# T

***Tactile Map.*** Tactile (or tactual) maps are raised-relief spatial representations that are to visual maps as Braille (a system of tactile writing with raised dots) is to visual text. Tactile maps enable visually impaired people to access geographical information through touch.

The few surviving European tactile maps from the early nineteenth century and before are isolated examples of one-off techniques, such as hand-carved wooden models, embroidered maps, or collages glued onto a backing (Eriksson 1998, 157–74). By the mid-nineteenth century, though, embossing machines developed in both Europe and America could employ engraved plates to emboss multiple copies of tactile paper maps, most often for schools for visually impaired children. Rival systems of tactile writing attracted more attention than tactile maps during the nineteenth century, stimulating controversy that subsided only after Braille became standard in the early 1900s. Embossing was still the method by which a Depression-era WPA (Works Progress Administration) project at the Perkins School for the Blind in Massachusetts reproduced a loose-leaf atlas of 350 tactile historical maps between 1936 and 1938. The primary use of tactile maps remained teaching world and regional geography to visually impaired children.

However, tactile map reproduction experienced another burst of technological innovation in the mid-twentieth century. The first thermoformed (or vacuum formed) maps were produced in Slovenia during the late 1950s. Thermoforming equipment extracted air, creating a vacuum and pulling a heat-softened plastic sheet, usually PVC (polyvinyl chloride, a plastic commercialized in America in the 1920s), onto a master model of a tactile map. Reuse of the master yielded multiple copies in durable plastic of raised relief maps with tactile images having different elevations and textures. During the mid-twentieth century three-dimensional topographic relief models reproduced cheaply in plastic became popular with sighted map readers, but the thermoform process had a more profound effect on tactile mapmaking.

Although institutional publishers had operated embossing equipment successfully, thermoforming enabled individuals to reproduce large numbers of tactile maps relatively cheaply (fig. 926). That led to more dispersed and informal production of tactile maps, still for teaching geography but also increasingly for mobility. Those trends reflected societal changes in post–World War II Europe and America as the popularity of the automobile led to increased mobility, the development of road and street signage, and the distribution of road maps. Achieving comparably independent mobility for visually impaired people required new ways of communicating spatial information. New programs training visually impaired veterans to use guide dogs and long white mobility canes eventually led to university training courses for mobility instructors. Mobility training also spread to schools for visually impaired students, where there was a 1950s influx of children affected by RLF (retrolental fibroplasia, a visual impairment caused by oxygen-fed incubators introduced in the 1940s). Initially, tactile maps with Braille labels seemed the most efficient form of geographical aids for mobility.

During the 1960s academic cartographers, members of an expanding field in postwar Europe and America, initiated serious scientific study of the design and use of maps, both visual and tactile. Mobility and instructional needs of visually impaired students coincided with readily available thermoform technology to arouse interest in tactile maps. Rather than investigating visual perception, tactile map research focused on the nature of visual impairment, especially tactual perception and spatial cognition. In contrast to visual mapping, the mainly sighted cartographers of tactile maps were less likely than users to know which map features to include or how best to represent them. Another difference was that map reading through touch occurs sequentially as fingers encounter raised images and depends upon memory to construct a

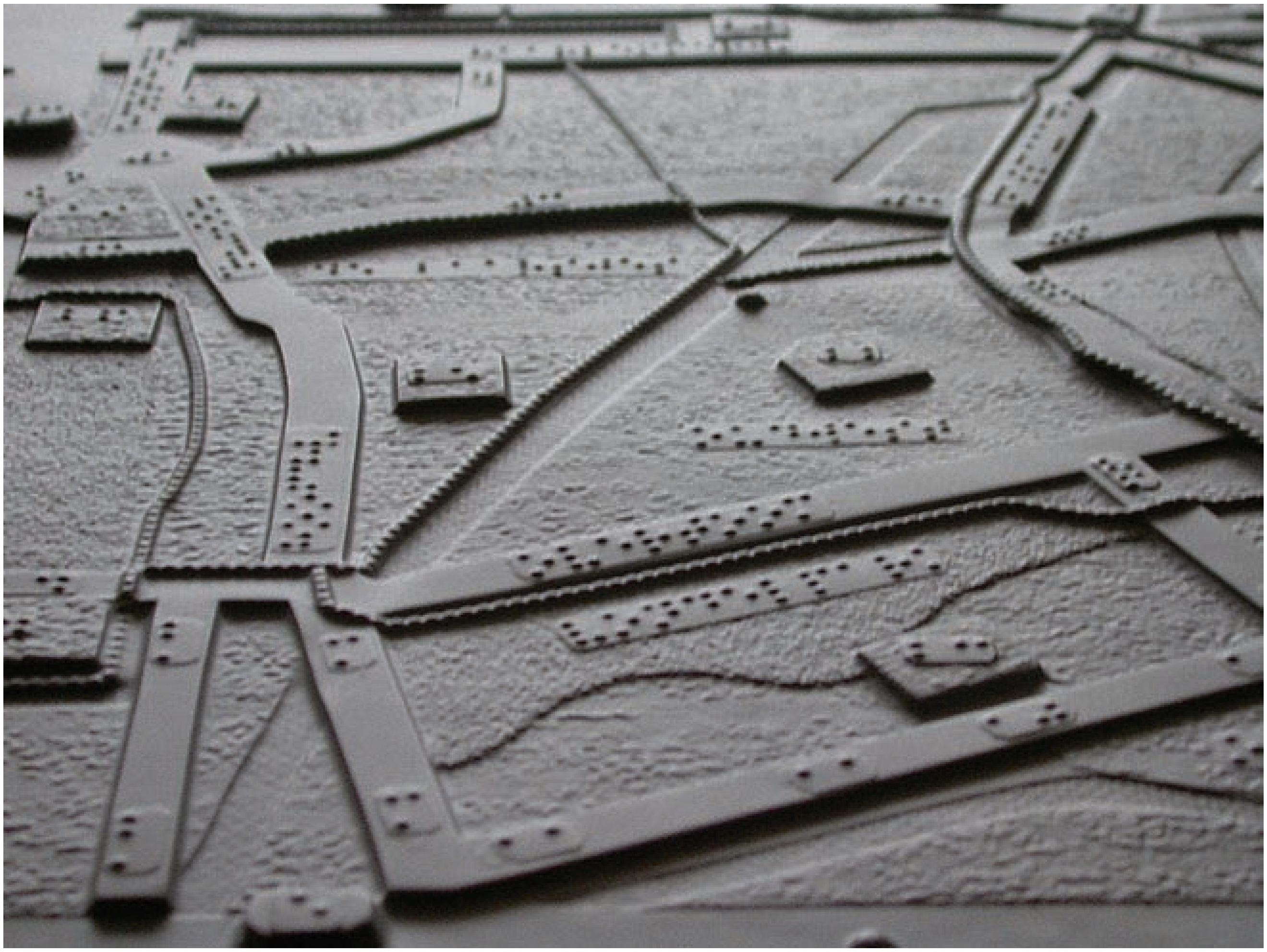

FIG. 926. PORTION OF A LARGE-SCALE THERMOFORMED CITY PLAN OF AMSTERDAM. The map shows major routes, street names, waterways, and points of interest and is part of a ring-bound hardcover atlas with detachable sheets.
Size of each sheet: 30 × 42 cm. From *Thermoform Atlas of Amsterdam* (Nijmegen, Netherlands: Bibliotheek Le Sage ten Broek [1995?]). Image courtesy of Jonathan Rowell.

complete picture (fig. 927). Seeking to underpin design with sound scientific principles, researchers employed experimental methods used in psychology and tested visually impaired participants. Investigations were primarily concerned with defining discriminable symbol sets (Wiedel and Groves 1969) and learning more about map use tasks in the absence of vision (Nolan 1976). Design guidelines for sizing and spacing symbols and Braille labels were established. Kits for making tactile maps introduced in the 1970s promoted widespread consistent use of recommended symbol sets (Edman 1992, 36; Bentzen 1997). They contained an instruction booklet and prefabricated point, line, and area symbols in various materials (molded plastic, profiled wire, and different cloths), enabling designers to build personal thermoform masters within strict design specifications (fig. 928).

The first strategic attempt to disseminate information and best practice was made through the Commission on Tactual and Low Vision Mapping, founded under the auspices of the International Cartographic Association (ICA) in 1984. The commission later regrouped, with slightly broader objectives, as the Commission on Maps and Graphics for Blind and Partially Sighted People.

New techniques for printing raised images, such as foaming ink and microcapsule paper, were introduced in the 1980s. Microcapsule paper (also called swell or capsule paper or, its trade names Minolta or Zy-Tex) was developed in Japan in the early 1980s. Thick paper, suitable for printing or photocopying, was impregnated with temperature-sensitive capsules filled with alcohol. After printing the paper was uniformly subjected to a controlled heat source. Only areas beneath ink deposits

FIG. 927. A CLIENT LOCATES HER DESTINATION BY TOUCH ON THIS DUAL-IMAGE THERMOFORM MAP OF BOSTON AND CAMBRIDGE. Printed on a plastic sheet at the scale of 1:30,480. Map designed by K. Lieneman (Boston: Howe Press of Perkins School for the Blind, [1980?]).
Size of the sheet: 44 × 60 cm. From Billie L. Bentzen, "Orientation Aids," in *Foundations of Orientation and Mobility*, ed. Richard L. Welsh and Bruce B. Blasch (New York: American Foundation for the Blind, 1980), 291–355, esp. 336. Permission courtesy of Billie L. Bentzen.

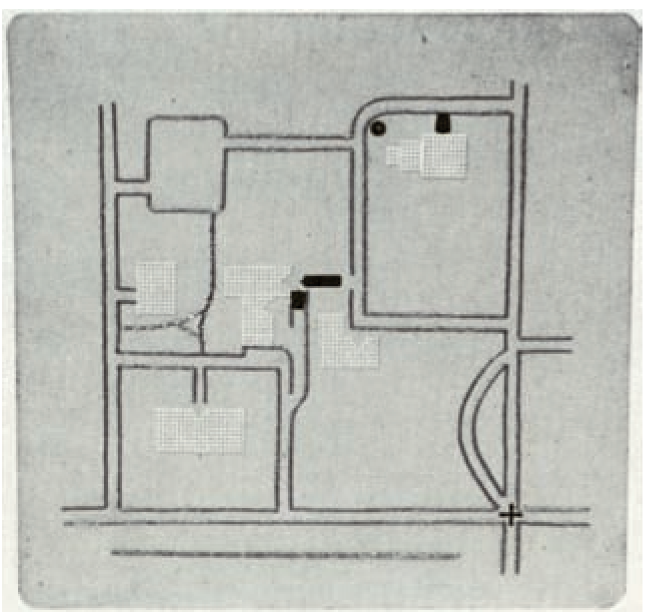

FIG. 928. MAP FROM KIT OF MAPMAKING PARTS (NOTTINGHAM, ENGLAND: BLIND MOBILITY RESEARCH UNIT, [1975?]). A tactile map master created with a kit of mapmaking parts, which includes line and point symbols tested for discriminability.
From Billie L. Bentzen, "Orientation Aids," in *Foundations of Orientation and Mobility*, ed. Richard L. Welsh and Bruce B. Blasch (New York: American Foundation for the Blind, 1980), 291–355, esp. 332. Permission courtesy of Billie L. Bentzen.

reached a critical temperature and burst, thereby raising printed areas permanently in relief and rendering them tactile. Although subject to wear and occasionally difficult to read, the resulting tactile images could be quickly and conveniently designed on a computer.

Computer design and microcapsule reproduction increased the potential reach of tactile maps but made their quality and consistency more difficult to control. Computer-design options were many, but only a small subgroup of symbols was suitable for tactile perception. The wide range of map types and features needing representation far exceeded the suitable tactile symbols and precluded standardization. The more difficult it became to find precise measures upon which to base tactile map design, the less important empirical studies and scientific enquiry became.

Those engaged in the construction of tactile maps increasingly took a practice-led approach, with few attempts to pool information. Although several authors published useful primers, guidelines, instruction manuals (Edman 1992; Bentzen 1997), and even a few empirical studies, academic curiosity about tactile mapping essentially declined during the 1980s.

Tactile maps continued in demand, but the anticipated increase in user numbers did not materialize. Tactile map use remained concentrated in schools and did not become global. Despite some hotspots of tactile activity (e.g., Eastern Europe, Scandinavia, South America), there was no official tactile mapping in large parts of the world, particularly developing nations. One factor may have been generally declining emphasis on tactile information. For example, Braille literacy among visually impaired people dropped in the United States from 50 percent in the 1960s to an estimated 12 percent by 2007 as the trend toward inclusionary education reduced the teaching of Braille in favor of other learning technologies (Brittain 2007).

Research revived in the 1990s but shifted focus from standardizing tactile maps toward experimentation with auditory and haptic (a term encompassing the sensations of movement and force, as well as touch) technologies. Spatial information provided through other senses could supplement or replace tactile maps. One approach involved automatically generated oral descriptions (such as the Nomad, the Talking Tactile Tablet, or the Talking Kiosk) for use alongside standard tactile maps. Another sought to replace fixed tactile graphics with dynamic multimodal devices, such as the haptic mouse, simulating the textures and shapes of the map by combinations of force feedback, vibrotactile sensation, and sound. The computer-animated visual map, a research emphasis of sighted mapping in the 1990s, was challenging the static visual map in a similar way. During the same decade experimentation with replacing mobility maps by real-time oral route instructions using GPS (Global Positioning Systems) electronic wayfinding devices formed an even closer parallel with the development for auditory in-car GPS navigation systems.

JONATHAN ROWELL

SEE ALSO: Harvard Laboratory for Computer Graphics and Spatial Analysis (U.S.); Interpolation; Software: Mapping Software

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***Tanaka, Kitirō.*** Kitirō Tanaka, a Japanese engineer who made significant contributions to the cartographic representation of relief, was born in Kyūshū, Japan in 1895. He graduated from the Kyūshū teikoku daigaku 九州帝国大学 (Kyūshū Imperial University) in 1921. After receiving a doctorate in technology, he was appointed professor at the Kyūshū Imperial University (renamed Kyūshū University in 1947) in 1938, emeritus professor in 1960, and professor at the Kyūshū sangyō daigaku 九州産業大学 (Kyūshū Industrial University) in 1964 (Tanaka 1974). He died in 1973.

After comparing conventional methods for varying brightness on an obliquely illuminated terrain surface, Tanaka derived mathematical formulas that provided a conceptual basis for the systematic representation of relief. He assumed a perfect terrain surface that could reflect received light in any direction and based his relief images on parallel rays of light originating in the northwest and inclined at an angle of 45 degrees to the horizontal. In principle, relative brightness could be calculated for each point on the surface according to its slope and aspect. That is, the relative amount of reflected light toward the viewer varied with the surface's angle of inclination to the horizontal plane at the point as well as with its angle of orientation, or compass direction. To facilitate practical application, Tanaka devised four approaches for creating hill shading from existing contour maps.

In Tanaka's orthographical relief method, also known as the inclined contour method, horizontal contours (i.e., contour lines on an existing topographic map) were transformed to inclined contours, an amalgam of traditional contour lines and vertical relief profiles produced by tracing the surface's intersection with a set of parallel planes. These planes, which faced south, were evenly spaced and inclined at an angle of 45 degrees to the horizontal plane, the same as the illuminating light. The thickness of the inclined contours varied to approximate the degree of illumination and produced an overall impression of relief that was geometrically similar to an orthographic image of the area. Even so, the multiplicity of lines tended to give the map a heavy, cluttered appearance. Inclined contours could be drawn mechanically and precisely by a draftsman without any artistic skill or understanding of the physical landscape (Tanaka 1928–30, 1932).

In Tanaka's relief contour method, also called the illuminated contour method, contour lines were drawn with a flat-point pen held at a fixed orientation representing the horizontal direction of incident light. The horizontal spacing of adjoining contours represented slope at various positions in the terrain, and their varied thickness represented the surface's aspect relative to the direction of the illuminating light. Relief contours were depicted in white along illuminated slopes and in darker color along other slopes, while the intervening horizontal spaces were rendered in a neutral color. The resulting map resembled a vertical photograph of a relief model made by placing cardboard layers one above the other (Tanaka 1950). An application of this method was used for a trial nautical chart in the 1930s (figs. 929 and 930) and then for the *Nihon kinkai shinsenzu (chōsoteki suihei kyokusen zuhō)* 日本近海深浅図 (彫塑的水平曲線図法) = *Depth Curve Chart of the Adjacent Seas of Japan* (*Relief Contour Method*), an official map issued by the Kaijō hoanchō 海上保安庁 (Japan coast guard) in 1952 as hydrographic chart no. 96.

In Tanaka's relief hachure method, hachures (short lines drawn perpendicular to horizontal contours) varied in thickness, separation, and coloring according to the principles underlying his relief contour method. Tanaka's relief hachure and altitude tint method added hypsometric coloring to the relief hachures to portray relative differences in elevation (Tanaka 1974).

