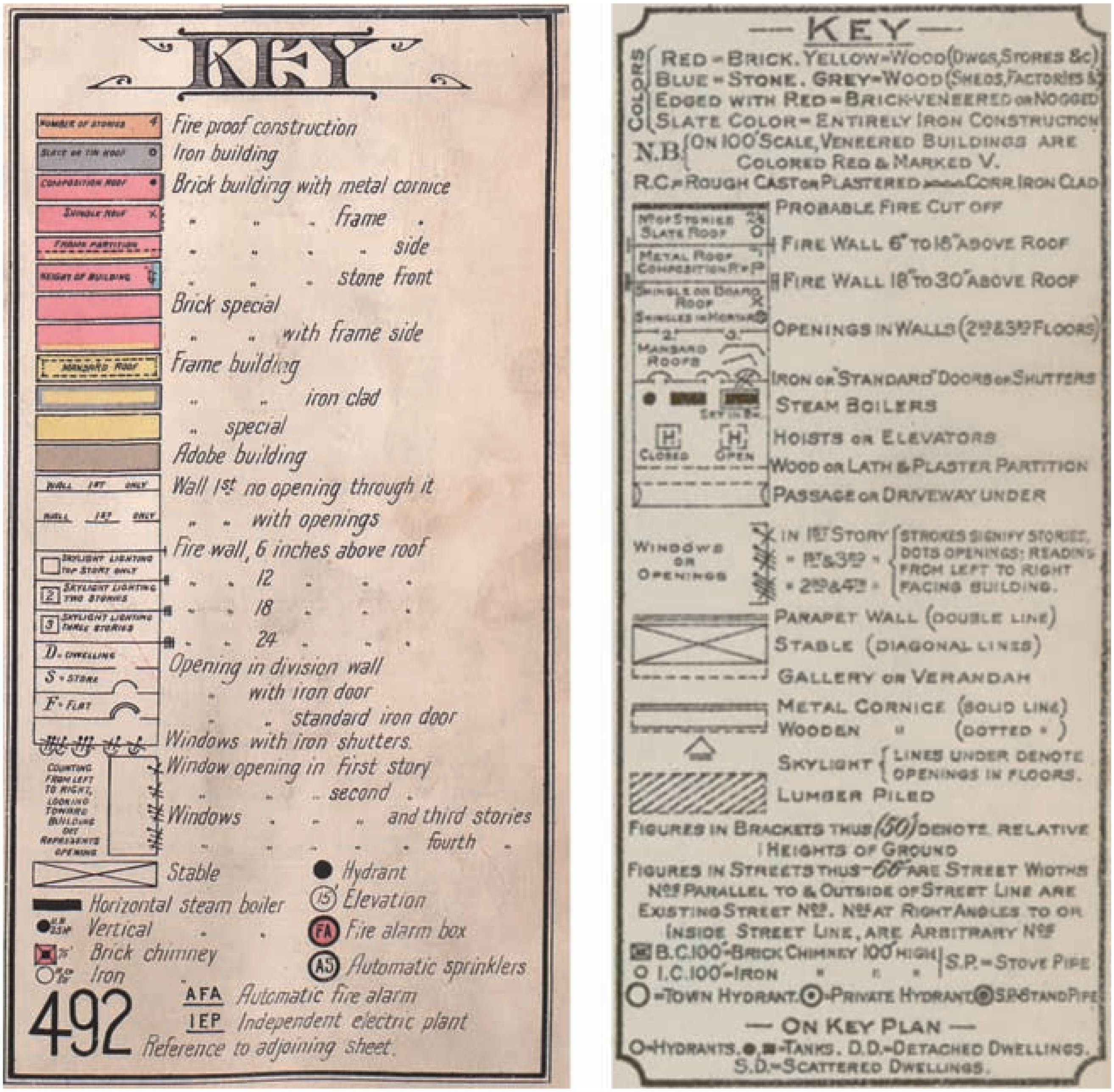

FIG. 268. TWO KEYS TO SYMBOLS ON FIRE INSURANCE MAPS. A standard feature accompanying Sanborn (left) and Goad (right) publications explained the use of colors for construction materials as well a variety of other symbols assisting underwriters in understanding a building's potential fire risk. Size of the originals: ca. 21.4 × 11.2 cm (left) and ca. 12.8 × 5.9 cm (right). Images courtesy of the Missouri Valley Special Collections, Kansas City Public Library, Kansas City, Missouri (left), and Library and Archives Canada, Ottawa (Archival reference no., R6990-428-0-E, Local class no., 440 Grimsby 1914) (right).

ings, while successors to the Sanborn Map Company have microfilmed and digitized major collections making them more widely available for research (Hayward 1977; Library of Congress 1981; Hoehn, Peterson-Hunt, and Woodruff 1976–77).

RONALD E. GRIM

SEE ALSO: Hazards and Risk, Mapping of

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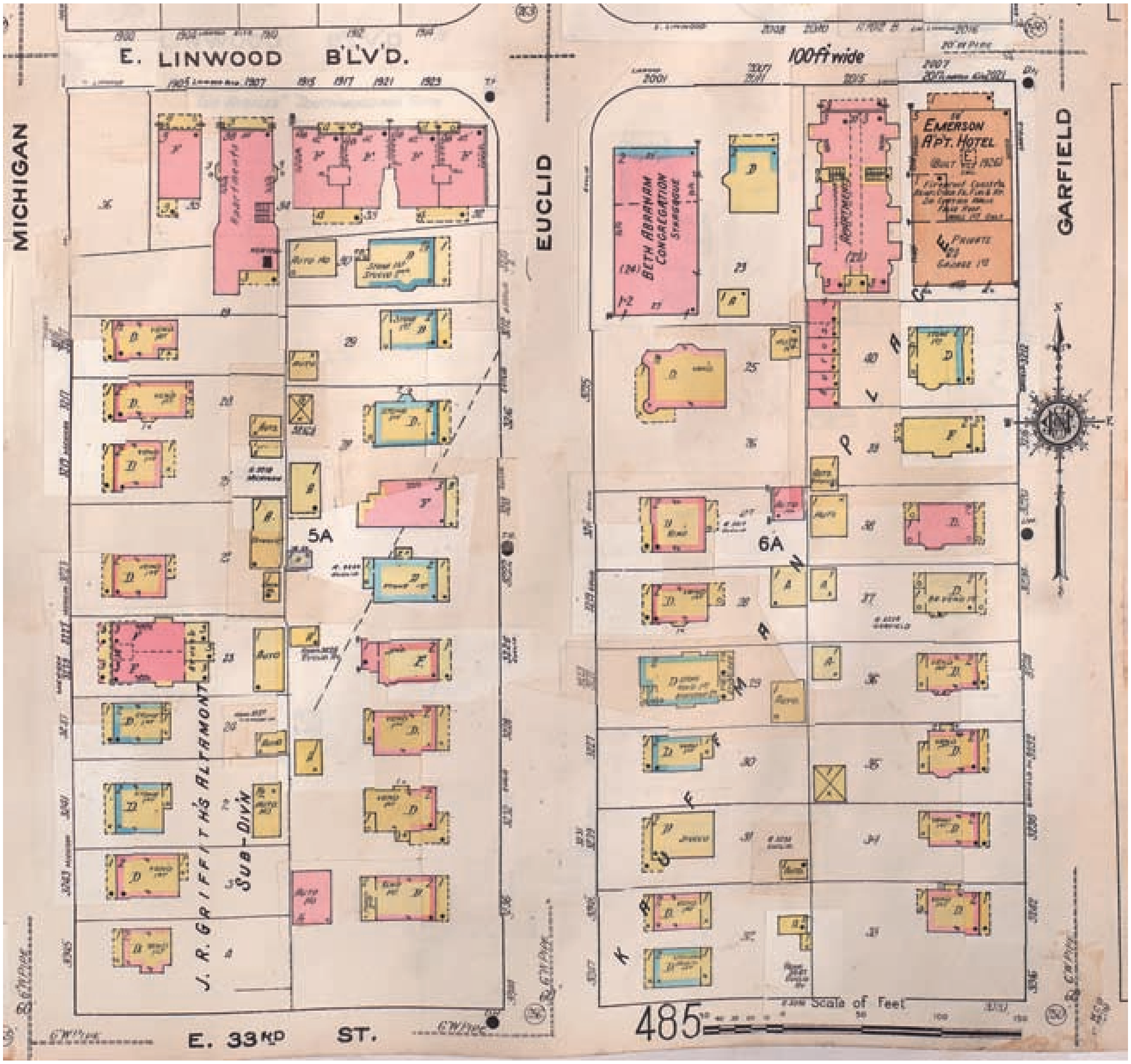

FIG. 269. DETAIL FROM A SANBORN MAP OF KANSAS CITY. From volume 4, 1909–57 (p. 470) of Sanborn map of Kansas City.

Size of the entire original: ca. 53.3 × 63.5 cm; size of detail: 33.8 × 36 cm. Image courtesy of the Missouri Valley Special Collections, Kansas City Public Library, Kansas City, Missouri.

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Forensic Mapping. As long as tribunals have been seated, some form of drawing has been presented to the trier of fact. Cartography has played a subtle role in picture drawings at trials, becoming a useful tool in the

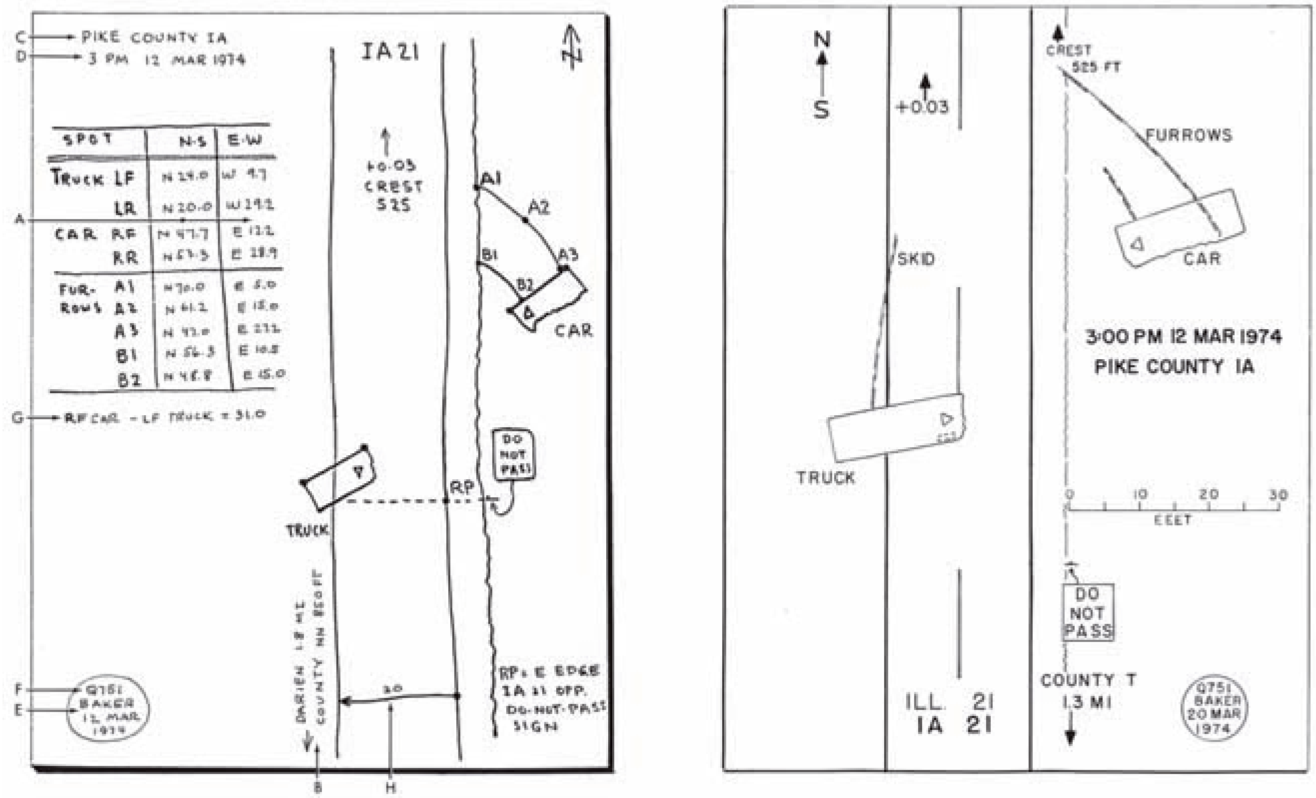

FIG. 270. FIELD SKETCH AND SCALE MAP OF VEHICLE CRASH. A complete field sketch with identifying information (left) and the scale map (right) prepared from data recorded on the field sketch. Size of each original: 15 × 11.5 cm. From Baker 1975, 139 (fig. 7–22) and 169 (fig. 7–76). Permission courtesy of the Northwestern University Center for Public Safety, Evanston.

analysis of critical events. Forensic artists have contributed to court proceedings with crime scene sketching, courtroom drawings, and vehicle crash location illustrations, among many other things (fig. 270). Prior to the twentieth century little, if any, change is noted in the judiciary chronicles.

For decades, police and legal investigators have utilized a baseline coordinate (Cartesian) or a trilateration system of measured distances to document evidence points at a crime or crash scene. Tools of the trade were 25-foot steel retractable tapes and 100-foot fiberglass tape measures. These tapes and wheeled devices such as the 1,000-foot walking wheel were used to make distance measurements, and scale plans of the scene were prepared on drafting paper. Rulers, protractors, compasses, French curves, T-squares, and lettering templates were used to draft hand sketches of crime scenes and crash locales. In the early 1990s, crime scene investigators and traffic collision reconstructionists recognized that modern technology in the form of electronic total stations, CAD software, and the art they had already developed gave them the ability to revolutionize their work product (fig. 271).