Tanaka's approach of first discerning underlying principles from a close examination of existing examples of hill shading and then developing practical methods for their application reflects a strategy that came to be known as reverse engineering. Because his methods of relief representation were amenable to numerical com-


FIG. 929. *SUKUMO-WAN TŌSHINKYOKUSEN ZU* 宿毛湾等深曲線圖 (DEPTH CURVE CHART FOR SUKUMO HARBOR AND VICINITY), 1939. One of the two trial sheets to publicize Tanaka's relief contour method. Red borders on the top and bottom indicate the chart was secret at one time. The left side is the traditional nautical chart; the right side shaded blue shows the submarine topography in the relief contour method. See figure 930.
Size of the original: 54 × 77 cm. Image courtesy of the Kaijō hoanchō.

puting, Tanaka's work not only informed the development of automated relief representation in the latter half of the twentieth century but also provided a pedagogic device useful in understanding slope, aspect, and hill shading (Kennelly 2002).

KEI KANAZAWA

SEE ALSO: Airbrush; Oblique and Perspective Views; Relief Depiction: Relief Shading; Terrain Analysis and Cartography

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***Tax Map.*** The context for the modern tax (or assessment) map is the fiscal cadastre, defined as "a cadastre compiled for purposes of taxation" of land or property

FIG. 930. DETAIL OF SUKUMO HARBOR CHART, 1939. The contour intervals are at two, five, ten, twenty, and thirty meters.
Size of detail: 17.6 × 14.1 cm. Image courtesy of the Kaijō hoanchō.

(Dale 1976, xxi). The Napoleonic national parcel-based fiscal cadastre, begun in 1807 and influential far beyond France and its possessions, is the best-known model. It was administered by the central government to serve the state. Its principal components were the maps produced from systematic cadastral surveys (though boundaries were not demarcated); the registers containing parcel numbers, area, land use, and land value; and detailed instructions.

With few exceptions the fiscal cadastre was largely unknown in North America until the last quarter of the twentieth century. Nevertheless, property in North America was assessed for municipal taxation purposes for more than 200 years. The tax map played a significant but far from universal role. It was defined as "a map drawn to scale and delineated for lot lines or property lines or both, with dimensions or areas and identifying numbers, letters, or names for all delineated lots or parcels" (National Association of Assessing Officers 1937, 2–3). The immediate functions of the tax map were to promote the discovery, recording, and description of properties and to facilitate valuation. Other uses were collecting taxes; searching deeds and identifying defects in title; and planning or managing housing, parks and forests, and public works. The tax map complemented a register of properties from which an assessment roll was produced. Although tax maps in the United States were considered "a primary requisite to [the] effective assessment of real property," in 1937 "a substantial portion of the 25,000 assessment districts [were] operating without this indispensable equipment" (National Association of Assessing Officers 1937, 1).

Constructing the twentieth-century tax map required one or more of the following methods: new cadastral or aerial surveys; reference to existing cadastral surveys, base maps, building registers, and other maps; compilation using legal descriptions held in a land registry or cadastre office; and the use of existing cadastral index maps (fig. 931). Cadastral surveys were made of individual parcels and subdivisions to support a land registration system based on deeds or titles, and in many European countries they supported development of a systematic cadastral map. The U.S. Public Land Survey System of the western states and the Dominion Land Survey of western Canada were important sources of parcel information for creating tax maps. New cadastral surveys undertaken exclusively for producing tax maps were generally confined to densely settled urban areas containing small lots of high value. Aerial surveys were

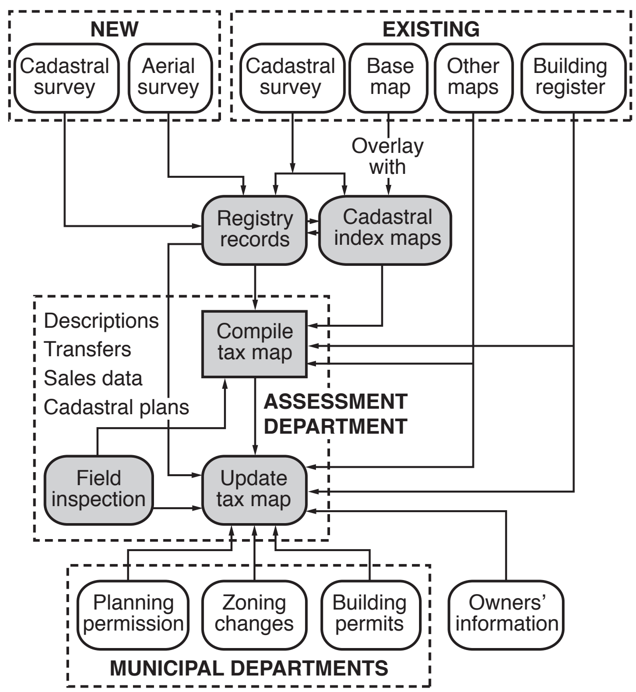


FIG. 931. GENERALIZED MODEL FOR CONSTRUCTION AND MAINTENANCE OF A TAX MAP.
Courtesy of Gerald McGrath.

recognized by the early 1930s as suitable for tax mapping. Controlled photomosaics were created for property surveys in 1935 by the Tennessee Valley Authority (National Association of Assessing Officers 1937). By 1978 photogrammetry was well established in the United States as the "usual way to make planimetric maps" (International Association of Assessing Officers 1978, 326), on which the tax parcel fabric was superimposed. Photogrammetric products used as a base for tax mapping included enlarged unrectified photographs; rectified photographs; photomosaics; photogrammetric line maps, originally in analog format and digital from about 1975; and orthophotographs (Hutchinson 1975). Existing planimetric or topographic base maps were also used in preparing tax maps. Illustrations from the United States include map products of the Geological Survey, the Coast and Geodetic Survey, the Department of Agriculture, and the Army Corps of Engineers. Cadastral index maps maintained in some land registration systems were of considerable value in compiling tax maps. In countries with systematic national cadastres such as Denmark, the Netherlands, and Sweden, the cadastral index maps were also used for property tax purposes. Until 1980 cadastral index maps were in hard copy format. The creation of digital cadastral databases brought into focus issues of duplicated effort in constructing maps, the cost of duplication, the need for coordination, relationships between the parcels recorded on cadastral maps and tax maps (were they identical?), and inconsistencies in data.

Most property tax systems relied heavily on the land registry or recorder's office for information on parcel ownership and descriptions, transfers of parcels, property sales, and cadastral plans. Such information was invaluable in creating tax maps. Updating them was helped by automatic advice on changes to parcels and parcel ownership received from the land registry. This dependency occurred in eleven of fourteen countries in a survey of property taxation (Youngman and Malme 1994). Other maps widely used in constructing tax maps included land value and zoning maps, particularly in urban areas, and maps of soils, soil fertility, land potential, and land use in rural areas. The recording of land use was reported in an inventory for Europe, parts of Canada, and the Commonwealth of Independent States (comprising some of the member states of the former Soviet Union) (HM Land Registry 2001). Keeping the tax map and its associated registers up-to-date as a basis for cyclic property assessments was a challenge throughout the century. In addition to the land registry, tax authorities relied on various municipal departments for information on development plan approvals, zoning changes, and building permits for new construction (Dale and McLaughlin 1988). Field inspections remained an integral part of producing and maintaining tax maps.

Property assessment organizations developed detailed specifications for tax maps. The most significant factors were the basis on which property or land tax was imposed; the existence of a well-organized land registry system; and the availability of a separate building register, as in Denmark and Norway. Typically the specifications defined map scales and sheet dimensions that reflected the sizes, values, and density of properties as well as the content and methods of depiction. For example, the New York State Rules for Real Property Tax Administration specified how base maps should be created by photogrammetry and at what scales (1:600, 1:1,200, 1:2,400, and 1:4,800). The detail required for each property on sectional maps included parcel boundaries; linear dimensions, street frontage, and, where greater than one acre, the computed area; tax map land parcel number; and a coordinate-locator number for the center of each parcel. Roads, streets, railroads, utility rights-of-way, and bodies of water were also noted. Drafting material and index maps were specified, as was the supporting information to be kept and maintained by the local assessment department.

Legislation governing property assessment and tax maps was the responsibility of the central government or, in a federal system, of the state, province, or canton. In some cases the administration of property assessment rested with a central government organization such as the valuer-general in each Australian state. County or municipal governments were responsible in most U.S. states (Youngman and Malme 1994). Municipalities were also responsible for administration in the Netherlands, though the necessary work could be undertaken in-house or contracted to the private sector.

Apart from the functions and uses of tax maps identified earlier, municipal departments for planning, building, building inspection, and administration of municipal property were also frequent users. Where the system of land registration functioned without cadastral maps and tax maps were available for public inspection, the latter were indispensable in property transactions though not legally binding. Users thus included private citizens, developers, real estate agents, surveyors, lawyers, banks, mortgage companies, and insurance companies. Depending on the method of construction and geometric quality, tax maps were acceptable alternatives to cadastral maps for some uses by the central government and public utilities (Dale 1976). Environmental assessment, monitoring, and management were added later as they became important at all levels of governance.

Following initiatives in Sweden, the 1970s witnessed intensive exploration and development of the concept of a multipurpose cadastre (Dale 1976). One objective was to integrate the records of legal rights, the fiscal assessment records and tax maps, and land use and land capability records (Wunderlich 1975). New Zealand reflected this approach in its decision to implement the first phase of a nationwide parcel-based land information system with core legal and fiscal cadastral data (Hawkey 1983). Richard E. Dahlberg (1984) noted at the time that most U.S. rural counties faced a practical difficulty insofar as parcel (tax) maps were not tied to a coordinate system that would permit easy linkage to natural resource or environmental data.

However, numerous counties and municipalities in the United States built land information systems with the tax map as the cadastral layer (Dueker and Kjerne 1988). Lane County in Oregon is an example. A mapping software system was developed locally in the early 1970s by the planning department. Capture of tax lot parcels in Eugene was completed in 1974, and for the remainder of the county in 1977. A data maintenance system and address file were implemented. Conversion

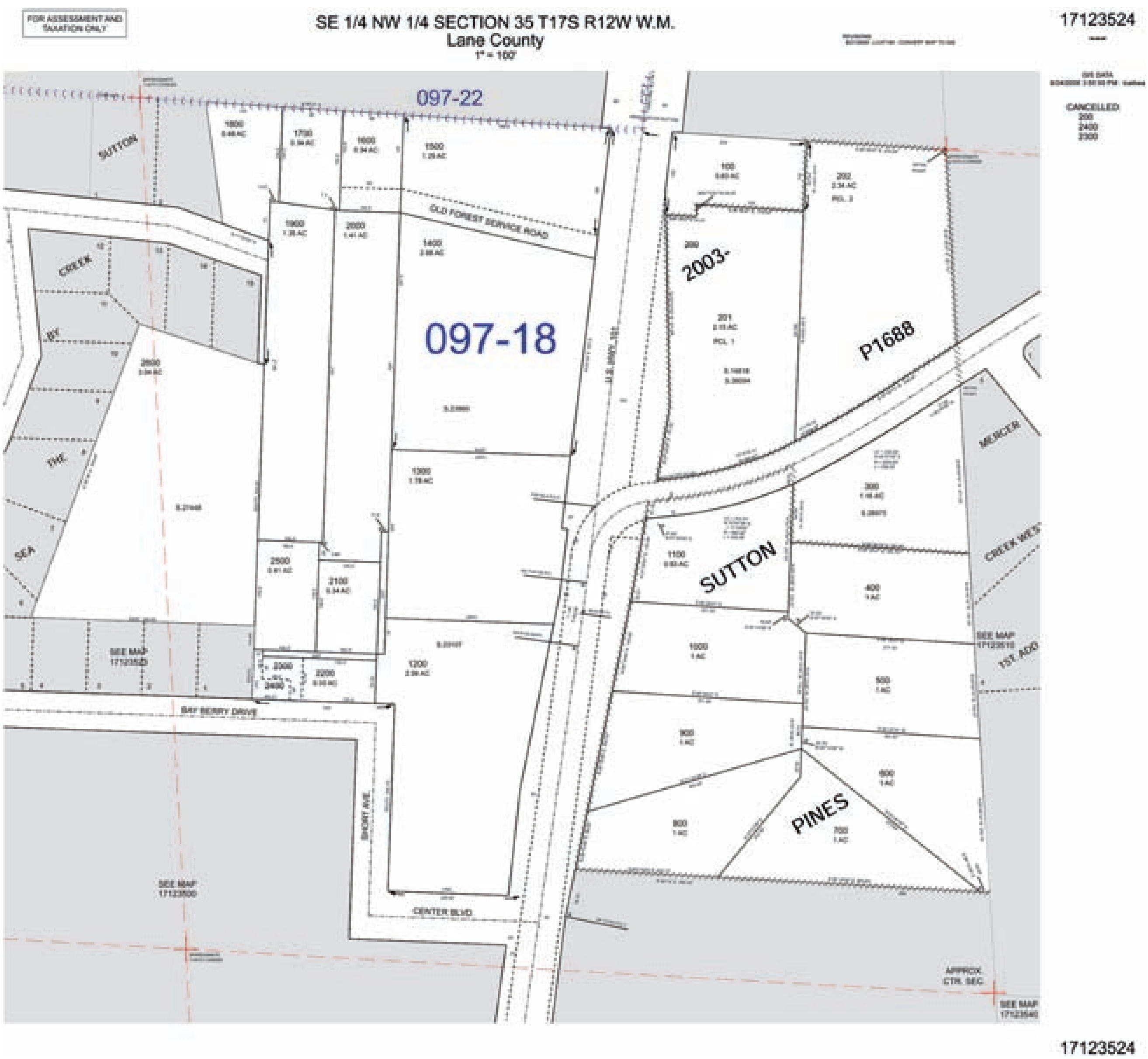


FIG. 932. TAX MAP OF LANE COUNTY, OREGON.

Image courtesy of the Lane County Department of Assessment and Taxation Cartographic Section, Eugene.

to improved geographic information system (GIS) and geographic database software was begun in 1985 with a new emphasis on public works and utility requirements. Personal computer–based GIS software was introduced in the 1990s. In 2002 the three-year Parcel Mapping Project was begun to convert the existing tax maps, and supporting survey and assessment data, into a complete and accurate tax lot parcel layer that would meet the enhanced positional standards of the Oregon Department of Revenue (fig. 932).

Computer-assisted mass appraisal (CAMA) techniques and modular software were being developed by the end of the 1980s to combine a variety of inputs so that market-value property assessments could be made more rapidly. The inputs included property data; recognized appraisal techniques such as income, sales comparison, and cost; comparisons with recent sales data; and statistical methods such as multiple regression analysis. The property data could include location, site characteristics, and data on improvements such as living area, year built, quality of construction, and condition. CAMA was adopted by many jurisdictions in the United States, Canada, and beyond. The next step was to integrate CAMA databases with the tax parcel layer in a GIS so that data could be exchanged in either direction and the analytical and modeling power of a GIS could be used in property assessment applications. A pilot project in Oklahoma developed a prototype data communication protocol as well as a unique parcel identifier common to both CAMA and GIS (Curry et al. 1990). Subsequent software development by numerous vendors refined and advanced the integration of CAMA and GIS.

Electronic government (also called e-government) originated about the end of the twentieth century as a movement to deliver public services more effectively using the Internet and other digital technology. Since GIS was being used increasingly to link, match, and combine property assessment data with other data sets using a tax parcel and its street address as the common identifier, parcel location became a form of personal identifier. Thus governments faced significant issues of defining personal data, developing a privacy policy and protocols to protect personal data, arranging secure access to online data and related transactions, and ensuring that user fees charged for online access would not discourage use. Efforts to address these issues continue.

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SEE ALSO: Administrative Cartography; Cadastral Map; Privacy; Public Access to Cartographic Information

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## *Television and Maps.*

Maps have been a part of television since its beginnings in the 1940s (Monmonier 1989, 203–5). The width/height ratio (4:3) of the convex television screen and its relatively low resolution imposed severe design limitations, but television could not only reach large audiences but also deliver animated displays and illustrate breaking news with timely maps. In most cases these maps were presented with a voiceover of an interpreter. Television forms a unique map viewing environment in which producers control the choice, design, timing, and duration of map presentations. Viewers have received these maps in varied environments, from very small to large screens, from total darkness to bright sunlight, and in private and public spaces, as well as in both color and black and white.

Access to television has been limited by governments and economic factors. By the end of the century, television was almost ubiquitous, but in many countries the government still controlled both content and access. Three incompatible systems had been developed for transmitting and displaying televised broadcasts, and receivers intended for one system did not work with the others. Each country adopted one of these standards, which limited the exchange of content. Ultimately, converters were developed so that programming could be shared worldwide. Satellite transmission further facilitated conversion and sharing.

Because programming was local and maps could appear and disappear in seconds, television maps were difficult to study until video recording became available in the late 1970s. Patricia Suzanne Caldwell, who carried out the first systematic study of maps on television (1979), observed that "distinctions and proportions in size, color, type, symbols, must all be exaggerated with the knowledge that their impression will be altered by the medium" (1981, 387). Her guidance on map design for television had little impact on the training of cartographers, however, and the television industry continued to use graphic artists to hurriedly produce maps and graphics that would be shown for only two to twenty seconds. Yet, even in the medium's earliest years some television weathercasters presented effective maps, often drawing them by hand on the air (Henson 2010, 86–89). Although cartographers had little influence on television maps, they studied television as arguably the medium whereby the greatest number of maps was seen by the largest number of viewers (Caldwell 1981, 382; Carter 1998, 18; Monmonier 1989, 203–22).

In the 1980s computer graphics were incorporated into television production and influenced the presentation of maps. This technology depended on a presentation of maps and satellite imagery prepared beforehand. Using chroma key, a presenter stood in front of a blank wall and interacted with maps running on the graphics system, while viewers saw the presenter standing in front of the maps. This technology has been particularly important in weathercasting. Because of competition for air time with other news stories, the time allocated for such presentations was often cut significantly minutes before going on air, thereby blunting the effectiveness of well-prepared maps (Carter 1998, 27).

Computer graphics technology has fostered in-house mapmaking as well as outsourcing. Software designed for television graphics helped presenters build their own presentations in the studio, but they could also be assembled from maps transmitted from an off-site specialty firm. Because many of these software developers and outside graphics firms had a good understanding of cartographic issues as well as access to superior resources, including satellite imagery, the quality and complexity of televised maps improved significantly.

The Weather Channel first appeared on American cable in 1982. Its focus was weather maps, twenty-four hours a day, seven days a week, and it soon became very popular. Because of fixed programming formats, viewers knew what types of maps to expect at specific times—"local on the eights"—and maps were not cut short by competition from other stories. Such presentations represent a unique map viewing environment in which familiar persons delivered new content in a familiar cartographic format (Carter 1998). The Weather Channel has employed focus groups for viewer feedback on map design and presentation.

Networks with international coverage, such as BBC and CNN, included weather segments with maps, but their content has been relatively basic. Local, regional, and national weather presentations with maps (see figs. 1126 and 1127) with great variation in the quality and content of the graphics have been part of television since its beginning in some countries.

By the end of the twentieth century, maps were often used to enhance news stories, particularly coverage of war and terrorism, natural and technological disasters, and elections. Television also broadcasts advisories and warnings about traffic congestion and severe weather, and many of these broadcasts employ maps. In the United States, television coverage of presidential elections commonly used choropleth maps on which states voting Republican were colored red and those voting Democrat were colored blue. Because of these maps the terms "red state" and "blue state" became part of the national vocabulary.

With the proliferation of narrowly focused cable channels in the 1990s, maps were employed to narrate or enhance stories in historical, scientific, environmental, travel, recreational, and educational programming (fig. 933). Television programs have also focused on maps or mapping, including the historical development and impact of cartographic technology. A large public


FIG. 933. ANIMATED TELEVISION MAP OF SOUTHEAST ASIA. Map showing the movement of troops from the north to the south during the Vietnam War. The map is from the CNN series Cold War, shown in 1998. In twelve seconds the base map was introduced and the arrow starting in the north extended south into this final image. This relatively simple map used to supplement a television program is representative of many television maps in the late twentieth century.
Image courtesy of James R. Carter.

has seen maps used with various degrees of effectiveness in television programming, sometimes to warn persons of impending danger, sometimes to explain an event, sometimes to help sell a product, and sometimes to express humor. Maps have become a small but essential part of the television industry.

JAMES R. CARTER

SEE ALSO: Chroma Key; Journalistic Cartography; Weather Channel, The (U.S.); Weather Map

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***Terrain Analysis and Cartography.*** The development of terrain analysis during the twentieth century was dominated by the needs of the military. However, the associated cartographic legacy reflects the growing importance of terrain to civilian applications, particularly during the postwar period, when terrain analysis became a vital component of land resource assessment, recreational planning, agricultural land capability assessments, and civil engineering projects.

Throughout the century there was little consensus as to what constituted terrain analysis. To the military mind, terrain analysis was "the process of interpreting a geographical area to determine the effect of the natural and man-made features on military operations" (Whitmore 1960, 375, quoting the *Dictionary of United States Army Terms*, 1953). To civilians, terrain analysis was simply one component of a wider field. Geographer Colin W. Mitchell (1973) defined terrain as the "expression of the geological character, the soil, and the surface geometry of the earth's crust" (13) and analysis as the "simplification of the complex phenomenon which is the natural geographic environment" (5). Classification and appraisal were viewed as distinct processes that, when added to analysis, formed what he termed terrain evaluation.

Much terrain analysis was conducted using standard topographic maps, which were originally geared to support this role. This review will therefore concentrate on those products that were the result of terrain analysis as distinct from the standard topographic, land use, soil, and geological maps and diagrams.

An intimate knowledge of the terrain was an established prerequisite for victory on the battlefield. The analysis of terrain combined with a detailed knowledge of the location of settlement, communication links, and climate were all critical to the military commander.

Peter Doyle and Matthew Bennett (1997, 1) maintain that World War I was "one of the first modern conflicts in which terrain analysis played a significant role, helping to determine not only the character, but also the outcome of many of the most important battles." Terrain analysis was of vital importance for the safe movement of troops as well as identifying the prime positions for observing the enemy. Topographic maps were used in conjunction with solid terrain models to brief personnel on the nature of the terrain to be crossed (Chasseaud 1990). Commanders also needed to know how surface conditions might change during prolonged periods of rain, drought, or frost. Consequently, knowledge of geology and hydrology as well as reliable meteorological forecasts were also vital. Assessment and subsequent mapping of ground suitability for engineering works for defensive constructions and offensive mining operations were also necessary. Geological analysis provided important information on the availability of a water supply and the location of aggregates for construction.

Surveys completed by the field companies of the United Kingdom Royal Engineers at scales of 1:10,000 and 1:20,000 provided suitable base maps for geological and water supply maps (Winterbotham 1919). The Tank Corps prepared ground suitability maps for the movement of tanks using local information and the dugout suitability maps prepared by the Royal Engineers (Doyle and Bennett 1997, 10). A series of annotated geological maps showing ground suitable for construction of dugouts, concrete emplacements, and trench positions was also published for the whole front (King 1919, 203–4). German geologists conducted terrain classification for troop and vehicle movements, locations for well borings, and tunneling for underground warfare. By 1918, the French Service géographique de l'armée had drafted tank maps that identified the surface conditions of potential battlegrounds as dictated by soil types. Terrain appreciation maps for parts of the Western Front were published by geologists assigned to the U.S. Expeditionary Force for use at corps level (Bryan 1920). The geologic maps for terrain analysis prepared by the U.S. forces, termed engineering geologic maps (at 1:50,000), covered areas that extended far beyond the front line and provided the physical conditions and constraints for construction of fieldworks.

Terrain analysis established itself as an essential and permanent military tool during World War II. Assessment of terrain suitability for military transport and armored vehicle access became an essential element of military intelligence. Special trafficability maps, known as Goings maps, were introduced to supplement normal topographic mapping. The output from terrain analysis for military applications usually took the form of intelligence reports accompanied by specially prepared maps. These reports were written in a form understandable to personnel trained purely in military tactics who, being pressed for time, wished to digest as little text as possible. Great emphasis was placed on maps combined with tabular notes of explanatory text.

German use of terrain analysis during World War II is well documented. German geographers and geologists contributed to the production of intelligence handbooks and maps to support military and governmental agencies. In the summer of 1940, specialist maps were prepared for Operation Sealion, the planned amphibious assault on southeast England (Rose and Willig 2004). British Ordnance Survey topographical maps acted as base maps for data on quarry sites for construction materials, coastal geomorphology, groundwater supply, and off-road trafficability.

Specialists in three major German intelligence organizations conducted terrain analysis: Mil-Geo in the army, Mar-Geo in the navy, and the Forschungsstaffel zu besonderer Verwendung of the Oberkommando der Wehrmacht (OKW) (Smith and Black 1946, 398–403). Mil-Geo published handbooks and small-scale maps that described the natural and cultural landscapes of all areas in which the Nazis planned to operate. Mar-Geo was established in about 1942 to focus on the problems of coastal defense. Nautical-geographical maps were prepared of selected coastal areas to show details of landforms and underwater conditions together with beach width and composition. The Forschungsstaffel was equipped to conduct both ground and air survey and undertake ground reconnaissance. It also benefited from having a blend of experts from complementary disciplines such as geography, geology, ecology, hydrography, and soil science, as well as specialists skilled in cartography and photogrammetry. Its first assignment resulted in a three-volume atlas of maps at 1:200,000 of geology, water supply, and Goings of the central Libyan Desert. Terrain evaluation maps (*Geländebeurteilungskarten*) were published at scales ranging from 1:50,000 to 1:500,000 with terrain evaluation data overprinted on existing topographic maps. Both the natural description and the military evaluation of the terrain were shown using elaborate color symbolization. The maps have been described as complicated but very readable, especially those produced for mobile armored units (Smith and Black 1946, 402).

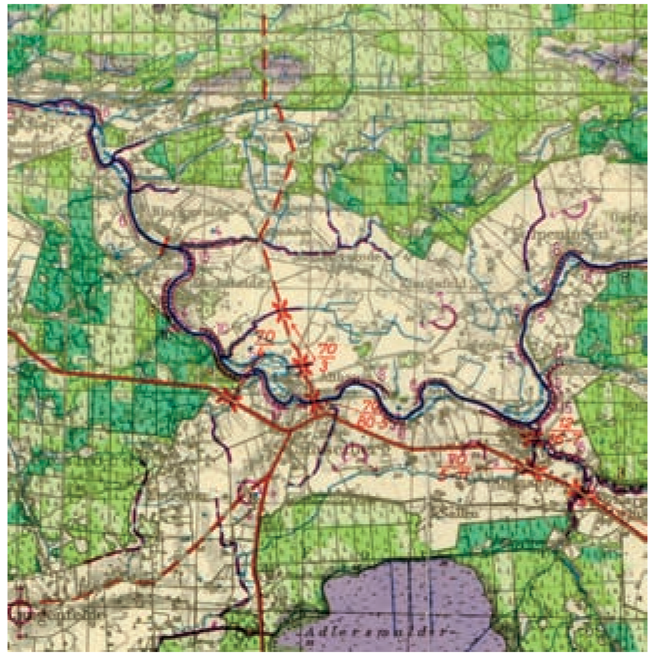

FIG. 934. DETAIL FROM A TERRAIN EVALUATION MAP (*GELÄNDEBEURTEILUNG*) FOR ARMORED VEHICLES, NOVEMBER 1944. Published by the Forschungsstaffel for the OKW at 1:100,000 scale. The Forschungsstaffel compiled the map by interpreting aerial photography combined with information supplied by the Wehrgeologenstelle. A remarkable amount of detailed information was provided including ground suitability (shades of purple), forest density (shades of green), and bridge weight limits (red text and line symbols). Furthermore, important viewpoints with their field of view (purple point symbols) and slope gradients deemed unsuitable for armored vehicles (purple line symbols) were also shown.
Size of detail: 12.1 × 11.9 cm. Image courtesy of Alastair W. Pearson.

Figure 934 demonstrates the sophistication with which the German army represented terrain. Published in November 1944 during the latter stages of the German resistance to the Red Army on the Eastern Front, maps of such high quality were still being produced by the German army even when the military situation had become desperate.

The interwar period witnessed a running down of Allied intelligence services to such an extent that military operations were conducted with a paucity of terrain information. Geographer W. G. V. Balchin (1987, 169) recalled that soon after the outbreak of hostilities, Baedeker's *Scandinavia* (revised 1912) was all that was available to pilots of British Bomber Command for operations in southern Norway.

The need for sound and up-to-date terrain intelligence to support operations was recognized by British Rear-Admiral John Henry Godfrey, director of Naval Intelligence. Godfrey requested that the School of Geography at the University of Oxford prepare a number of confidential reports on Norway, Finland, the Soviet Union, and various other locations of strategic importance. One impact of these reports was the forming of Naval Intelligence Department 6 (NID 6), in May 1940, which later moved to Oxford in the autumn of 1940 to be known as the Inter-Service Topographical Division (ISTD). ISTD's primary task was to conduct terrain analysis in support of Allied military operations in almost all theaters of the war. The work of this unit was largely unknown until recent research revealed how it contributed significantly to the development of terrain analysis as a major postwar discipline (Rose and Clatworthy 2008).

ISTD's cartographic contribution included the provision of supplementary topographical information to published topographic maps. For example, the sheets of North Africa published by the Service géographique de l'armée at 1:500,000 were overprinted with supplementary land cover symbols in red that included "Swamp and water obstacles," "Scrub-covered areas," "Sand-dune areas," "Vineyards," and "Approximate boundaries between flat areas and less regular country." Text annotations provided information for trafficability (or Goings) over that particular piece of terrain (fig. 935), for example, "Salt-marsh area, dry in summer, but going is treacherous and reconnaissance necessary." Not all annotations were as useful to the commander. Areas described as "Formerly pasture for nomads' cattle" and "Monotonous country" were of questionable tactical value.

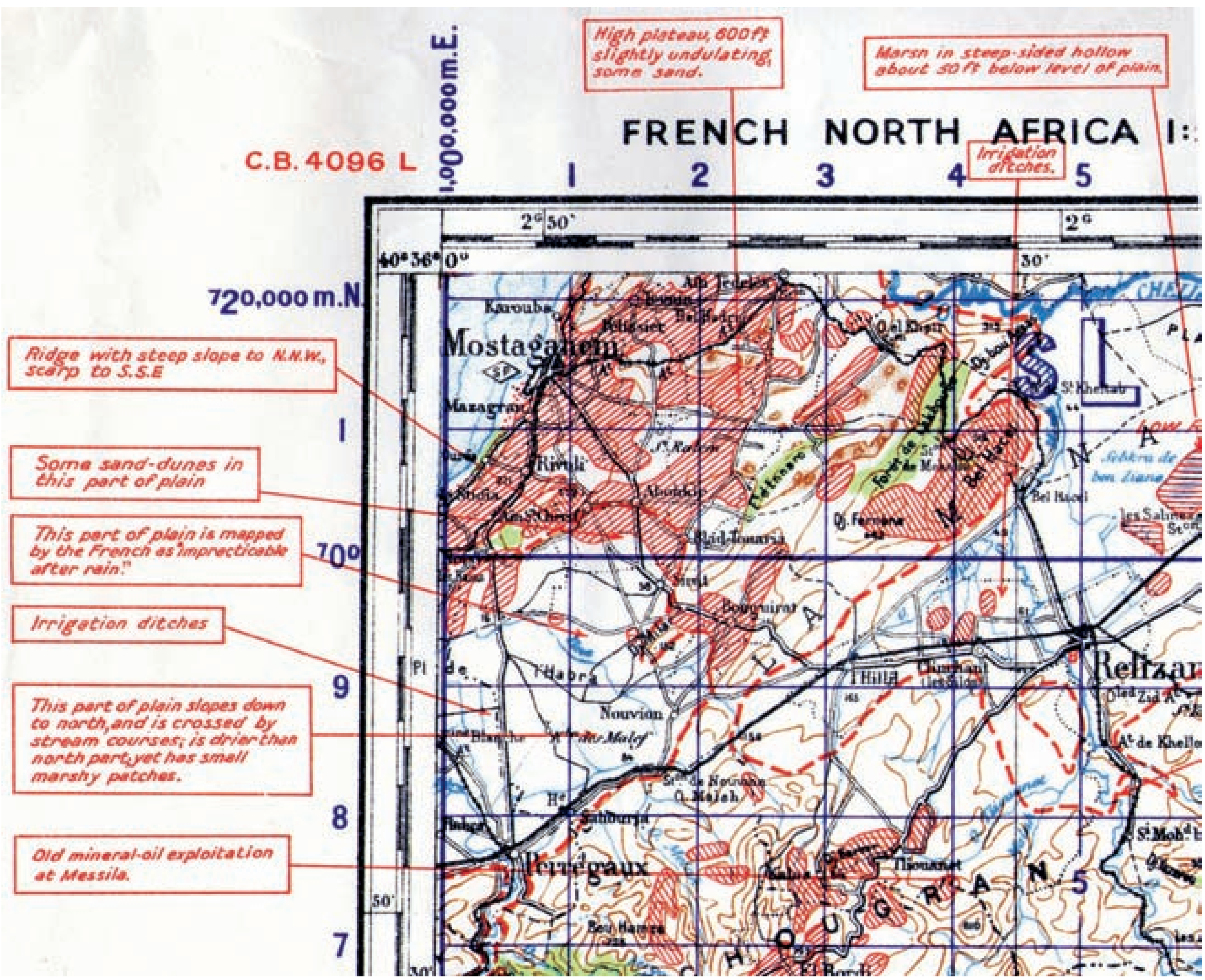


FIG. 935. DETAIL FROM THE *MASCARA* SHEET (NI 31-NW) PUBLISHED IN AUGUST 1942. Size of detail: 15.1 × 18.6 cm. Image courtesy of Alastair W. Pearson.