The benefit to society was provided by the economic gains when the police applied this technology to their task, more so in traffic-related events than crime scenes. It has long been recognized that motor vehicle traffic crashes have a detrimental economic effect in the community where the event occurs. In addition to property damage and personal injury, there are indirect losses—delayed deliveries, late personnel arrivals, fuel expenses, and the greenhouse gases emitted when a thousand vehicles are idle on the highway for hours.

Participants attending a traffic crash conference in 1990 coined the term "forensic mapping" for the art and science of electronically documenting a point or coordinate where physical evidence related to a crime is located and then using an automated system to create a map showing this location. Three experts in particular introduced this type of electronic mapping to the law enforcement community: Robert S. McKinzie (Kansas), Mick Capman (Michigan), and Dennis Payne (Florida),

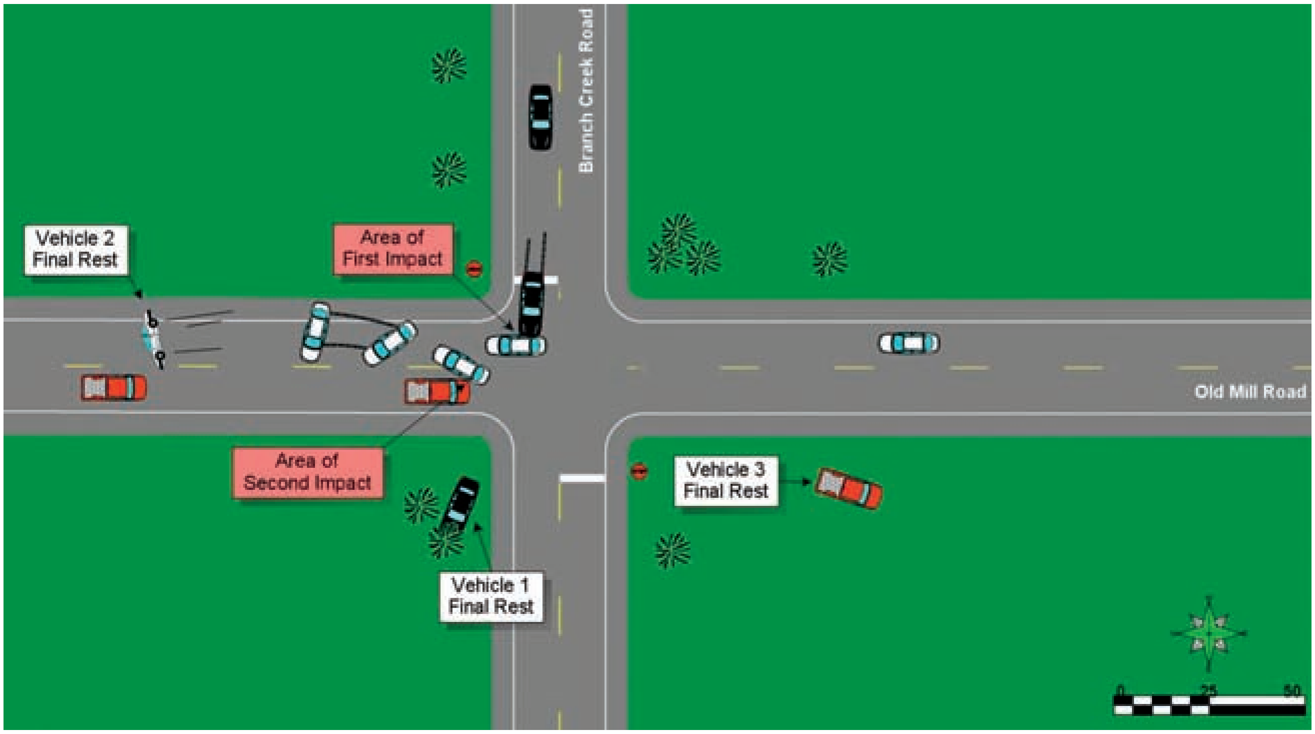

FIG. 271. SCALE DIAGRAM OF ACCIDENT SITE. This example depicts the location of vehicles as they approach and depart the area of impact. It is a useful piece of demonstrative evidence and, if based on accurate measurements, can be used to determine important characteristics of the accident scene such as lines of sight and the speeds and locations of vehicles at different times.
Image courtesy of Jonathan McGehee, VCE Inc., Nashville.

all formerly in law enforcement. A new tool was at hand for the crime and crash reconstructionists. It provided more accurate measurement of critical evidence in a timely fashion, relieved some of the economic cost to these events, and met the requirements of the judicial system. Some in the surveying community challenged the application of their traditional tools to critical events, claiming surveying was being performed. A clear distinction was made; forensic mapping did not require a license and was significantly different from surveying in that investigators had to recognize and categorize physical evidence and then make measurements useful in the judicial analysis of the crash or crime. The International Association of Accident Reconstruction Specialists was formed in 1980, while the Professional Society of Forensic Mapping was not established until 1993. Both societies have been active in promoting, standardizing, and professionalizing forensic mapping activities.

What lay ahead was the integration of the science supporting electronic mapping into the judicial community with strategies for meeting associated legal challenges. One very early formal training seminar devoted to the judicial aspects of forensic mapping was organized in 1992 by Professor Stephen Thompson at Kansas State University–Salina and Keith Raymor, a senior representative from the Sokkia Corporation, a manufacturer of total station surveying equipment. This specialized training class was essential for students who were accomplished in crime and crash scene investigation but were void of the science behind forensic mapping. Over the next several years, class participants and others succeeded in developing forensic mapping into an art based on the science of electronic mapping. Developing an application protocol for forensic mapping was absolutely necessary, as history had shown with the application of traffic radar in law enforcement. An operator had to (1) articulate what the forensic mapping system does, and in a basic form, how it accomplishes the mapping task; (2) ensure that the recognized protocol has been followed; (3) demonstrate that the cartographic depiction is a fair and accurate representation of the observations and measurements made, and (4) ascertain that the technology was accepted as reliable by others within the discipline. While a few courts accepted the objections of attorneys, the judiciary has consistently found the cartographic products created by forensic mapping specialists to be generally reliable and accepted as evidence describing the event.