The British Army was also heavily involved in the production of maps based on the air photo interpretation of terrain. The Goings overprints were prepared at various scales to assist in the movement of both wheeled and tracked military transport and armored vehicles during military campaigns. Though not as sophisticated as the equivalents produced by the German army, Goings maps provided terrain analysis data in an easily readable form using a minimum of extra cartographic work. The maps illustrated lines of approach and natural obstacles based on interpretation of air photographs (fig. 936). The colored Goings information was overprinted on specially designed topographic base maps, often printed in monochrome. Typically, the overprint colors followed the convention established during operations in the Middle East with good or easy going in red, fair going in yellow, difficult going in green, and impassable in blue. Metalled roads were shown as solid or dashed red lines depending on their width. Natural obstacles for vehicles and infantry were also shown, but constructed defenses were depicted on an accompanying defenses overprint. Text annotations explained the land cover using descriptive terms such as “rock,” “scrub,” “terrace cultivation,” and “scattered trees.” As the annotated information was often derived from photographs only, the map represented the going for the weather conditions present at the time of photography. Areas classed as easy and fair going could be rendered impassable for considerable periods of time after rain. Warnings to this effect were printed in the legend.

When the United States entered the war, it quickly became apparent to the chief of engineers of the U.S. Army that the army was in no position to conduct terrain analysis in support of military operations. The Corps of Engineers simply did not have the resources to create its own section. However, meetings between representatives of the Corps of Engineers and the chief geologist of the U.S. Geological Survey (USGS) led to the establishment of the Military Geology Unit (MGU) in June 1942. The unit operated as part of the USGS (which in turn was

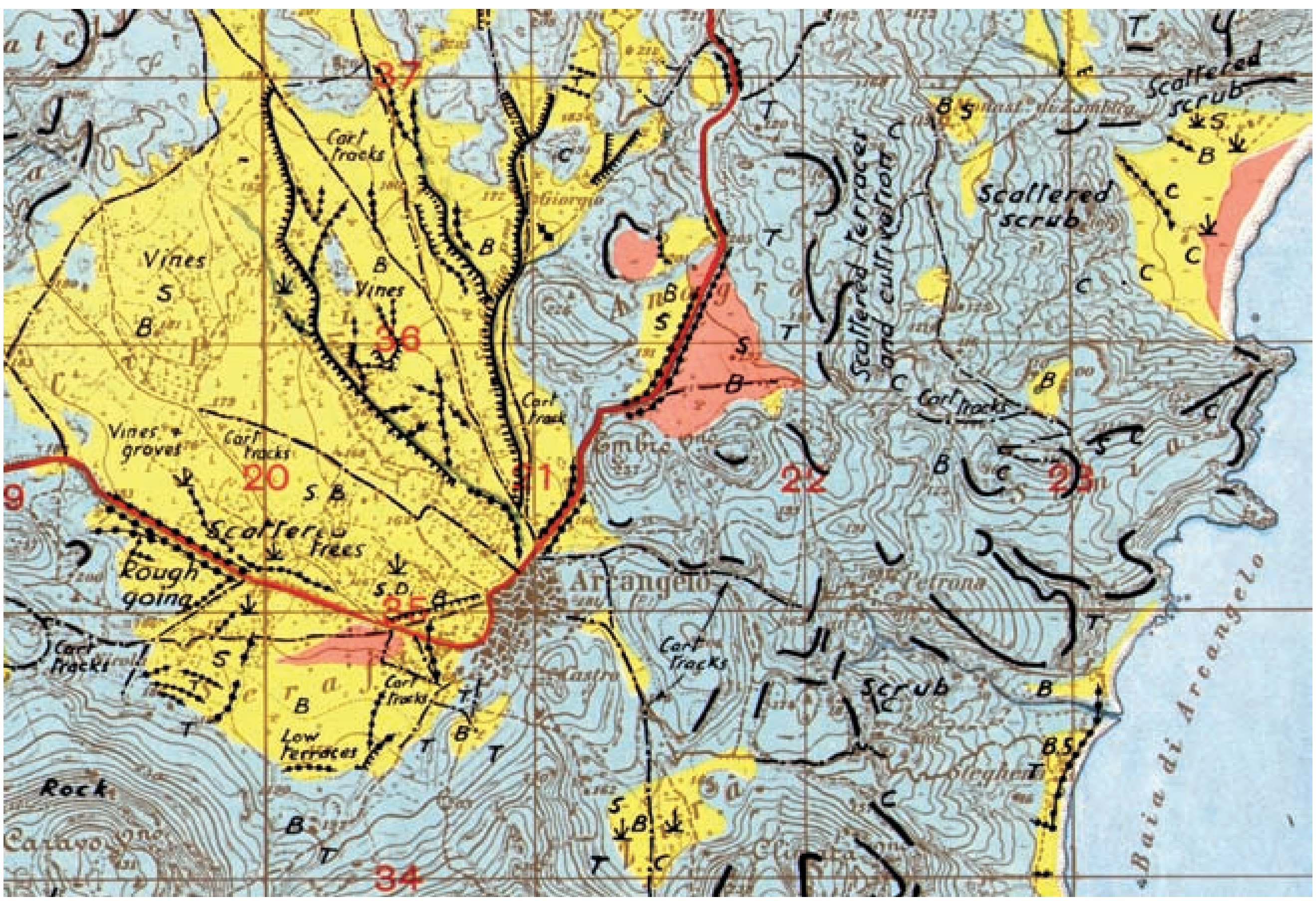


FIG. 936. DETAIL FROM A TYPICAL GOINGS MAP, 1944. This sheet is part of the Greek island of Rhodes and was prepared by 512 Field Survey Company, Royal Engineers, from air photograph interpretation conducted by the Army Air-Photo Intelligence Unit (AAPIU), part of the Middle East Intelligence Unit (MEIU), Heliopolis, Cairo, in March 1944.
Size of detail: 13.3 × 19.6 cm. Image courtesy of Alastair W. Pearson.

part of the Department of the Interior), growing from an initial complement of ten geologists to sixty geologists and soil scientists during 1943 (Smith 1964, 320–28) and sending personnel to Britain to work in the ISTD. The MGU was commissioned to conduct geological and terrain studies for areas of strategic importance, initially in Europe and North Africa. Terrain intelligence folios prepared for Operation Husky (the invasion of Sicily) addressed tactical field problems in addition to standard strategic planning and so impressed military circles that the unit was inundated with requests for similar work. The unit expanded further, and during 1944 MGU teams were sent to the Central Pacific, Southwest Pacific, and European theaters. Terrain appreciation maps that were included in the folios were typically divided into terrain units with an accompanying table that described the effect of the terrain on the movement, cover, and concealment of troops and vehicles. Folios included additional maps showing rivers, pictorial views, roads and railways, water supplies, airfield sites, soils, construction materials, fuels, vegetation, geology, and climate. The reliability of each map and description was provided. Folios included impressive isometric terrain diagrams of the topography as adjuncts to topographic maps (fig. 937). Preparation of the diagrams began with the creation of a projection using an isometrograph, and profiles of terrain were added using contours on a topographic map. The final stage consisted of completing the diagram with reference to available geology, topographic maps, and any other relevant information.

The MGU had expanded its operations to include the publication of trafficability studies, which showed in detail the effects of slope, soil, vegetation, drainage, weather, and natural and man-made obstacles on movement. Though admirable in terms of detail, these maps were not designed to be read at a glance (figs. 938 and 939). Greater reliance was placed on soil scientists to predict ground conditions—hence the sheets were pre-


FIG. 937. DETAIL FROM AN ISOMETRIC TERRAIN DIAGRAM, LAKE RANAU AREA OF SOUTHERN SUMATRA. As with all types of parallel projection, objects drawn with an isometric projection did not appear larger or smaller as they extended closer to or away from the viewer. In some situations the depth and altitude were difficult to gauge.
Size of detail: 17.1 × 25 cm. Image courtesy of Alastair W. Pearson.

pared by the USGS with the collaboration of the Bureau of Plant Industry, Soils, and Agricultural Engineering.

Even though terrain intelligence products provided invaluable information, commanders were ill advised to put all their faith in them. For example, to consider routes as impassable was risky as evidenced by the German attacks in the Ardennes in 1944, the so-called Battle of the Bulge. Nevertheless, World War II had a profound effect on how commanders perceived the role of terrain analysis. The skills expected of the terrain analyst now transcended those of the geographer and geologist to include soil scientists, ecologists, botanists, meteorologists, and hydrologists.

Terrain analysis during the postwar period became much more standardized in its approach due in part to the polarized political climate of the Cold War era. The armies of the North Atlantic Treaty Organization (NATO) and the Warsaw Pact tended to adopt similar strategies at strategic, operational, and tactical or field levels. While the strategic level would be concerned with the location of settlement, transport networks, and physiographic regions for planning military campaigns at the subcontinental scale, the tactical or field level would examine the terrain to assist in formulating battlefield tactics. The third and intermediate operational level would serve as the "critical link between the capabilities of tactics and the goals of strategy," dealing with campaigns to accomplish strategic goals by military forces at the theater level (Palka 2003, 291–92).

As the postwar period progressed, the threat of nuclear weapons being used on the battlefield forced tacticians to contemplate separating groups of soldiers so that only a relatively small number would be vulnerable at any one time. Greater onus rested on each group having both sufficient prior terrain intelligence to act independently and having the capability to collect its own data. Each unit would have to move rapidly and be supported from depots at the rear by helicopters or vertical takeoff and landing aircraft. These new tactics placed greater emphasis on the army providing its own terrain intelligence during conflicts rather than relying on the assistance of civilians or civilian organizations. In order to be effective, the expertise would have to accompany or be close to operations. Identification of safe helicopter landing sites or the swift preparation of short landing strips for aircraft required terrain analysts to be on site. The possibility of exposure to radiation on the battlefield meant that skills in geochemistry, geophysics, and mathematics assumed greater importance for the terrain analyst.

Developments in the application of the natural sciences to terrain intelligence gathering such as radar, infrared photography, and airborne spectrophotometers provided new opportunities to improve the quality and speed with which terrain maps could be produced. These new devices were accompanied by a more quantitative approach to terrain analysis. Hitherto, descriptions had been largely qualitative with areas described as, for example, "too steep to be negotiated by a tank." Devices capable of calculating the load-bearing strength of a surface such as penetrometers and shearmeters yielded measurements that could provide quantitative representations of the terrain. Multivariate analysis of landform characteristics as developed by geomorphologists such as Arthur Newell Strahler (1954) became a tool used in the compilation of terrain intelligence maps and reports. Statistical sampling methods, frequency distribution analysis, and testing techniques accelerated the compilation process, but the final map and report had to remain easy to read and interpret.

The Department of the Army's Terrain Analysis Field Manuals formalized procedures for terrain analysis in the United States (FM 30–10, 27 March 1972; FM 21–33, 15 May 1978; FM 5–33, 11 July 1990). These manuals served as a primary source for terrain analysts whose contribution became an integral part of intelligence preparation of the battlefield (IPB) and played a key role in military operations. During peacetime, terrain analysts were directed to furnish databases with detailed information on a wide range of terrain characteristics.

The U.S. Defense Mapping Agency (DMA) was responsible for producing the standard planning terrain analysis database (PTADB) and the tactical terrain analysis database (TTADB) used by the terrain analysts to support the needs of command. Much peacetime effort was devoted to extending these nondigital databases to improve worldwide coverage. Standard formats and legends were outlined in DMA product specifications for the hard copy TTADB. Much stress was placed on standardizing terrain analysis products, and the manuals explained the concept of formatting data in standard factor overlays. Analysts produced and maintained the overlays on acetate or mylar, and after final working copies were completed, cartographic and reproduction support produced the final overlays for the terrain analysis databases.

To provide rapid terrain analysis support to the commander in the field, the Digital Topographic Support System (DTSS), along with the Digital Features Analysis Data (DFAD), were developed to incorporate the military geographic information (MGI) into a digital computer database. Given that commanders expected terrain analysis products to be provided almost instantly, it was inevitable that terrain analysis maps became much more ephemeral in nature as acetate overlays or screen-based visualizations. The need to have standing stocks of printed maps was thus reduced dramatically.

Terrain analysts were concerned with all types of

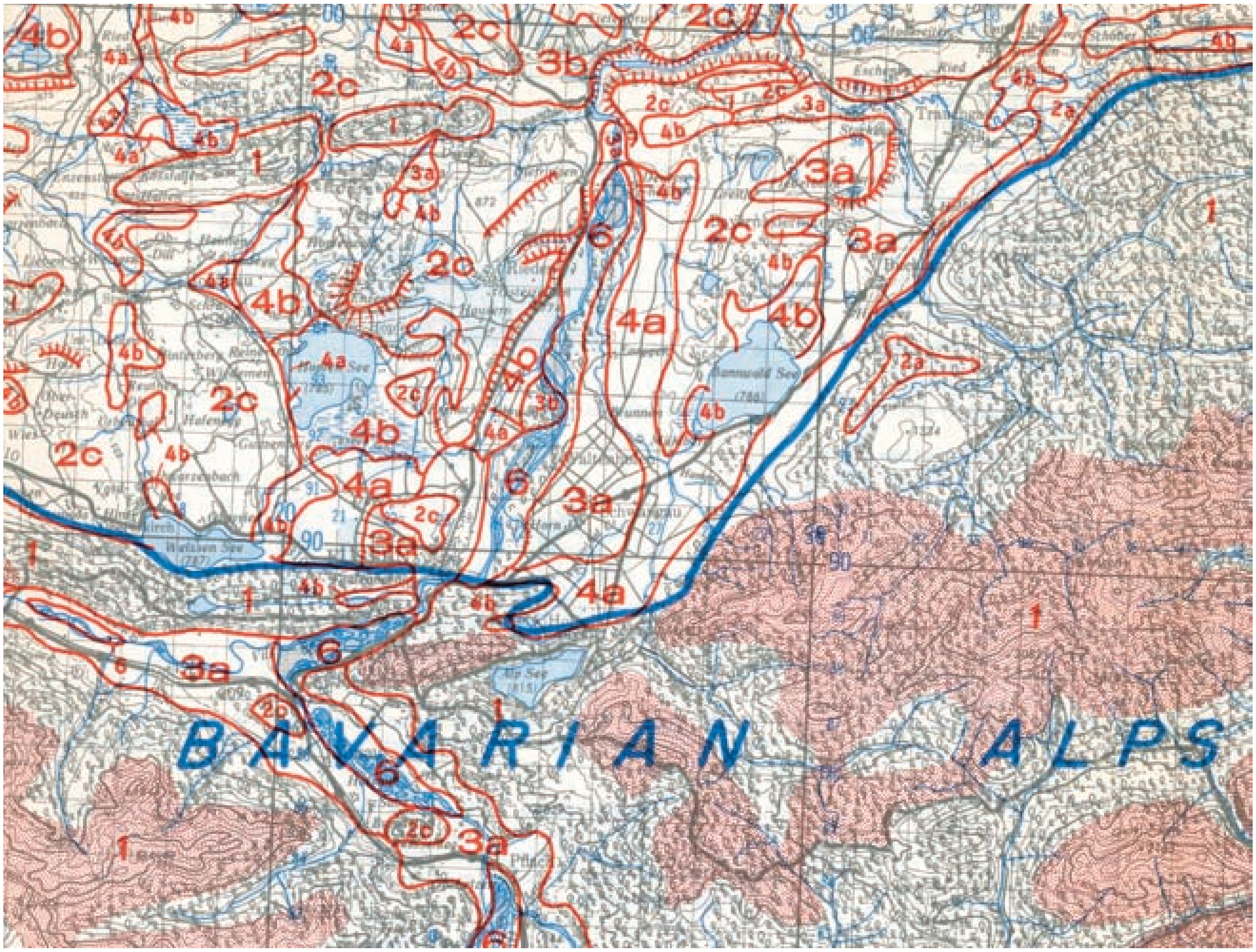


FIG. 938. DETAIL OF THE SUITABILITY FOR CROSS-COUNTRY MOVEMENT (TRAFFICABILITY), 1945. Map sheet Y-5 (*Füssen*) prepared by the U.S. Geological Survey with the collaboration of Division of Soil Survey, Bureau Plant Ind., Soils and Agricultural Engineering for Chief of Engineers, U.S. Army at a scale of 1:100,000. This sheet was published as part of a rush job undertaken in January 1945 at the request of the European Theater of Operations (ETO). ETO requested sixty-five quadrangles of Germany at a scale of 1:100,000, eighteen of which were to be delivered to Paris by 21 January—providing just five days to complete the work. Trafficability information was overprinted in red on base maps that had been published as part of A.M.S. Series M641 by the U.S. Army earlier in the war. (See fig. 939.)
Size of detail: 17.9 × 23.7 cm. Image courtesy of Alastair W. Pearson.

movement of personnel and equipment, be it on existing routes or across open country. When looking at routes, terrain analysts were concerned with the load that the infrastructure could support, which led to the development of road and bridge maps. The Falklands War (2 April–14 June 1982) demonstrated the continued value of high-quality terrain analysis for planning and briefing purposes (fig. 940). However, with the rapid development of automatic data capture and analysis techniques, the Military Survey of the United Kingdom took the opportunity to develop and deploy a pilot computerized terrain analysis system for headquarters-level operation. Though clearly beneficial and efficient, its completion coincided with the end of the Cold War and its operation was discontinued. Nevertheless, military requirements for terrain intelligence were changing. The static nature of the military standoff between NATO and the Eastern Bloc countries was replaced by a series of conflicts in very different environments over much shorter periods of time. Military forces would typically be sent to unfamiliar territories as part of a United Nations peacekeeping force, as was the case during the wars associated with the breakup of Yugoslavia between 1991 and 1995.

Interpretation of aerial photography formed an integral part of site investigations for engineering projects


FIG. 939. KEY TO TRAFFICABILITY MAP SHOWN IN FIGURE 938. Eleven terrain unit types were identified and explained with the aid of this key. A table also provided the number of days in every month that each terrain type would be trafficable, and climate data were also provided by the Weather Division, Headquarters, Army Air Forces and the U.S. Weather Bureau.
Size of detail: 25 × 8.2 cm. Image courtesy of Alastair W. Pearson.

since the interwar years (Ray 1960; Hittle 1949). For example, the interpretation of aerial photography for highway construction had been undertaken during the late 1920s (Sarason 1930). However, it was during the postwar period that terrain analysis, or terrain evaluation as it was often termed, became a common element in support of engineering projects, road developments, urban and regional planning, and resource and agricultural land capability assessments. The basic skills used to support terrain analysis included morphological mapping; surveying; the interpretation of air photographs and satellite images; soil and vegetation surveys; climate; and surface and groundwater monitoring. Terrain analysis could assess the geological environment in terms of the character of the rocks and soils, the hydrological conditions, the landscape, and all earth processes relevant to the proposed engineering activities (Broster and Bruce 1990).

Resource surveys in relatively undeveloped parts of the world provided new cartographic representations of terrain. The Australian branch of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Division of Land Research and Regional Survey, published outstanding examples of such work. Resource surveys of Australia, New Guinea, and Papua New Guinea were started in 1946 using techniques developed during World War II. The landscape was divided into uniform landscape units or land systems, which were in turn subdivided into land units. The land systems maps were published at scale of 1:250,000 or 1:1,000,000 and were accompanied by block diagrams (see fig. 459). Land systems were grouped according to their basic geological rock type and depicted using a distinctive color hue. Each individual land system within the rock type would then be differentiated by subtle variation in hue, saturation, and/or brightness, supplemented by a text label. Each land system would be described in terms of its topographic characteristics, soils, vegetation, and elevation range in the key.

This increased activity in terrain analysis for a variety of applications demonstrated a lack of standardization of symbols and the classification system being employed. The Military Engineering Experimental Establishment (MEXE) at Christchurch in Dorset, England, and the Soils Laboratory at Oxford University attempted to tackle this issue by devising a classification system for terrain. MEXE conceived of a system for predicting terrain characteristics by storing recurrent and uniform physiographic units that were recognizable on aerial photographs of landscapes in the same climatic zone. The assumption of this pioneering work was that the world could be divided into a finite number of recurrent landscape patterns (RLPs), or land systems as they became known, that could be further subdivided

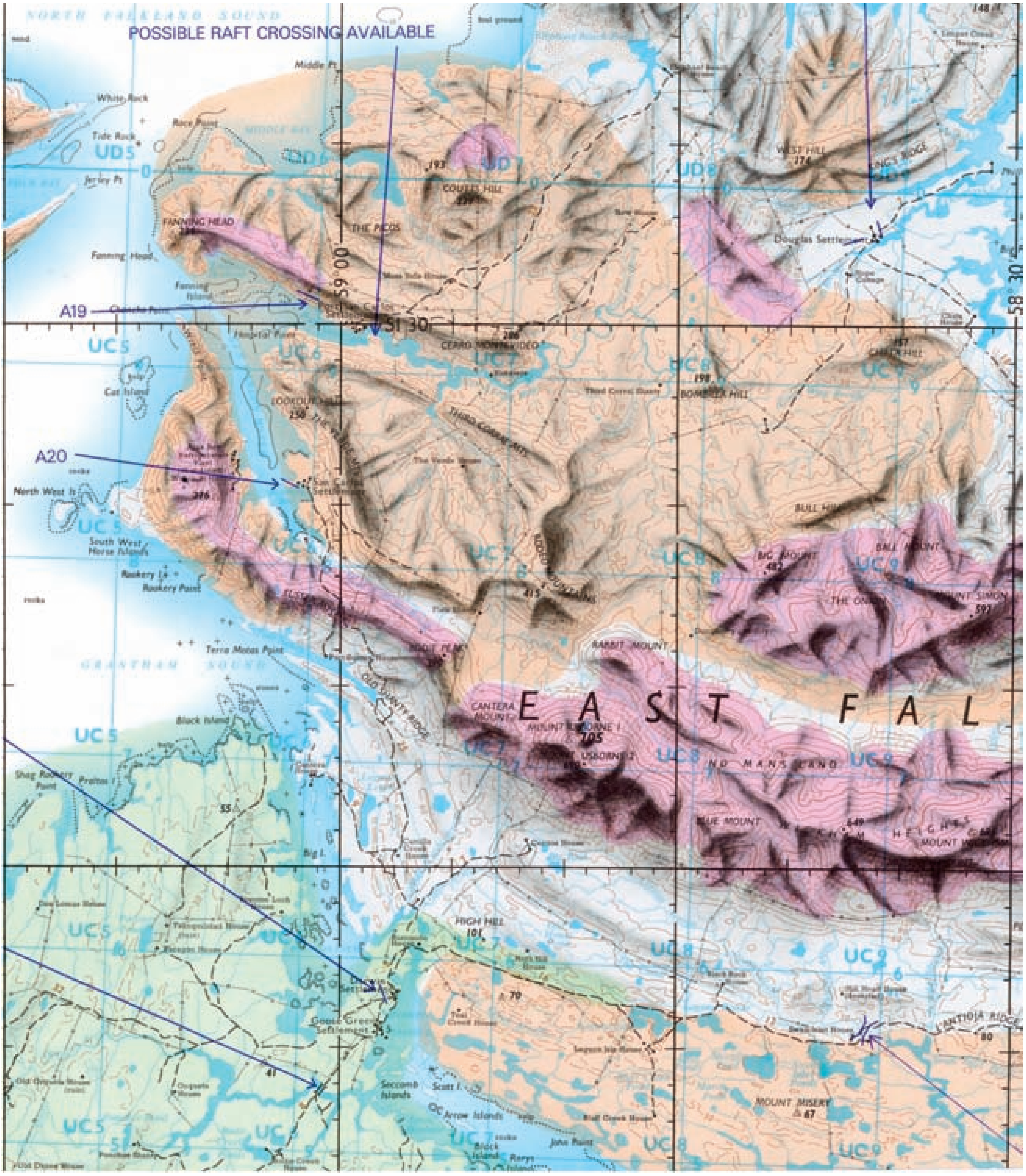


FIG. 940. DETAIL FROM *FALKLAND ISLANDS ROYAL ENGINEERS BRIEFING MAP*, 1982. This map (GSGS 5453 Edition 3-GSGS, 1:250,000) was produced by the headquarters engineer-in-chief and the Forty-Second Survey Engineer Regiment and was based on the British Royal Marines and Royal Engineers reconnaissance and from information gleaned through interviewing over forty Falkland Islanders. Studies conducted by the British Antarctic Survey and geologists of the Royal Engineers also contributed to the map. The color scheme differs significantly from the British Goings maps of World War II, being more in line with modern convention. Green areas depict "firm ground usually passable" and magenta areas represent "bog, or rock not passable to vehicles." Size of the entire original: 105.1 × 115.2 cm; size of detail: 24 × 21 cm. Image courtesy of Alastair W. Pearson.

into their constituent facets. Extensive fieldwork and experimentation (Beckett and Webster 1965) led to the hope that such an approach could offer worldwide coverage for military and civilian use. However, following the conclusion of the research, the terrain prediction capability passed into civilian hands; the military applications became peripheral. Classification systems tended to be adapted and designed for the specific projects with few if any finding wider acceptance across the various terrain analysis activities around the world.

Given the range of both military and civilian activities, it was perhaps inevitable that terrain analysis would fail to attain the organic unity of a single academic discipline or indeed an identifiable map type of its own. Nevertheless, the cartographic legacy of terrain analysis during the twentieth century demonstrates how vital such products became as the century progressed.

ALASTAIR W. PEARSON

SEE ALSO: Anaglyph Map; Cave Map; Holographic Map; Land Systems Analysis; Physiographic Diagram; Relief Depiction: Relief Map; Viewshed Mapping

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***Tharp, Marie.*** Marie Tharp was a pioneering cartographer whose work with oceanographer Bruce C. Heezen revealed the detail of the world's ocean floor and helped launch the plate tectonics revolution. She was born in Ypsilanti, Michigan, on 30 July 1920, and died in Nyack, New York, on 23 August 2006.

Tharp grew up immersed in maps. Her father worked for the U.S. Department of Agriculture as a soil surveyor and mapmaker. In her youth, such work was deemed inappropriate for a "lady." Graduating in 1943 from Ohio University with a bachelor's degree in English and music, she had resigned herself to a career as a schoolteacher until the University of Michigan began recruiting women for graduate studies in geology to make up for the loss of male students serving in the armed forces during World War II. Tharp enrolled and earned a master's degree in 1944.

Hired by Stanolind Oil & Gas Company in Tulsa, Oklahoma, Tharp was kept in the office doing clerical work—collating field reports by male geologists. In 1948, after earning another master's degree (in mathematics from the University of Tulsa), she moved to New York. Tharp sought work at the geology department at Columbia University and was referred to W. Maurice Ewing, who was busy organizing the Lamont Geological Observatory (eventually the Lamont-Doherty Earth Observatory). Ewing—not terribly open-minded about the role of women in science, particularly in oceanography—put her to work drafting maps and images for his male graduate students.

By 1952, Tharp was working exclusively with Heezen, a protégé of Ewing's. Heezen asked her to prepare profiles of the North Atlantic based on soundings (depth data) obtained primarily from echo sounders. Echo sounders, invented in 1911, used sound waves to measure water depth and did so faster and more accurately than traditional methods of lowering weighted cables over the sides of ships.

Tharp and an assistant, Hester Haring, painstakingly sorted a hodgepodge of ships' tracks into six roughly parallel profiles, arranged from west to east, and plotted the depths along each. Near the middle of each profile Tharp noticed a narrow, jagged mountain range with an unusual feature at its center—a deep, steep-sided, flat-bottom trough, or rift valley, formed where the earth's crust slowly splits. Although Heezen initially dismissed the finding as "girl talk," he hired Howard Foster to plot the locations of earthquakes in oceans and found that those in the Mid-Atlantic coincided with Tharp's rift valley (Tharp 1999, 33–34). Data from other oceans confirmed that where there was a midocean rift, there were earthquakes, and where there were earthquakes, there was often a rift. So much for "girl talk." In 1956 Ewing and Heezen announced the discovery of the largest geological feature on the planet—a 65,000-kilometer-long ridge-and-rift system that snaked across the world's ocean floors.

Heezen had also asked Tharp to map the ocean basins. Unfortunately, bathymetric (contour) maps, similar to topographic maps for land, were out of the question because the U.S. Navy had classified much of the depth data out of Cold War security concerns. To get around the restriction, Tharp applied Armin K. Lobeck's physiographic mapping technique—which showed the shapes of landforms as if viewed from above—to the ocean floor.

Tharp and Heezen's first map, of the North Atlantic, was published in 1957. Their second, of the South Atlantic in 1961, added to the discomfort of scientists unwilling to consider Alfred Wegener's idea that continents can move—the map revealed almost perfect conformity in shape of the Mid-Atlantic Ridge with the Atlantic coastlines of South America and Africa. Wegener's observation of the similarity in shapes of South America's and Africa's Atlantic coasts launched his development of continental drift theory, but skeptics dismissed this similarity as mere coincidence. Adding a third feature, the Mid-Atlantic Ridge (see fig. 888), to the mix made it all but impossible to argue that dumb luck was responsible.

In 1967, the National Geographic Society asked Heezen and Tharp to produce full-color physiographic maps of the world's ocean basins (see fig. 611). The magazine teamed them with Heinrich C. Berann, an Austrian artist who painted panoramic maps (see fig. 631). The success of those maps encouraged the trio to begin work on a full-color world ocean floor map in 1973 for the Office of Naval Research. The *World Ocean Floor* panorama was published in 1977.

Tharp's maps and geological profiles shook many geologists, including Heezen and Ewing, out of their complacent dismissal of continental drift, helped inspire Harry Hammond Hess's theory of seafloor spreading, and triggered research that led to the development of the theory of plate tectonics. The significance of her work was best expressed in the citation for Lamont-Doherty Heritage Award in 2001: "For scientists and lay people alike, Heezen and Tharp's maps revolutionized our understanding of our planet almost as dramatically as Copernicus did centuries before. Their World Ocean Floor Panorama hangs on the walls of offices and hallways throughout all oceanographic institutions—a ubiquitous source of reference and inspiration, and arguably the closest thing earth science has to iconography."

DAVID M. LAWRENCE

SEE ALSO: Geophysics and Cartography; Hydrographic Techniques: Sounding; Marine Chart; Marine Charting: United States; Oceanography and Cartography; Relief Depiction: Relief Map; Scientific Discovery and Cartography; Women in Cartography

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***Thematic Atlas.*** See Atlas: Thematic Atlas

***Thematic Mapping.*** This entry examines change over the twentieth century in the design, construction, and use of thematic maps as well as related institutional developments. Unlike general reference maps, which provide an overview of various phenomena pertaining to a region and are often created by large mapping agencies, thematic maps focus on the distribution of social or physical phenomena at relatively small scales and are typically created by a single individual or a small team of researchers. There is no sharp line between the two types (Petchenik 1979) insofar as thematic maps often include basic information typically found on general reference maps. For this entry, a map is considered a thematic map if its author appeared to focus on the distribution of a particular social or physical phenomenon.

Because thematic maps often display information from social or physical surveys, this entry does not include relatively realistic representations of the landscape such as bird's-eye views, panoramas, or virtual environments (Slocum et al. 2009, 460–77). Similarly excluded are pictorial treatments like the superb physiographic diagrams of Erwin Raisz.

While the notion of a thematic map has existed since the 1600s, the term "thematic map" is relatively new, first used by the German geographer Nikolaus Creutzburg in 1953. In Arthur H. Robinson's English-language cartography textbook *Elements of Cartography*, the term did not appear until the third edition, published in 1969. Other terms that have been used for thematic map include distribution map, statistical map, and special-purpose map.

Two basic questions can be asked about the design and construction of thematic maps in the twentieth century: what new thematic mapping methods were developed, and what changes occurred in the "look" of thematic maps? The latter question led to a systematic survey of maps in two prominent geographic journals, the *Annals of the Association of American Geographers* and the *Geographical Journal*, sampled at twenty-year intervals between 1900 and 2000. Maps for each of the twenty-year intervals were examined, categorized, and evaluated for changes in map design. A more detailed discussion of this survey and its findings is published elsewhere (Kessler and Slocum 2011).

The systematic survey of the two journals as well as an examination of the cartographic literature indicates that the history of thematic cartography in the twentieth century can be divided into four distinct eras defined by the state of computing technology: precomputer era (1900–1958), mainframe computer era (1959–76), desktop computer era (1977–90), and Internet era (1991 onward). Although the focus here is the twentieth century, a few post–2000 developments are noted as related innovations or elaborations of twentieth-century practices.

## Precomputer Era (1900–1958)

The precomputer era corresponds closely with what graphics historian Michael Friendly (2008) called the "modern dark ages" (1900–1950) in statistical graphics and thematic mapping. Friendly contrasted his modern dark ages with the two preceding periods, termed the "beginnings of modern graphics" (1800–1850) and the "golden age of statistical graphics" (1850–1900). Although the 1800s witnessed numerous innovations in thematic mapping—indeed, Robinson's classic *Early Thematic Mapping in the History of Cartography* (1982) focuses on the nineteenth century—influential developments during the early 1900s set the stage for the growth of thematic cartography in subsequent years and make Friendly's term "dark ages" an inapt description of the state of thematic cartography prior to 1950.