By the mid-1990s, electronic mapping and measurement technology was improving at an exponential rate compared to the changes in the art of characterization and identification within the coding process. Very little had changed in the identification of roadway evidence and the geometry on which it relies. The user was presented with a real time map generation process, using such products as Evidence Recorder software produced by MicroSurvey Software Inc. in West Kelowna, British Columbia, Canada. Each point of interest is graphically displayed in map form on the field data collector and is also available as coordinate data. The map display has drastically reduced errors in the coding of points. The electronic total station instruments used to measure polar coordinates in the field seem light years ahead of the earliest units operated. A few of the modern features include maximum ranges reaching 5,000 meters and the ability to measure with and without a prism or reflector at a range of 500 meters.

As police and private users of forensic mapping began to take advantage of this modern technology, it was realized that the speed at which this process was applied was as important as the accuracy with which the points were being recorded. The fiscal advantages of modern mapping technology were such that its application not only improved the information the judicial system received, but reduced the economic loss caused by motor vehicle crashes and other events. Accidents could now be processed in minutes, reducing disruptions to traffic flow on motorways. The resourcefulness of law enforcement users began to reap financial benefits to their communities as techniques such as AIM (active incident management) were applied. The goal of AIM has grown from mapping intersections where numerous traffic crashes occur to mapping sites where incidents are in need of management. The sites identified as high management areas are subject to forensic mapping, and the electronic maps can be reused, adding only the physical evidence for that specific incident. Infrastructure protection is yet another aspect of forensic mapping, and it uses tools such as a spherical camera and software such as SceneWorks. The high dynamic graphical range of these tools provides infrastructure protection details with precise location information. In some analyses this new technology may become a virtual walk through the site before and after an event. These and other forms of forensic mapping provide accurate documentation to assist the trier of facts with the primary goal of preventing such events in the future.

STEVEN MCKINZIE

SEE ALSO: Persuasive Cartography; Property Mapping Practices: Professional Practice in Land Surveying

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Forestry and Cartography. Over the course of the twentieth century, forestry and cartography developed many important links with each other. The nature of those links needs to be made clear from the outset, for "forestry" and "cartography" can refer not only to basic categories of human practices upon the land but also to two distinct academic research fields. When we take the terms to have their first (broader) meanings, three main historical themes become apparent. One theme is the daily administrative uses of maps by foresters. Another is cartography's role in shaping definitions of "forest" itself. The final theme is the increased reliance upon representational technologies to quantify and frame issues relevant to forestry practice and forest health. All three powerfully structured the history of forestry and cartography since 1900.

The story of administrative forest mapping in the twentieth century must be understood in the context of its roots in early modern European statecraft. Forestry proper began in Europe as a coherent set of appraisal practices shared by communities of state land managers. Like early cadastral and land use maps, forestry maps of the eighteenth and nineteenth centuries reflected in their very designs the specific practical aims of the people doing the mapping. Early concerns centered almost exclusively on the "fiscal forestry" of annual taxable yield; maps, accordingly, pictured forests as dot-like symbols (denoting trees of certain minimum size) to be tabulated, compared, and adjusted every year (Scott 1998, 11–15). To produce these maps, foresters in Russia, Prussia, Germany, and the Scandinavian countries developed efficient means of cruising timber—carrying out a field survey that obtained a reasonably good sample of sheer timber volume for a particular tract of land. When leading foresters like Bernhard Eduard Fernow and Raphael Zon emigrated to the United States in the late nineteenth century, they brought with them not only professional mores and standards but also these highly particular cartographic techniques.

For about three decades after the founding of the

FIG. 272. *NATURAL VEGETATION*, 1923, BY HOMER L. SHANTZ AND RAPHAEL ZON. Compare figure 273. Size of the original: 42.7 × 60.9 cm. From O. E. Baker, ed., *Atlas of American Agriculture: Physical Basis Including Land Relief, Climate, Soils, and Natural Vegetation of the United States* (Washington, D.C.: United States Government Printing Office, 1936), 4–5 (fig. 2).