A key development during the early 1900s was the rise of national atlases and specialty atlases focusing on particular themes. The pioneering *Atlas öfver Finland* (1899), arguably the first comprehensive national atlas, heralded several prominent national atlases, including the *Atlas of Canada* (1906), *The Survey Atlas of Scotland* (1912), the *Atlas of Egypt* (1928), and the *Bol'shoy sovetskiy atlas mira* (1937–40). The development of atlases during this period led an anonymous reviewer to describe the two or three decades preceding 1940 as the "age of national atlases" (Anonymous 1940, 340). Although Mark Monmonier (1994) noted that the growth rate for national atlases was even higher after 1950, it is clear that the early 1900s was a period of unprecedented growth for both national atlases and thematic atlases, and that atlases published in the first half of the century included numerous thematic maps addressing a wide variety of topics (table 51 and fig. 941).

Atlas publishing broadened to include new thematic

Table 51. Social and physical thematic topics included in early twentieth-century national atlases. Adapted from *National Atlases: Their History, Analysis, and Ways to Improve Standardization,* ed. Gerald Fremlin and L. M. Sebert, Monograph 4, *Cartographica* (Toronto: B. V. Gutsell, 1972), 75–81.

| Physical topics | Population topics | Economic topics | Cultural matters | Special topics |
|---|---|---|---|---|
| Surface Geology | Population Distribution | Industry | Education | Political and Administrative |
| Geophysical Regions | Social Characteristics | Agriculture | Cultural Problems | Historical Maps |
| Topography | Ethnic Distribution | Transportation and Telecommunications | Public Health | Regional Maps |
| Climate | Settlement Modes | Commerce | Sports and Tourism | Specialty Maps |
| Hydrology | | Economy | | |
| Soils | | | | |
| Vegetation | | | | |
| Animal Distribution | | | | |
| Natural Regions | | | | |


FIG. 941. THEMATIC MAP SHOWING THE GROWTH OF CITIES IN THE WESTERN SOVIET UNION BETWEEN 1910 AND 1935. *Karty rosta gorodov soyuza SSR*, with insets of Leningrad and Moscow (top left) and the Donets Basin (Donbas) region (lower left).

Size of the original: 31 × 25.4 cm. From volume 1 of the *Bol'shoy sovetskiy atlas mira* (Moscow: Nauchno-izdatel'skiy institut Bol'shoy sovetskiy atlasa mira, 1937), pl. 127.

topics during the early 1900s, when commercial cartographic publishers, most notably Bartholomew, Denoyer-Geppert, George F. Cram, Hammond, Justus Perthes, Nystrom, and Rand McNally, recognized an emerging niche market for specialty atlases focusing on particular themes. For example, Rand McNally's *New Imperial Atlas of the World* (1904) touted the importance of the United States and its recent territorial acquisitions—the Philippines, Cuba, and Puerto Rico—and Hammond's *Pictorial Atlas of the World* (1912) included novel topics such as a world map of languages spoken in conducting commerce. Eager to produce atlases with an identifiable market and certain profits, cartographic publishers produced numerous specialty atlases aimed at the ordinary citizen.

Events on the world scene were a catalyst for specialty atlases. In particular, the numerous war atlases produced between 1914 and 1918 served to educate a largely geographically illiterate world about distant places and events. Rand McNally's *Atlas of the European Conflict* (1914) was typical of this genre. Although most firms simply repackaged existing single-sheet maps into an atlas format with little thought about redesign, the National Geographic Society took public opinion about map design seriously. Its new Cartographic Division, formed in 1918, drew a map of the Western Front that was noteworthy for its overwhelming number of place-names, which was immediately appreciated by the society's readership and became its signature cartographic design (Schulten 2000, 12).

After World War I federal agencies such as the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers, and their counterparts in other countries initiated new surveys of climate patterns, sea currents, elevation, and other aspects of the physical world. To synthesize these new physical data, Rand McNally introduced *Goode's School Atlas* (1923), which became a standard college-level geography textbook and was reissued in numerous subsequent editions. An intriguing aspect of the atlas was the interrupted Mollweide (homolographic) map projection developed by J. Paul Goode in 1916 (fig. 942). Goode designed this composite, pseudocylindrical, equal-area world map to counteract what he saw as the frequent misuse of the Mercator projection. In the preface to the atlas, he opined that because "North America is much larger than Africa [on the Mercator world map]. . . . Greenland is larger than South America. . . . This distortion of area is so bad that it becomes pedagogically a crime to use Mercator's map for studies of the relative sizes of continents and oceans, or for areal distribution of any kind" (Goode 1923, x). While Goode's interrupted Mollweide projection was used in the atlas until 1948, his more familiar interrupted homolosine projection, which fused together sinusoidal and Mollweide projections at latitudes 40°44′11.8″ N and S, first appeared in the 1932 edition and continued beyond the century's end as the atlas's preferred projection for world maps (see fig. 784).

The early 1900s were also notable for the appearance of several novel thematic mapping techniques, in particular the dasymetric map and the cartogram. While the development of the dasymetric method is often attributed to John Kirtland Wright, V. P. (Benjamin) Semënov-Tyan-Shanskiy developed both the concept and the term in 1911 (Petrov 2008, 134). Although the roots of dasymetric mapping are apparent in the nineteenth century, methods for constructing dasymetric maps were unclear at that time and the term "dasymetric" was not used.

Any discussion of the evolution of cartograms is problematic because the term "cartogram" has been used to refer to a wide variety of maps. Erwin Raisz (1938, 257) observed that "some authors, especially in Europe, call every statistical map a cartogram." By the 1970s, though, cartogram referred largely to a map in which distortion of geographic space is based on the values of a theme, such as population. Although the roots of the modern cartogram can be found in the late 1800s (Funkhouser 1937, 355), the first contiguous-area cartogram, so called because it attempts to minimize distortion of the shape of areal units while preserving contiguity relationships, appears to be a map used by Hermann Haack and H. Wiechel to depict election results for the German Reichstag in 1903 (Eckert 1921–25, 1:150; Fabrikant 2003, 82).

A third characteristic of the early 1900s was the development of numerous map projections specifically tied to small-scale thematic mapping. As atlas ownership was becoming more widespread, the need arose for world map projections that avoided the distortions of the Mercator projection. Starting in the early 1900s, several important pseudocylindrical projections were developed that greatly facilitated small-scale thematic mapping. Max Eckert developed six pseudocylindrical maps suitable for world maps; named Eckert I through Eckert VI, they varied in characteristics and appearance (see fig. 216). His Eckert IV saw considerable usage in thematic atlases and world sheet maps, including several published by the National Geographic Society. Other pseudocylindrical projections developed in the early 1900s included the Boggs eumorphic, Craster parabolic, Kavrayskiy (V–VII), Wagner I–VI, Putniņš ($P_1$, $P_1'$, $P_2'$, $P_3$, $P_3'$, and $P_4'$), quartic authalic, and McBryde-Thomas flat-polar quartic projections.

A fourth characteristic of the early 1900s was the technological advances that would eventually broaden the cartographer's capability to map a variety of thematic data. The greatest advance for mapping was Orville and

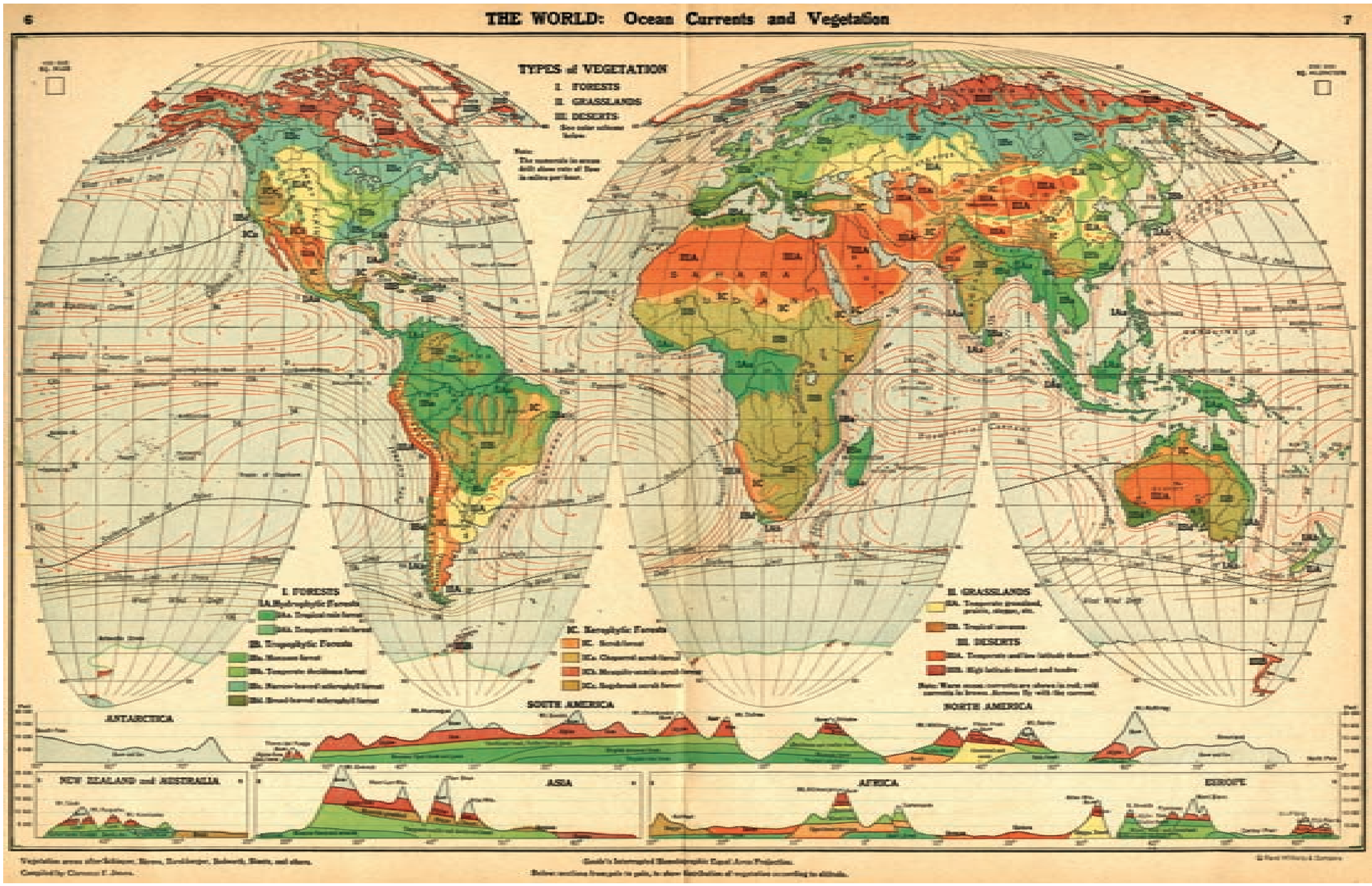



FIG. 942. J. PAUL GOODE'S INTERRUPTED MOLLWEIDE (HOMOLOGRAPHIC) PROJECTION. Size of the original: 26.7 × 41.7 cm. From Goode 1923, 6–7.

Wilbur Wright's pioneering 1903 flight of a powered, human-piloted, heavier-than-air flying machine. The airplane quickly became an important means of data collection, allowing individuals to look downward on the earth in real time. About the same time, George Eastman was marketing a light-sensitive film that replaced glass-plate negatives, thus making cameras much more portable. World Wars I and II initiated a tremendous amount of data collection and brought together the airplane and film-based cameras for large-scale mapping.

During World War I aircraft and aerial photography played an important role in reconnaissance mapping (Monmonier 1985, 85–89). Aerial photographs of the complex arrangement of trench networks would later be used to create maps showing enemy troop positions and allow strategists to plan for and visualize battle plans. Aerial photography was also used extensively in the United States in the 1930s by the U.S. Department of Agriculture for photographic coverage of the farmlands of the Midwest; by the USGS for its large-scale topographic maps; and by the Tennessee Valley Authority to site and plan its massive hydroelectric power plants in the southern United States. Coupling the airplane with the camera allowed a vertical perspective of the earth to be mapped at very high levels of positional accuracy. While positional accuracy is not the main requirement of a thematic map, aerial photography provided an efficient way to collect accurate information on coastlines, highways, hydrological networks, and other basic features critical to thematic mapping.

Improved photomechanical techniques associated with map production were another important technical achievement (Cook 2002). Around 1900 it was common to draft maps at a large size and then photographically reduce them to compensate for the limited drafting skill of mapmakers and imprecise drafting instruments. The early 1900s witnessed several inventions: technical drawing pens with standard widths, standard templates for lettering and symbols, preprinted lettering and symbols, and specialized phototypesetting equipment. Other photomechanical improvements that followed included standard colors for printing inks; photomechanical process color printing and the associated greater use of color on thematic maps; tint screens in preset percentage increments; the evolution of photographic proofing methods (to predict the look of the map prior to publication); the diazo process for reproducing maps; and scribing, which by the 1960s, according to Karen Severud Cook (2002, 148), had become "the highest state of the art in map production."

A fifth characteristic of the early 1900s was the role that cartographers, graphic artists, and others played in the evolution of mapmaking and ultimately in establishing the discipline of cartography. In addition to Goode, Raisz, and Wright, already mentioned, William Morris Davis, Richard Edes Harrison, Guy-Harold Smith, Max Eckert, and Eduard Imhof made noteworthy contributions (McMaster and McMaster 2002; Fabrikant 2003). Davis did superb work with three-dimensional physical diagrams (fig. 943), which may have provided an impetus for the three-dimensional thematic maps promoted by George F. Jenks and Dwight A. Brown in the 1960s. Harrison is well known for his illustrations that appeared in *Time* and *Fortune* magazines. Figure 944, an illustration from his *Look at the World*, includes a small thematic inset. Although Harrison's maps were intended largely as general reference maps, their unique visual perspective and design have been noted by many cartographers and undoubtedly influenced the thematic map design efforts of others. With these maps, there clearly was a connection between cartography and warfare, as the editors of *Fortune* stated: "The maps deal with political and military strategy and with world trade; but their main purpose is not to locate supply routes and battle lines. . . . Instead they try to show *why* Americans are fighting in strange places and *why* trade follows its various routes. They emphasize the geographical basis of world strategy" (Harrison 1944, 7).

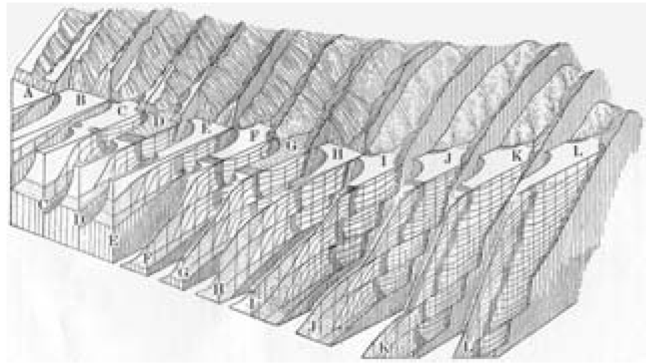


FIG. 943. AN EXAMPLE OF WILLIAM MORRIS DAVIS'S THREE-DIMENSIONAL PHYSICAL DIAGRAMS. This diagram is a small multiple showing stages in the evolution of shore features and reefs of a subsiding island.
Size of the original: 10.5 × 19 cm. From William Morris Davis, "The Islands and Coral Reefs of Fiji, Part II: Relation of Volcanic Islands to Coral Reefs," *Geographical Journal* 55 (1920): 200–220, diagram following 212 (pl. 9).

In Germany, Eckert published his two-volume *Die Kartenwissenschaft* (1921–25), which Daniel R. Montello (2002, 287) identified as an important precursor to Robinson's classic *The Look of Maps* (1952), even though Eckert's opus was nearly devoid of illustrations, possibly because of the high cost of graphics reproduction at that time. In Switzerland, Imhof founded what Sara Irina Fabrikant saw as "most probably the world's first academic cartography department." Although

# Russia from the South

Eckert did not initiate a course titled Thematic Cartography until 1954, he had lectured on cartographic design as early as 1923 (Fabrikant 2003, 82).

Toward the end of the precomputer era, several academic cartographers in the United States—Robinson at the University of Wisconsin, Jenks at the University of Kansas, and John Clinton Sherman at the University of Washington—began to train noteworthy numbers of graduate students, many of whom extended the philosophy of their mentors by becoming faculty members elsewhere (McMaster and McMaster 2002, 310–16). The Wisconsin, Kansas, and Washington programs all emphasized thematic cartography.

Accompanying the growth of academic cartography programs and changes in technology was a change in the nature of cartography courses. Initially, courses dealing with mapmaking focused on mechanical procedures involved with pen-and-ink drafting. Goode's course in cartography at the University of Chicago involved compilation of thematic maps, for example, graduated symbol and isometric maps, and construction of map projections (McMaster and McMaster 2002, 307). Early cartography textbooks such as Raisz's *General Cartography* (1938) included chapters on the history of cartography, scale and map projections, drafting techniques, and the novel application of surveying and aerial photography. Additional chapters discussed statistical maps, diagrams, and cartograms.