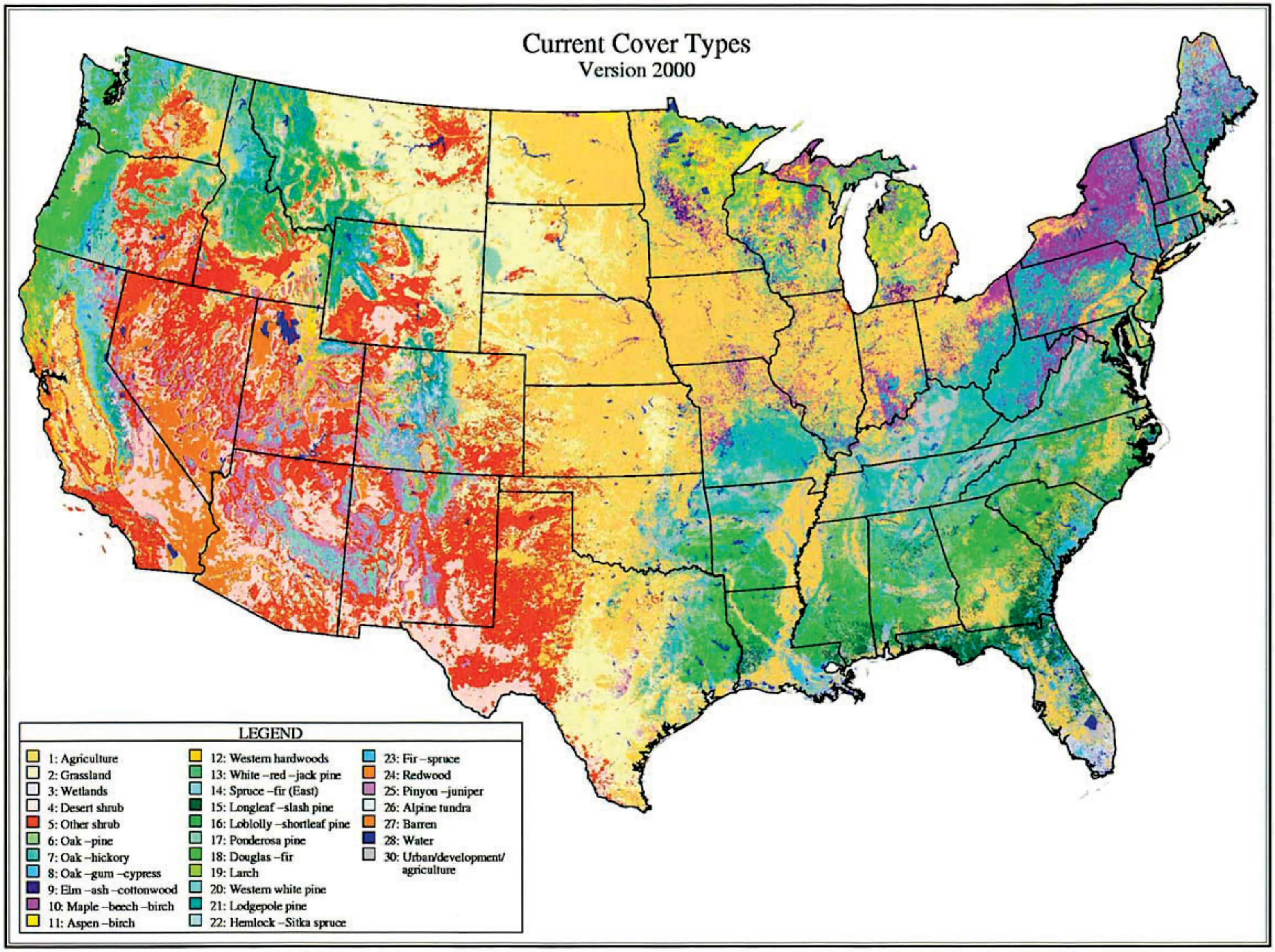

FIG. 273. *CURRENT COVER TYPES, VERSION 2000.* Compare figure 272: two attempts at picturing the nation. What has changed in seventy-five years are not only the distribution of forest types themselves, but the goals and methods of making synoptic representations at small scales.
From Kirsten M. Schmidt et al., *Development of Coarse-Scale Spatial Data for Wildland Fire and Fuel Management* (Fort Collins: U.S. Dept. of Agriculture, Forest Service, Rocky Mountain Research Station, 2002), 35.

United States Forest Service (USFS) in 1905, American foresters under Gifford Pinchot followed their European forebears: in the new public forests, timber yield was by far the single most important variable to appraise and map, so the refining of cruising and mensuration techniques received its due emphasis (LaBau et al. 2007). But the sheer size and areal diversity of New World forests made them fundamentally different in kind than those found in Northern Europe. This geographical condition created an opportunity for regional foresters scattered across North America: they could experiment with a range of additional types of administrative maps fit for distinctive functions. For instance, the disturbing frequency and ease with which forests in the Great Lakes states and Canada could ignite into devastating fires called forth innovations in tracking fire risks. In regions like Alaska and western Canada, aerial photographic surveys fit perfectly into the administrative toolkit of lonely foresters charged with protecting the enormous western reserves from disease, blight, insects, and, most especially, unwanted fires (Spurr 1948). Another example of a new kind of map suited to American environmental and institutional conditions was the boundary plat. Since the USFS constantly sold and acquired lands, the boundaries of and the land uses within the national forests constantly changed. The cumulative Forest Atlas, assembled in Washington, D.C., recoded most transactions in map form; like township plats compiled by the General Land Office, the Forest Atlas served as a monumental (and distinctly twentieth-century) archive. A final example was the development of maps not concerned with annual yields or timber volume, but with tree species. Here, too, North American environmental diversity created a vast laboratory within which foresters could try out new techniques for depicting phenomena like land cover, watershed health, soil erosion, and, especially as the century wore on, regional biodiversity (Checkovich 2004).

This last example suggests that over time foresters changed their very definitions of a forest's composition and functions within the biosphere. For Raphael Zon and William N. Sparhawk in 1923, forested land was "land covered with woody growth of economic importance." For the Food and Agriculture Organization (FAO) of the United Nations in 1990, what defined a forested area was the density of its "canopy threshold" (Mather 2005, 270). Zon and Homer L. Shantz's pioneering map of forest vegetation of the United States delineated eighteen classes of forest type (fig. 272); in 2000 USFS national maps included twenty-nine cover types (fig. 273). For indigenous dwellers of tropical rainforests in the 1990s, meanwhile, the geographic information system (GIS) could be used to help delineate and rationalize "non-wood forest products" and even categories unvalued by the market, such as homelands (Mather 2005; Robbins 2003). Clearly, "forest" has been "a problematic and hybrid category" (Mather 2005, 272). Crucially, cartography has played a central role throughout this entire conceptual evolution. Indeed, maps have been powerful not so much for depicting forests as they actually are but for the ways they have structured human forestry practices. In the Progressive Era, as social theorist David Demeritt (2001, 433) argued, the "way in which the forest as a whole [in the United States] was pictured as a singular and finite quantity went largely unquestioned. This quantitative picturing provided both the context and the impetus for the governmental institution of scientific conservation and the far-reaching reconstruction of nature, civic society, and the state that scientific conservation entailed."

Viewing forest maps in such broad social contexts leads to the third major theme of the twentieth century. Foresters have used increasingly sophisticated representational technologies in order to understand forestry problems in ways that suit the cultures and demands of their times and places. Just as aerial photographic surveying emerged as a tool suited to supervising isolated tracts of forest stands in regions of sparse settlement, so too have remote sensing, quantitative biodiversity sampling, and computerized forest cover modeling developed as tools suited to a world in which the health of forests as ecosystems is understood to be perpetually threatened by a burgeoning global population. In such an environment the questions of what even counts as "forest knowledge" and how to coordinate information contained in various forestry institutes and databases are ones that the FAO had to confront each time it issued a state-of-the-art Forest Resources Assessment (1980 and 2000). As geographer Alexander S. Mather (2005, 272, 277) put it, "The more numerous the forest values, the greater the range of administrative bodies required to provide data. . . . Perhaps the world forest in 2000 is like France in 1800: it is not yet capable of being reduced to statistics because of lack of capacity and weaknesses in centralisation and administration."

Just as it was for American foresters in 1900, for the international community of foresters in 2000, achieving synoptically a "snapshot image" of global forest cover, health, and use was as much a social and institutional challenge as a technical one. The fluid interplay of all the same factors in different combinations—nature, technology, and human interests—have made "forestry and cartography" a rich, interdependent enterprise throughout the twentieth century.

ALEX CHECKOVICH

SEE ALSO: Biogeography and Cartography; Environmental Protection

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Fractal Representation. The mathematician Benoit B. Mandelbrot introduced the concept of fractals in 1975, when he published *Les objets fractals: Forme, hasard et dimension*. Mandelbrot's book was not known to the broader scientific community until an expanded version was published in English two years later (Mandelbrot 1977; 1983). Since then, fractal geometry has generated great interest from a wide range of disciplines, with research and applications ranging from physics and fluid dynamics to movies and the arts. During the 1980s and 1990s, fractals dominated the scientific literature (Lam and De Cola 1993; Peitgen and Saupe 1988), and an understanding of the basics of fractals became a hallmark of scientific literacy.

A fractal is a geometrically complex shape that can be used to generate a larger, more extensive shape like that of a cloud, coastline, river, tree, topography, city boundary, land use pattern, or other everyday feature found on maps. (The fronds that make up the fern in figure 274 offer an oversimplified but nonetheless useful introduction to the notion of an object composed of miniature versions of itself.) Classical (Euclidean) geometry cannot readily describe these complex shapes. For example, a coastline is neither straight nor circular, and no other classical curve can describe its form well without extra effort. Similarly, topographic surfaces of the earth can hardly be measured by classical geometry because of their irregularity. Fractal geometry was developed to overcome this problem.