Robinson recognized the need to establish formal training for future cartographers as a prerequisite for advancing research on the effectiveness of thematic symbolization and map design in general. During World War II, the Cartography Section of the Office of Strategic Services (OSS), under Robinson's direction, produced numerous thematic maps, and it was during his work with the OSS that Robinson recognized the impact of inadequate cartographic training on the ability to create effective thematic maps. Although thematic maps created in his section "carried the major communication load," those working there "were unprepared for such responsibility" because they were not "cartographers as we know them today" but largely "engineers or draftsmen" (Robinson 1979, 98–99).

The inappropriateness of Friendly's description of the first half of the twentieth century as the modern dark ages was confirmed by the aforementioned survey of two prominent geographic journals (Kessler and Slocum 2011). Although thematic maps were generally better designed in the latter portion of the century, not all early thematic maps were characterized by poor design. Indeed, the quality of map design varied considerably throughout the century, as summarized in figure 945, which used a ten-point scale, with one representing the most poorly designed map and ten indicating the best possible designed map, to compare the design quality of the maps sampled. Note that four maps in the *Geographical Journal* for 1900 scored higher than 8.0.

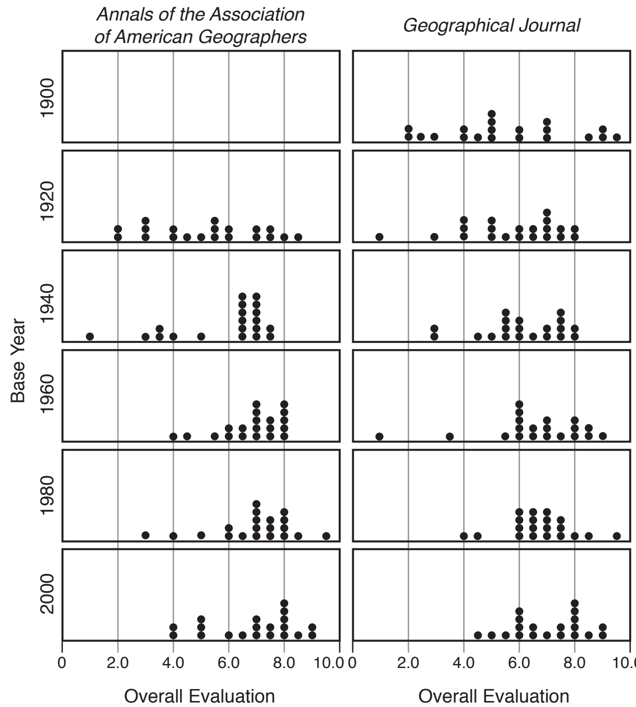



FIG. 945. DISPERSION GRAPHS ILLUSTRATING THE QUALITY OF MAPS DESIGNED FOR THE *ANNALS OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS* AND THE *GEOGRAPHICAL JOURNAL*. Twenty thematic maps were evaluated for each of the two journals at twenty-year intervals (using base years of 1990, 1920, etc., and adjacent years if necessary to obtain twenty maps). One was the lowest possible score and ten was the highest possible score. After Kessler and Slocum 2011, 307 (fig. 9).

## Mainframe Computer Era (1959–76)

The first computer-drawn maps appeared in the 1950s, when first commercial computers became available (Ceruzzi 2003, 44). These early computer maps were produced mostly by meteorologists, geologists, and other earth scientists, not by geographers or cartogra-

(*Facing page*)

FIG. 944. AN EXAMPLE OF RICHARD EDES HARRISON'S EARLY WORK, 1941. The right half of Harrison's *Russia from the South* with an inset of population. Size of the original: 34.5 × 27.5 cm. From Harrison 1944, 37.

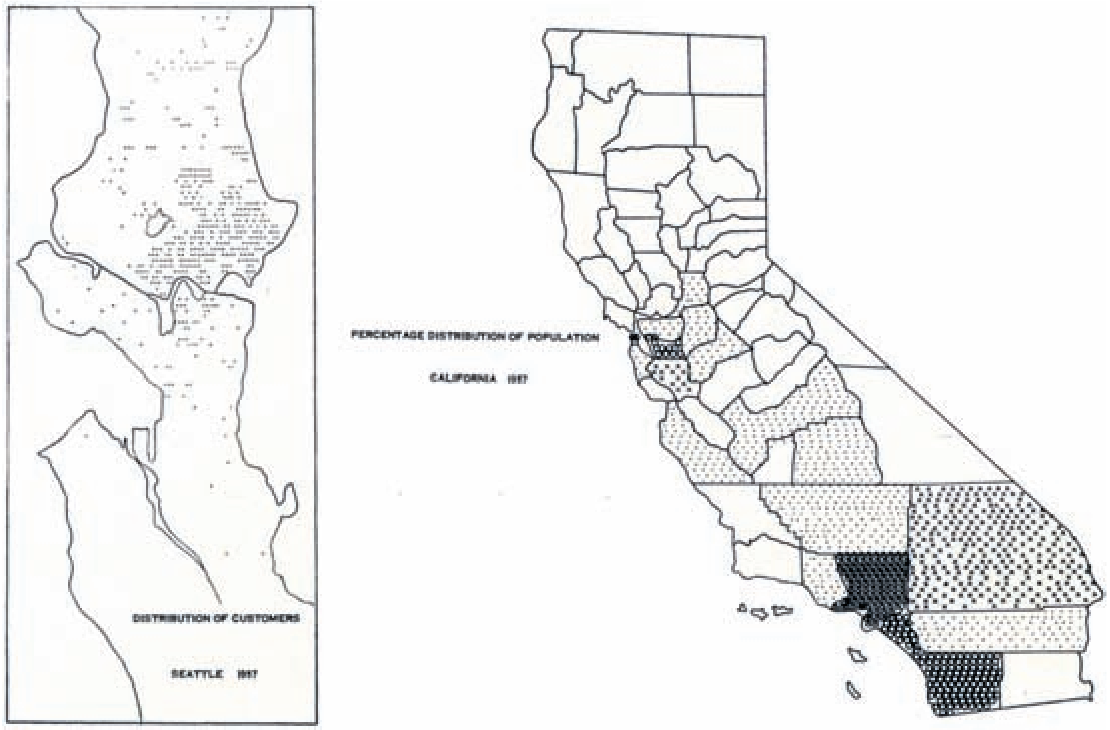



FIG. 946. COMPUTER-PRODUCED MAPS BY WALDO R. TOBLER IN THE LATE 1950s.

After Tobler 1959, 530 (two of three maps in fig. 6). Permission courtesy of the American Geographical Society, New York.

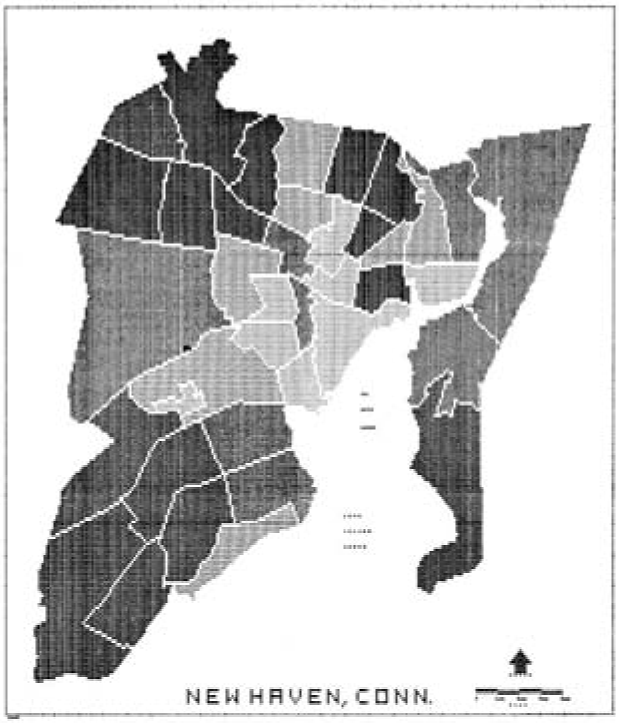
phers (Rhind 1977, 71). One of the first geographers to create computer maps was Waldo R. Tobler, who in 1959 published his seminal paper "Automation and Cartography," which provides the starting point for this era.

The term "mainframe" describes the large centralized computers in use at the time. Mainframe users had to submit punch cards containing computer code and data and then wait for a coarse-texture map to be printed six to ten lines to the inch on a line printer—Tobler indicated that he used a typewriter for output (fig. 946 shows two of his maps). Tobler, who eventually became one of the leaders in developing innovative software for thematic mapping, disseminated much of his software in the *Selected Computer Programs* series at the University of Michigan in the early 1970s.

A key milestone during the mainframe computer era was the SYMAP (synagraphic mapping) system, developed in 1963–64 under the direction of Howard T. Fisher at Northwestern University, and after 1965 at Harvard University. Designed to display maps on a line printer, SYMAP produced coarse choropleth and isarithmic maps (fig. 947). Even so, the software was sold to more than 500 institutions, and provided many cartographers worldwide with their first introduction to computer mapping. Another early popular software package was SURFACE II, which focused on isarithmic mapping and was developed by the Kansas Geological Survey (Chrisman 1988, 293).

Several people at Harvard's Laboratory for Computer Graphics at the time that SYMAP was developed played critical roles in the growth of geographic information systems (GIS). The most influential was Jack Dangermond, who founded and became president of Environmental Systems Research Institute (ESRI), which marketed popular software for thematic mapping as well as GIS. Another prominent person during this era was David P. Bickmore, who directed the Experimental Cartography Unit (ECU) in the United Kingdom; one of its goals was to produce the kind of high-quality maps (including thematic maps) that cartographers had traditionally expected (Rhind 1988).

The mainframe era witnessed continued growth in academic cartography programs; the formation of numerous new journals, in particular, the *Canadian Cartographer* in 1964, the *Cartographic Journal* in 1964, and the *American Cartographer* in 1974; the founding of the International Cartographic Association in 1959 and an associated publication, the *International Yearbook of Cartography*, in 1961; and the inauguration of the Auto-Carto conferences in 1974 (Chrisman 1988, 296–97).




An example of conformant (or "choropleth") type mapping, produced by the SYMAP program, Version V -- which is now available. One of a series of maps run in connection with a housing study based on 1960 census tract data, this example shows the relative median value of owner-occupied housing units. The darker the tone, the higher is the value.

FIG. 947. COARSE OUTPUT ASSOCIATED WITH CHOROPLETH MAPS PRODUCED USING SYMAP.
In *Context* 1 (February 1968), 3; image taken from Nicholas R. Chrisman, *Charting the Unknown: How Computer Mapping at Harvard Became GIS* (Redlands: ESRI Press, 2006), CD-ROM. Permission courtesy of Donald Cooke.

Another key development during this period was the publication in 1967 of Jacques Bertin's classic *Sémiologie graphique: Les diagrammes, les réseaux, les cartes*. Although North American cartographers eagerly adopted Bertin's conceptual framework based on the geometry of map symbols and the principle of "visual variables," other aspects of Bertin's theory were largely ignored (Muller 1981). His book's full impact was not felt until an English-language translation appeared in 1983, *Semiology of Graphics: Diagrams, Networks, Maps*.

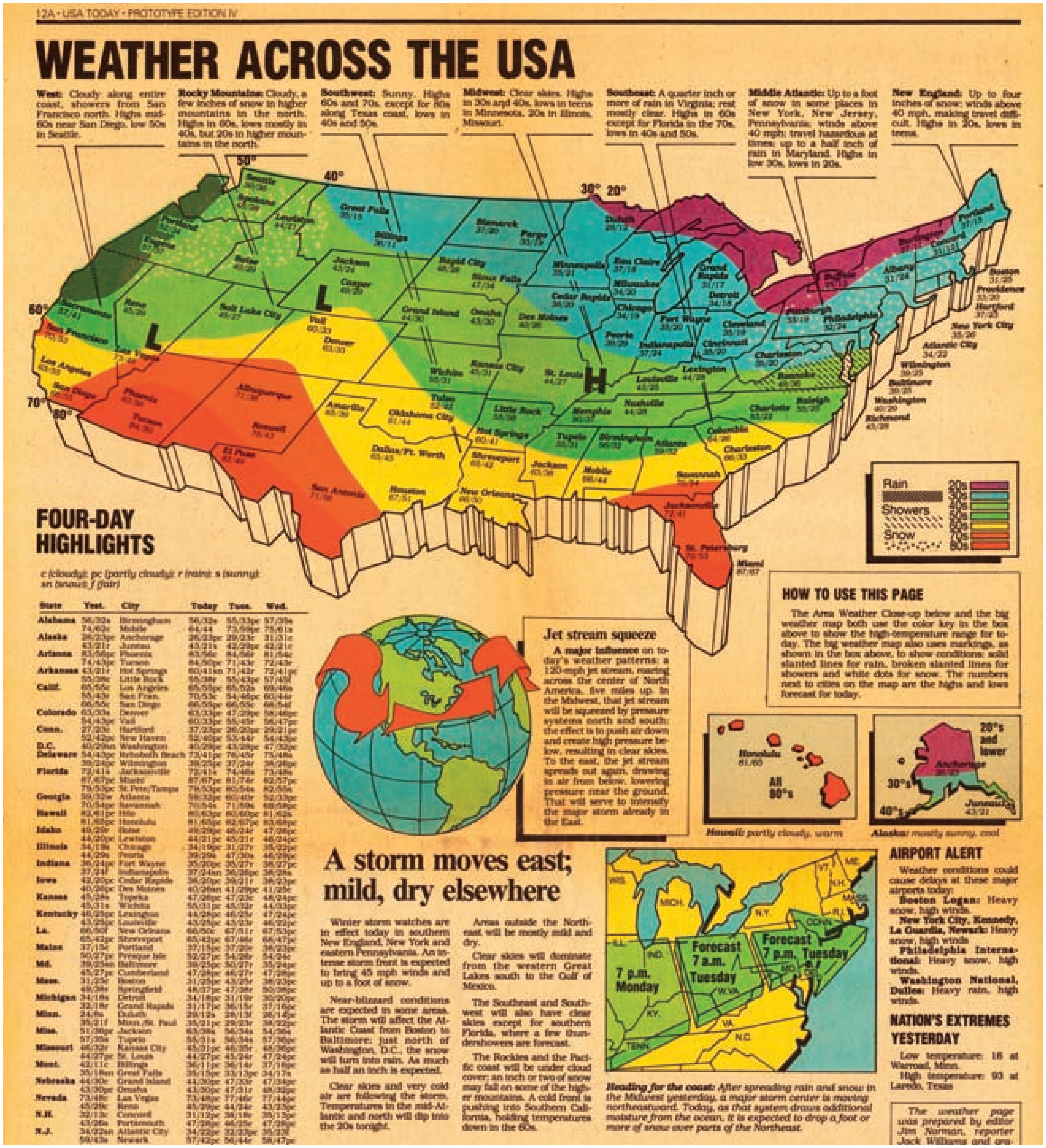
In addition to its ties with automated cartography, this era also witnessed the flowering of cognitive map design research, which focuses on understanding the cognitive processes involved when people read and interpret maps—an understanding that ultimately enables maps to be designed more effectively (Montello 2002, 284). A seminal event for cognitive map design research was the publication of Robinson's *The Look of Maps* in 1952, but it wasn't until the 1960s and 1970s that this research blossomed. Map design research usually involved noting the accuracy and time required for human subjects to complete various map reading tasks. These highly empirical investigations included the eye movement studies of Jenks and his students. Among the more prominent of these investigators is Theodore R. Steinke (1987, 55), who sought to improve the design of thematic maps by analyzing recordings of subjects' eye movements (see, e.g., fig. 658).

### Desktop Computer Mapping Era (1977–90)

In 1977 Apple Computer, Radio Shack, and Commodore International all introduced desktop computers, with Apple introducing the first desktop computer with color graphics (Ceruzzi 2003, 263–64). This new era permitted cartographers to design maps interactively on their desktops. Although sophisticated illustration software, notably Aldus FreeHand and Adobe Illustrator, would not be available for another ten years, some researchers (e.g., Sibert 1980) began to experiment with using desktop computers to design maps. Similarly, GIS software for desktop computers, most notably PC ARC/INFO, the precursor of ArcGIS, became available in the late 1980s.

During this era, cartographers began to more fully replicate the high graphic-arts quality of traditional manual production methods. This process had begun during the mainframe era, as exemplified by the work of Bickmore at the ECU, but now cartographers had the necessary hardware and software to complete the process, which was essentially finished by the early 1990s (Slocum 1995). Near the end of the desktop mapping era, cartographers also began to realize that rather than emulating the traditional manual process, the real power of interactive graphics would be to develop software that would help researchers explore spatial data. The notion emerged that, rather than creating a single optimal thematic map, cartographers should devise software that encourages exploration of multiple perspectives of the data (MacEachren and Ganter 1990).