In classical geometry, the dimension of a curve is defined as 1, a plane as 2, and a volume as 3. This property is called topological dimension and is characterized by integer values. In fractal geometry, a curve can have a noninteger-dimensional value ranging from 1 to 2, depending on its complexity or irregularity. This noninteger dimension, called fractal dimension (D), is used as a parameter to describe the curve's complexity. The more geometrically complex the curve, the higher its fractal dimension. A straight line will have a fractal dimension of 1, but as complexity increases, the irregular curve can wander up and down (without crossing itself) and eventually fill a two-dimensional space, yielding a fractal dimension of 2. Similarly, the fractal dimension of a point pattern can range from 0 to 1 and a surface from 2 to 3.

The fractal dimension of a shape or pattern can be explained and mathematically derived through the concept of self-similarity, whereby every part of a fractal object resembles the whole. A common example is the fern in figure 274, where every frond is a much-reduced image of the whole fern. Many curves and surfaces are self-similar, meaning that each portion of a curve or surface can be considered as a reduced-scale version of its whole. The degree of self-similarity is used to define the theoretical fractal dimension, as specified by the equation $D = \log N / \log(1/r)$, where r is a similarity ratio of a curve (i.e., a scale reduction factor) and N is the number of steps needed to traverse the curve.

This equation is applicable only to theoretical shapes and objects that are strictly self-similar. Most natural shapes are not strictly self-similar but rather statistically self-similar. Hence, the fractal dimension must be estimated through the regression technique. The empirical D of a curve can be estimated by regressing the total length of the curve (y axis) against the step size used to measure its length (x axis). When both are defined in logarithmic form, the regression equation is $\log L = k + b \log \delta$, where L is the length of the curve, δ is the step size, b is the slope of the regression, and k is a constant. The fractal dimension is then estimated from the slope of the equation, where $D = 1 - b$.

Fractal theory has deep roots in cartography. In fact, the derivation of fractals was related to a key question in cartography: How much real-world detail should be represented in a map? Ten years before Mandelbrot published his book on fractals, he posed an intriguing question that cartographers had also been asking: How long is the coast of Britain? (Mandelbrot 1967). He observed that the measured length of a coastline varied with the size of the walking-divider used to measure its length; the smaller the walking-divider step size, the longer the coastline. Called the Steinhaus paradox after Polish mathematician Hugo Steinhaus, this relationship is closely related to a number of fundamental issues in cartographic representation, such as the effects of map scale and generalization on subsequent measurement and analysis. The increase in length due to the decrease in step size can be represented by a ratio, which corresponds directly with the self-similarity ratio and the fractal dimension. The larger the increased length due to a decreased step size, the higher the coastline's fractal dimension.

Another equally fascinating aspect of the fractal model is its simulation ability. Based on the Brownian motion model in physics and the self-similarity concept,

FIG. 274. IMAGE OF A FERN ILLUSTRATES THE CONCEPT OF SELF-SIMILARITY. This image exemplifies the derivation of *fractal* from the Latin *fractus*, meaning broken or fractured. Very basically, an object is considered a fractal if any small part of it, when enlarged, resembles the whole graphically or statistically. Created using the MATLAB program.

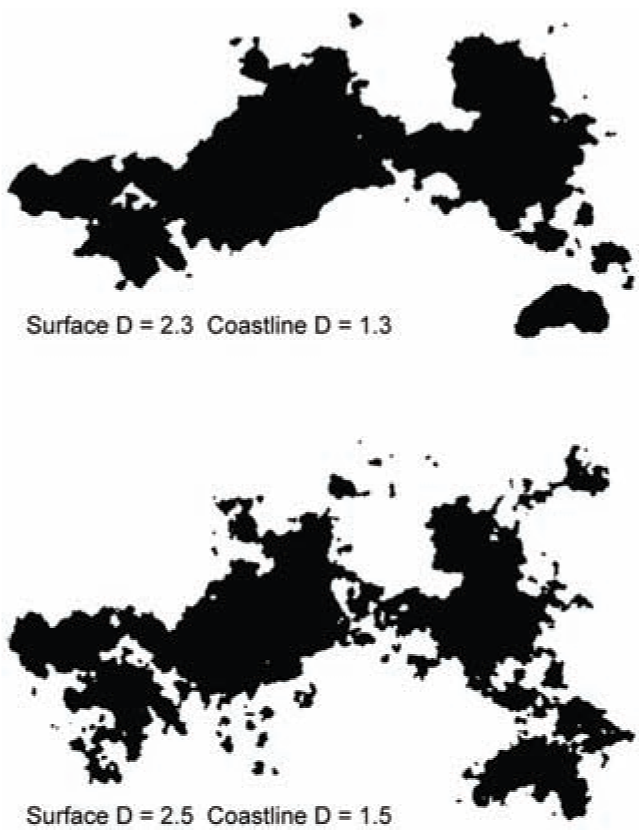

FIG. 275. TWO EXAMPLES OF FRACTIONAL BROWNIAN SURFACES AND COASTLINES. Note that the more complex coastline in the lower example has the higher fractal dimension. Based on Mandelbrot 1983, 267. Copyright © 1977, 1982, 1983 by Benoit B. Mandelbrot. Used by permission of Henry Holt and Company, LLC. All rights reserved.

Mandelbrot derived a general stochastic model for generating curves and surfaces of various dimensions (fig. 275). This simulation ability opened up a new era of computer graphics that has also affected cartography. The graphics generated based on the fractal model, coupled with color and other computer graphics enhancement, have attracted enormous attention and been utilized in famous movies such as the sequels to *Star Wars*, originally released in 1977. Since then, a number of algorithms for generating curves and surfaces have been introduced, including the shear displacement method, the modified Markov method, the inverse Fourier transform method, and the recursive subdivision method, to name a few (Lam and De Cola 1993).

Given its strong applicability to cartography, the fractal model found many early applications in mapping. In fact, cartography was among the first disciplines to employ the fractal model, applications of which fall largely into two categories. The first type of application uses the fractal dimension as an index for describing the complexity of point patterns, curves, and surfaces. In a pioneering article, Michael F. Goodchild (1980) demonstrated that fractal dimension can be used to predict the effects of cartographic generalization and spatial sampling, a finding useful in choosing the appropriate resolution of pixels and polygons for different GIS and remote sensing studies. Many other related application studies followed, such as using the fractal dimension to describe the complexity of coastlines, terrains, shoreline erosion, coral reefs, soil properties, cities, and settlement patterns. Applications of the fractal model have also been extended to the use of remotely sensed imagery in examining changing land cover/land use patterns. By computing the fractal dimension of pixel reflectance values within a series of moving windows, a layer of local fractal dimension values can be created. This additional layer of information has been useful in increasing the accuracy of land use/land cover classification and change detection.

The second type of application focuses on using the fractal model for simulating terrestrial as well as extraterrestrial objects for both analysis and display (fig. 276). The fractal model provides an effective tool for curve and surface generation, which is the inverse of cartographic generalization. Among the cartographic objects that can be simulated are coastlines, terrains, trees, natural landscapes, and city growth. These simulated fractal curves and surfaces have been used as hypothetical test data sets to examine the performance of various cartographic algorithms such as spatial interpolation, terrain analysis, and data structure analysis. In addition, fractal curve generation has been used as an interpolation method and as an inverse of curve generalization by adding more details to the generalized curve (fig. 277). These kinds of applications have made the fractal model a very popular tool, largely because of its visual impact and ability to generate realistic-looking landscapes.

As with any innovative technology, there were major theoretical and technical issues in applying the original fractal model, such as the oversimplified representa-

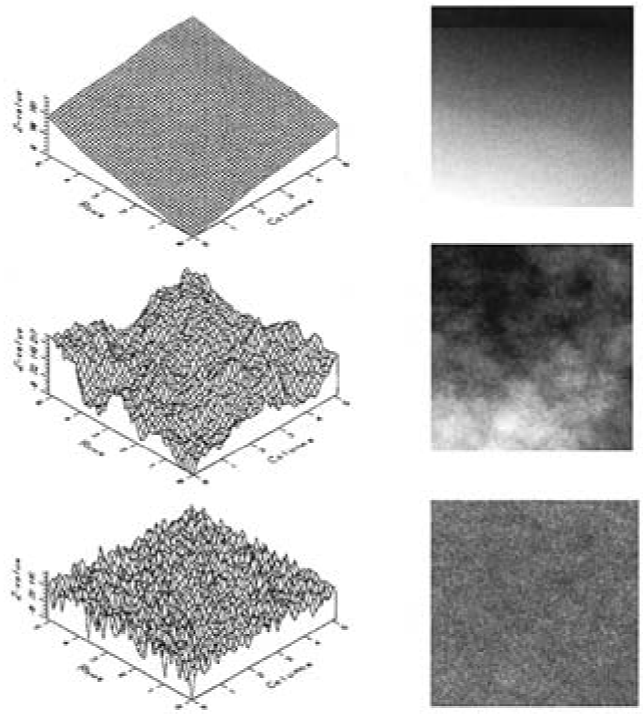

FIG. 276. THREE SIMULATED SURFACES AND CORRESPONDING IMAGES. From top to bottom, $D = 2.1$, 2.5, and 2.9.
From Lam et al. 2002, 28 (fig. 1). Reproduced by permission of Taylor & Francis.

tion of real-world shapes and forms by a single index (fractal dimension) and the different interpretations and algorithms used to derive the dimension by different researchers. Subsequent studies improved the basic fractal model by incorporating various strategies such as the development of multifractals and local fractals and the development of software for fractal calculation and generation. In cartography, the primary impact of fractal representation in the twentieth century was that it linked the field to the wider scientific literature and further reinforces the analytical tradition of cartography.

NINA SIU NGAN LAM

SEE ALSO: Electronic Cartography: (1) Data Structures and the Storage and Retrieval of Spatial Data, (2) Electronic Map Generalization; Mathematics and Cartography; Terrain Analysis and Cartography

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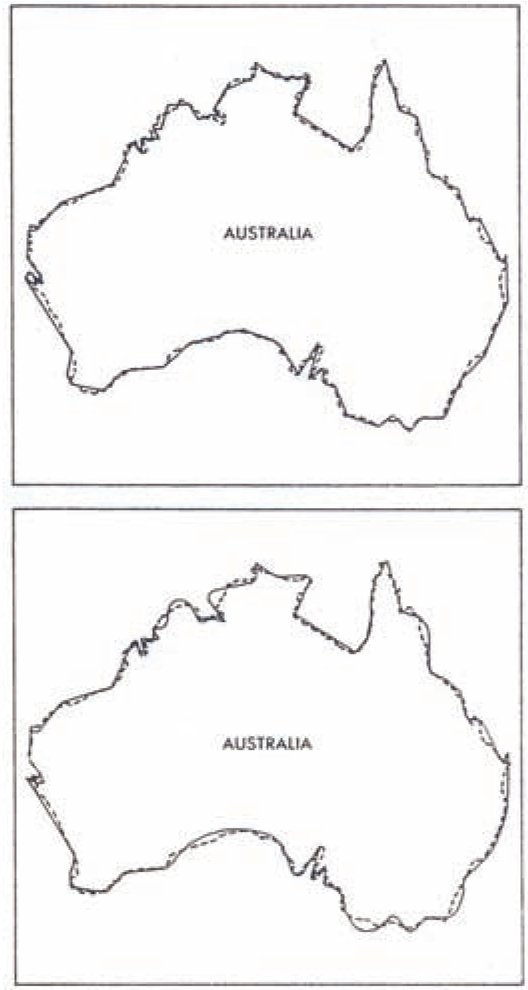

FIG. 277. AUSTRALIAN COASTLINE GENERATED BY FRACTAL METHOD AND CUBIC SPLINE. Better accuracy was achieved using the fractal method (top) than the cubic spline with sixty-four data points (bottom).
Image courtesy of Nina Siu Ngan Lam.

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Peitgen, Heinz-Otto, and Dietmar Saupe, eds. 1988. *The Science of Fractal Images*. New York: Springer-Verlag.

Freytag-Berndt und Artaria KG (Austria). The origin of this map publishing firm dates back to 1878, when it was founded by Gustav Freytag. Unlike the directors of other Viennese map publishers, such as Artaria & Co. or Verlag Ed. Hölzel, Freytag was a trained cartographer. Born in Germany in 1852, he moved to Vienna in 1866 to train as a lithographer in the lithographic firm of his uncle, Friedrich Köke, where the maps for the publishing house Artaria & Co. were produced. After stays in Leipzig and Berlin, Freytag returned to Vienna in 1878 and started a cartographic-lithographic business of his own at age twenty-seven. The outstanding representations of landforms on maps by Freytag soon made them products in demand.

In 1885 the firm's name became G. Freytag & Berndt after Wilhelm Berndt, a businessman born in Bohemia, became involved in the financial side of the firm. At that time the business consisted of a lithographic establishment and a printing and publishing house. After several years the name was changed again to Kartographische Anstalt G. Freytag & Berndt. It flourished impressively and soon achieved a leading position at home, as well as abroad. In the 1890s a sales branch was opened in Leipzig. Subsequently Vienna and Leipzig became the dual publishing locations of the firm. By the end of the Austro-Hungarian monarchy in 1918, the firm had grown into one of the largest map publishing houses of Europe. Its maps depicted numerous regions and countries of the world.

Advertisements in the periodical *Kartographische und Schulgeographische Zeitschrift*, published by Freytag & Berndt, listed a wide range of cartographic products. In 1912, for example, there were maps of political events and military operations predating World War I. Other maps intended for daily use by travelers included railway maps, as well as road maps of Central Europe for cyclists and motorists (more than thirty sheets at the scale of 1:300,000). Tourists could buy reliable hiking maps showing marked hiking routes in parts of the Eastern Alps and Bohemia (published since 1888, mostly at the scale of 1:100,000 but sometimes larger). After 1900 the first ski route maps showing classified ski runs were published.

The atlases offered in 1912 included several pocket atlases. The geographical-statistical *Universal-Taschenatlas* by Anton Leo Hickmann, first published in 1894, became a best seller and was enlarged several times, being republished almost every year. Such pocket atlases contained topographic and thematic maps, as well as tables of applied statistics. They were published first in German, Czech, and Romanian editions, later also in French and English editions. *G. Freytag's Welt-Atlas*, in the same small format, also found many customers and appeared in at least six editions by 1918.

Starting in the 1890s, Freytag & Berndt published a series of school atlases in cooperation with the geography teacher Johann Georg Rothaug. They included atlases for primary schools (*Volksschulen*) and middle schools (*Bürgerschulen*), with numerous editions for special regions, as well as editions in the Czech and Italian languages.

Kartographische und Schulgeographische Zeitschrift advertisements also listed physical (landform) and thematic school wall maps. The physical wall maps, like those of the European part of Russia (1:2,000,000, 1913) and the Balkan Peninsula (1:800,000, 1914), were edited by Johann Georg Rothaug and Hugo Hassinger. The thematic wall maps of Europe (1913) were edited by Rudolf Rothaug. Freytag was responsible for a railway wall map of the Austro-Hungarian monarchy (1:750,000, 1914). Spanish editions of ten school wall maps were produced for export to Latin America.

Other products for the educational market included school globes compiled by Johann Georg Rothaug and first published in 1908. Teaching aids were also produced for foreign educational markets, such as maps and atlases in Bulgarian or in Turkish for schools in the Ottoman Empire. Silent (*stumme*) maps and atlases, so called because they lacked geographical names and descriptive text, could be used in any school, whatever the language of teaching. Three such products were advertised: *Stummer Studienatlas für das Kartenzeichnen* and *Geographischer Zeichenatlas* (twenty-nine maps in a folder) by Johann Georg Rothaug and *Stumme Karten für den geographischen und geschichtlichen Unterricht* by Franz Sobalik.

At the turn of the twentieth century Freytag, who always had devoted himself to the cartographic representation of landforms, created his own special color sequence for hypsometric tints. That sequence was employed in his cartographic establishment for physical maps from 1905 and became typical for such products (fig. 278).

After World War I Freytag retired from the business. The publishing house lost much of its market due to the demise of the Austro-Hungarian monarchy in 1918. In 1920, though, it succeeded in absorbing the cartographic department of the firm Artaria & Co. A splendid business location, still in the city of Vienna, and additional publications added to the firm's prestige. During the period between the two world wars the firm produced popular tourist hiking maps, city maps of Vienna, and pocket and school atlases. From 1921 until the early 1930s the pocket atlases of Hickmann were published by Freytag & Berndt in editions revised by Alois Fischer. *G. Freytag's Welt-Atlas* continued to appear from 1921 until 1932. Hans Kaindlstorfer took over the revision of Rothaug's school atlases, and from the early 1930s onward the publishing house itself became responsible for their further development. After 1932 the first school atlases for secondary schools (*Hauptschulen*, founded in Austria in 1928), were published.

During World War II, in 1940, the firm published an atlas for current affairs, *Atlas zum Zeitgeschehen*. In the same year the firm was renamed Freytag-Berndt und Artaria KG, a name it would retain until 2006.

After World War II the structure of map publishing by the firm altered completely. During the second half of the twentieth century a range of products were developed that continued to typify the work of Freytag-Berndt

FIG. 278. DETAIL FROM *KARTE DER BEZIRKE STADT & LAND SALZBURG UND HALLEIN*, 1918. This map detail, showing mountainous terrain with Gustav Freytag's topographic color scale, comes from a primary school atlas by geography teacher Johann Georg Rothaug that was approved for use in Salzburg schools in 1918.

Size of the entire original: ca. 44.2 × 33.5 cm; size of detail: 16.4 × 33.5 cm. From Johann Georg Rothaug and Karl Adrian, *Heimats-Atlas: Stufengang des ersten geographischen Unterrichts* (Vienna: G. Freytag & Berndt, 1918), 4–5. Courtesy of the T. R. Smith Map Collection, University of Kansas Libraries.

und Artaria KG at the beginning of the twenty-first century.

The branch of the firm that produced school atlases was enlarged in the 1950s, but that trend was reversed in the 1970s. After 1979 only one school atlas, for pupils ten to fourteen years of age, continued to be published.

During the 1960s the publication of tourist maps at 1:100,000 was suspended. They were replaced by hiking maps and leisure maps at 1:25,000 and 1:50,000. At the beginning of the twenty-first century a large variety of hiking and leisure maps for the Eastern Alps in Austria, some regions of neighboring countries (Germany, the Czech Republic, Slovakia, Hungary, and Slovenia), and islands in the Mediterranean Sea (Crete, La Palma, Mallorca, and Tramuntana) were available. Road maps with extensive tourist information were published for numerous European countries (fig. 279); regions of Africa (Egypt, East Africa, and South Africa) and Asia (the Middle East, India, China, Central Asia, Japan, Malaysia, and Thailand); North and South America; Australia; New Zealand; and other areas.

Large-scale city maps and town plans were produced for Vienna, all of the larger towns in Austria, and the capitals of European countries. Small-scale maps of the world (physical and political) were also published. In addition, individual products were created for special customers. Multimedia products and digital data also appeared from the 1990s onward.

Even before the political changes in Europe in 1989, the publishing house maintained contact with neighboring countries in the eastern part of Central Europe. Subsequently commercial relations increased. The firm began by outsourcing some fields of cartographic work to Prague, Bratislava, and Budapest. From the 1990s onward special sales organizations in those cities supplied their local markets with the cartographic products of Freytag-Berndt und Artaria KG. In Germany the publishing house Rother (Munich) also belonged to Freytag-Berndt und Artaria KG. Therefore, at the beginning of the twenty-first century the firm could truly be called an international institution.

INGRID KRETSCHMER

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

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FIG. 279. *AUTO ATLAS: ÖSTERREICH 1:300.000 KARTENTEIL MITTELEUROPA 1:2,000.000* (VIENNA: KARTOGRAPHISCHE ANSTALT FREYTAG-BERNDT U. ARTARIA, 1958). Opening with an index map and an explanation of cartographic signs on the front endpaper, this road atlas of Austria also helps the map user navigate its map contents by means of numbered tabs at the right margins of the pages. Height of page: 27 cm. Courtesy of the T. R. Smith Map Collection, University of Kansas Libraries.

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