A prominent event in this era was the launch of the newspaper *USA Today* in 1982, which emphasized the use of graphics and color, most notably in its large full-color daily weather map designed by George Rorick (Pompilio 2004). This style signaled a dramatic change in the design and use of daily weather maps. Previously, most newspaper weather maps were small black-and-white illustrations with coarse patterns and simple styles, created by graphic artists at the Associated Press or United Press International and sent by wire to subscribing newspapers. *USA Today*'s full-page weather package (fig. 948) spurred other newspapers to receive their weather maps from private graphic firms capable



12A • USA TODAY • PROTOTYPE EDITION IV

# WEATHER ACROSS THE USA

**West:** Cloudy along entire coast, showers from San Francisco north. Highs mid-60s near San Diego, low 50s in Seattle.

**Rocky Mountains:** Cloudy, a few inches of snow in higher mountains in the north. Highs in 60s, lows mostly in 40s, but 20s in higher mountains in the north.

**Southwest:** Sunny. Highs 60s and 70s, except for 80s along Texas coast, lows in 40s and 50s.

**Midwest:** Clear skies. Highs in 30s and 40s, lows in teens in Minnesota, 20s in Illinois, Missouri.

**Southeast:** A quarter inch or more of rain in Virginia; rest mostly clear. Highs in 60s except for Florida in the 70s, lows in 40s and 50s.

**Middle Atlantic:** Up to a foot of snow in some places in New York, New Jersey, Pennsylvania; winds above 40 mph; travel hazardous at times; up to a half inch of rain in Maryland. Highs in low 30s, lows in 20s.

**New England:** Up to four inches of snow; winds above 40 mph, making travel difficult. Highs in 20s, lows in teens.



## FOUR-DAY HIGHLIGHTS

*c (cloudy); pc (partly cloudy); r (rain); s (sunny); sn (snow); f (fair)*

| State | Yest. | City | Today | Tues. | Wed. |
|---|---|---|---|---|---|
| Alabama | 56/32s | Birmingham | 56/32s | 55/33pc | 57/35s |
| | 74/62c | Mobile | 64/44 | 73/59pc | 75/61s |
| Alaska | 26/23pc | Anchorage | 26/23pc | 29/23c | 31/31c |
| | 43/21r | Juneau | 43/21s | 42/29pc | 42/21c |
| Arizona | 83/56pc | Phoenix | 83/56c | 84/56r | 81/54c |
| | 74/43pc | Tucson | 84/56pc | 71/43r | 72/43r |
| Arkansas | 43/21r | Hot Springs | 60/41sn | 71/42r | 72/41pc |
| | 55/38c | Little Rock | 55/38r | 55/43pc | 57/45f |
| Calif. | 65/55c | Los Angeles | 65/55pc | 65/52s | 69/46s |
| | 55/43r | San Fran. | 70/53c | 54/46pc | 60/44r |
| | 66/55c | San Diego | 66/55pc | 66/55c | 66/54f |
| Colorado | 63/33s | Denver | 63/33pc | 47/29pc | 58/46pc |
| | 54/43pc | Vail | 60/33pc | 55/45r | 56/47pc |
| Conn. | 27/23c | Hartford | 37/23pc | 26/20pc | 29/21pc |
| | 52/42pc | New Haven | 52/40pc | 53/44r | 54/43pc |
| D.C. | 40/29sn | Washington | 40/29pc | 43/28pc | 47/32pc |
| Delaware | 54/43pc | Rehoboth Beach | 73/41pc | 76/45r | 73/48s |
| | 39/24pc | Wilmington | 39/25pc | 37/24r | 39/26pc |
| Florida | 72/41s | Jacksonville | 72/41s | 74/46s | 73/48s |
| | 87/67pc | Miami | 87/67pc | 81/74r | 82/57pc |
| | 79/53pc | St. Pete/Tampa | 79/53pc | 80/54s | 82/55s |
| Georgia | 59/32w | Atlanta | 59/32pc | 60/40r | 52/33pc |
| | 70/54pc | Savannah | 70/54s | 71/59s | 69/59pc |
| Hawaii | 82/61pc | Hilo | 80/63pc | 80/60pc | 81/62s |
| | 81/65pc | Honolulu | 81/65pc | 82/67pc | 83/68pc |
| Idaho | 49/29r | Boise | 49/29pc | 46/24r | 47/26pc |
| | 44/20pc | Lewiston | 44/21pc | 45/21r | 46/24pc |
| Illinois | 34/19s | Chicago | 34/19pc | 31/27r | 35/22pc |
| | 44/29s | Peoria | 39/29s | 47/30s | 46/29pc |
| Indiana | 36/24pc | Fort Wayne | 35/20pc | 35/27r | 38/27pc |
| | 37/21f | Indianapolis | 37/24sn | 39/26pc | 38/26s |
| Iowa | 42/20pc | Cedar Rapids | 38/20pc | 39/21r | 36/23pc |
| | 40/26pc | Des Moines | 40/26sn | 41/29pc | 41/25c |
| Kansas | 45/28s | Topeka | 47/28pc | 47/33r | 48/24pc |
| | 45/31s | Wichita | 55/31pc | 45/32r | 44/33pc |
| Kentucky | 46/25pc | Lexington | 44/28pc | 46/35r | 47/24pc |
| | 43/25pc | Louisville | 43/25pc | 43/23r | 46/22pc |
| La. | 66/50f | New Orleans | 66/50c | 67/51r | 67/53pc |
| | 65/42pc | Shreveport | 65/42pc | 67/46r | 68/47pc |
| Maine | 37/15c | Portland | 37/15pc | 37/20r | 36/23pc |
| | 50/27pc | Presque Isle | 52/27c | 54/26r | 54/24c |
| Md. | 39/25sn | Baltimore | 39/25pc | 30/27r | 35/24pc |
| | 43/27pc | Cumberland | 47/28pc | 46/27r | 47/28pc |
| Mass. | 31/25c | Boston | 31/25pc | 43/25r | 38/23pc |
| | 48/38r | Springfield | 48/37pc | 47/26r | 52/26pc |
| Michigan | 34/18s | Detroit | 34/18pc | 31/19r | 30/20pc |
| | 32/18r | Grand Rapids | 31/17pc | 36/15r | 37/16pc |
| Minn. | 24/8s | Duluth | 29/12s | 28/13f | 26/14pc |
| | 35/21f | Minn./St. Paul | 35/21pc | 29/23r | 38/22pc |
| Miss. | 51/36pc | Jackson | 63/38s | 56/34s | 54/36s |
| | 57/35s | Tupelo | 55/31s | 56/34s | 57/36pc |
| Missouri | 46/32r | Kansas City | 45/31pc | 46/35r | 48/36pc |
| | 44/27pc | St. Louis | 44/27pc | 45/24r | 47/24pc |
| Mont. | 42/11c | Billings | 36/11pc | 36/14r | 37/16pc |
| | 35/18sn | Great Falls | 35/15pc | 33/13pc | 34/17s |
| Nebraska | 44/30c | Grand Island | 44/30pc | 47/33r | 47/34pc |
| | 43/30pc | Omaha | 43/30pc | 47/31r | 48/32pc |
| Nevada | 73/48c | Las Vegas | 73/48pc | 77/46r | 77/44pc |
| | 45/28c | Reno | 45/26pc | 44/24r | 43/25pc |
| N.H. | 32/13c | Concord | 31/12pc | 38/18r | 35/13pc |
| | 43/26s | Portsmouth | 47/28pc | 46/26s | 47/28pc |
| N.J. | 34/22sn | Atlantic City | 34/22pc | 32/23pc | 35/23f |
| | 59/43s | Newark | 57/42pc | 56/44r | 58/47pc |

### Jet stream squeeze

**A major influence** on today's weather patterns: a 120-mph jet stream, roaring across the center of North America, five miles up. In the Midwest, that jet stream will be squeezed by pressure systems north and south; the effect is to push air down and create high pressure below, resulting in clear skies. To the east, the jet stream spreads out again, drawing in air from below, lowering pressure near the ground. That will serve to intensify the major storm already in the East.

### HOW TO USE THIS PAGE

The Area Weather Close-up below and the big weather map both use the color key in the box above to show the high-temperature range for today. The big weather map also uses markings, as shown in the box above, to show conditions: solid slanted lines for rain, broken slanted lines for showers and white dots for snow. The numbers next to cities on the map are the highs and lows forecast for today.



***Hawaii:** partly cloudy, warm*

***Alaska:** mostly sunny, cool*

## A storm moves east; mild, dry elsewhere

Winter storm watches are in effect today in southern New England, New York and eastern Pennsylvania. An intense storm front is expected to bring 45 mph winds and up to a foot of snow.

Near-blizzard conditions are expected in some areas. The storm will affect the Atlantic Coast from Boston to Baltimore; just north of Washington, D.C., the snow will turn into rain. As much as half an inch is expected.

Clear skies and very cold air are following the storm. Temperatures in the mid-Atlantic and north will dip into the 20s tonight.

Areas outside the Northeast will be mostly mild and dry.

Clear skies will dominate from the western Great Lakes south to the Gulf of Mexico.

The Southeast and Southwest will also have clear skies except for southern Florida, where a few thundershowers are forecast.

The Rockies and the Pacific coast will be under cloud cover; an inch or two of snow may fall on some of the higher mountains. A cold front is pushing into Southern California, holding temperatures down in the 60s.



***Heading for the coast:** After spreading rain and snow in the Midwest yesterday, a major storm center is moving northeastward. Today, as that system draws additional moisture from the ocean, it is expected to drop a foot or more of snow over parts of the Northeast.*

### AIRPORT ALERT

Weather conditions could cause delays at these major airports today:

**Boston Logan:** Heavy snow, high winds.

**New York City, Kennedy, La Guardia, Newark:** Heavy snow, high winds.

**Philadelphia International:** Heavy snow, high winds.

**Washington National, Dulles:** Heavy rain, high winds.

### NATION'S EXTREMES YESTERDAY

Low temperature: 16 at Warroad, Minn.

High temperature: 93 at Laredo, Texas

*The weather page was prepared by editor Jim Norman, reporter Jack Williams and gra-*

FIG. 948. *USA TODAY* WEATHER MAP, "WEATHER ACROSS THE USA." From the July 1982 Prototype IV issue of *USA Today*, page 12A. The newspaper would premiere 15 September 1982.
Size of the entire page: 53.5 × 32.5 cm; size of portion shown: 38.1 × 32.5 cm. From USA Today (Academic Permission), July 1982. 

of providing camera-ready artwork (Monmonier 1989, 118–21; 1999, 171–74). Although *USA Today's* emphasis on graphics (at the expense of text) drew criticism from some journalists (Gladney 1993), by the end of the century colorful thematic maps were common in a wide variety of newspapers and magazines.

### Internet Era (1991 onward)

Launch of the World Wide Web (quickly known as simply the web) in 1991 ushered in a new era for cartography. Not only could anyone with Internet access search for a wide range of thematic maps, but Internet users could now design their own thematic maps. Though desirable as a democratization of cartography because professional map designers were no longer essential (Morrison 1997, 17–18), the web also brought the danger of illogically designed maps, and thus the potential for misinterpretation in map use (Slocum et al. 2009, 8). Figure 949 illustrates a poorly designed map offered on the web.

Closely associated with the rise of the Internet was the growth of animated mapping. Although mapmakers could not fully embrace the potential of animated mapping (Campbell and Egbert 1990), by the end of the century cartographers had produced numerous animated thematic maps, many of which were available over the Internet (fig. 950) (Slocum et al. 2009, 389–407). These developments were fueled by the availability of animation software applications, notably Flash and Director.

The continued growth of interactive mapping and data exploration led to a new paradigm for cartography—geographic visualization, or geovisualization—intended to help researchers discover unknowns in a highly interactive environment and promoted enthusiastically by Alan M. MacEachren and his students (1999). Thematic maps became an integral part of geovisualization software, and the complexity of the problems tackled often required complex multivariate thematic maps.

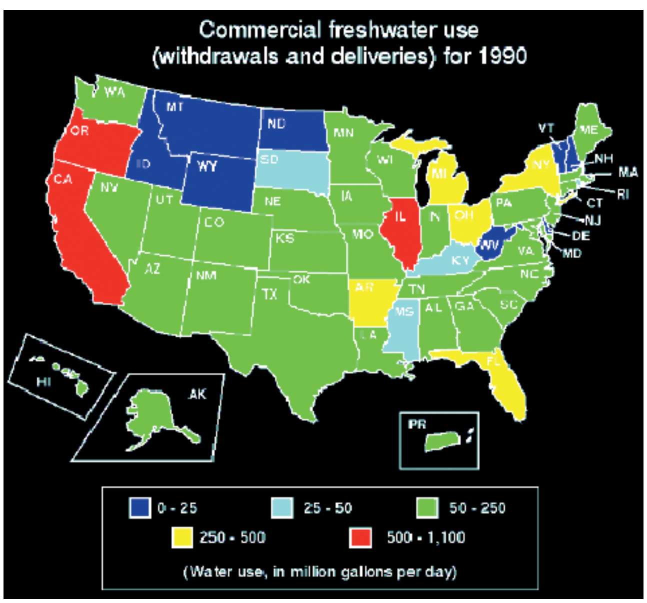



FIG. 949. A POORLY DESIGNED WEB MAP. An illogical color scheme, overlapping class limits, and text that is difficult to read are exacerbated by a computing environment that provided a limited number of available colors.
Image courtesy of the U.S. Geological Survey, *Water Use in the United States* website.

### Developments in Traditional Thematic Symbolization Methods

The twentieth century witnessed numerous elaborations or enhancements of traditional thematic symbolization methods, including choropleth, isarithmic, dot, dasymetric, proportional-symbol, flow, three-dimensional, and multivariate maps as well as cartograms. Figure 951, which summarizes the relative frequency of univariate thematic mapping methods encountered in the survey of two geographic journals, omits dasymetric maps, three-dimensional maps, and cartograms, which were comparatively scarce (Kessler and Slocum 2011). Indeed, the issues sampled included no three-dimensional maps or cartograms.

CHOROPLETH MAPPING. A key development in choropleth mapping was optimal data classification, promoted by Jenks and his students, who used a computer program to find natural breaks in data by minimizing the variation within classes and maximizing the variation among classes (Jenks and Caspall 1971). Adolf Ficker introduced the notion of optimal categories separated by natural breaks in the late 1860s (Funkhouser 1937, 324), but systematic implementation was impractical before the ready availability of mainframe computers in the late 1960s. Although there are a variety of criteria for selecting a classification method (Slocum et al. 2009, 251–70), the optimal method began to influence map design once it became an option in widely available mapping software. Perhaps the biggest incentive occurred in the mid-1990s, when a variant became the default data classification method in ESRI's ArcGIS package.

A second important development in choropleth mapping occurred in 1973, when Tobler introduced the so-called unclassed map, which obviated the need for categories by using subtle changes in the percentage of area inked to depict subtle numerical differences. Tobler used a pen plotter to draw customized cross-hatched symbols for every areal unit and created unique gray tones by varying the spacing of each symbol's constituent lines

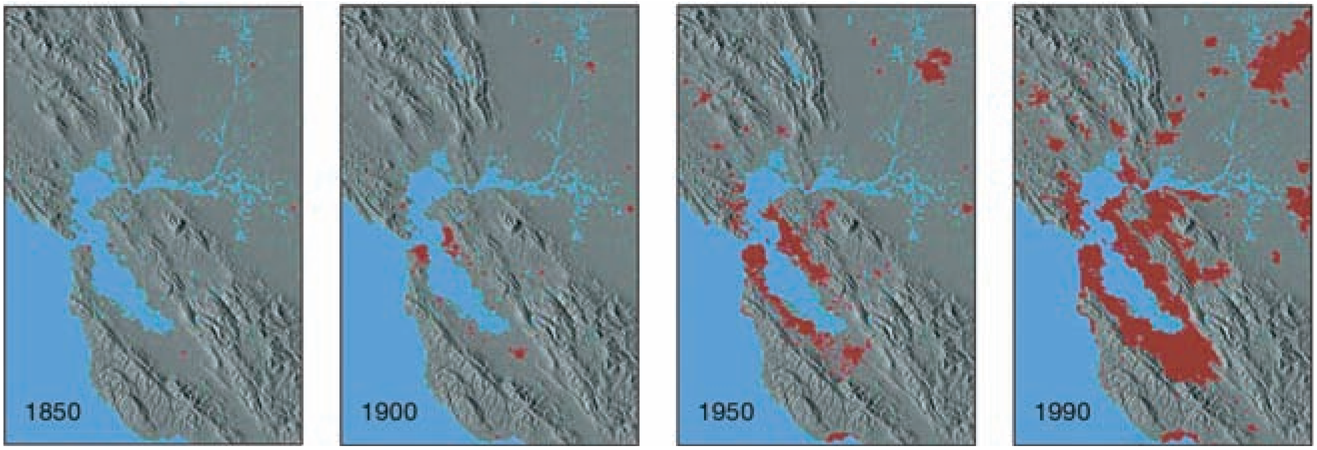



FIG. 950. ANIMATED MAP, EARLY 1990s. Four frames from an animation depicting urban growth in the San Francisco–Sacramento region.
Image courtesy of William Acevedo, U.S. Geological Survey.

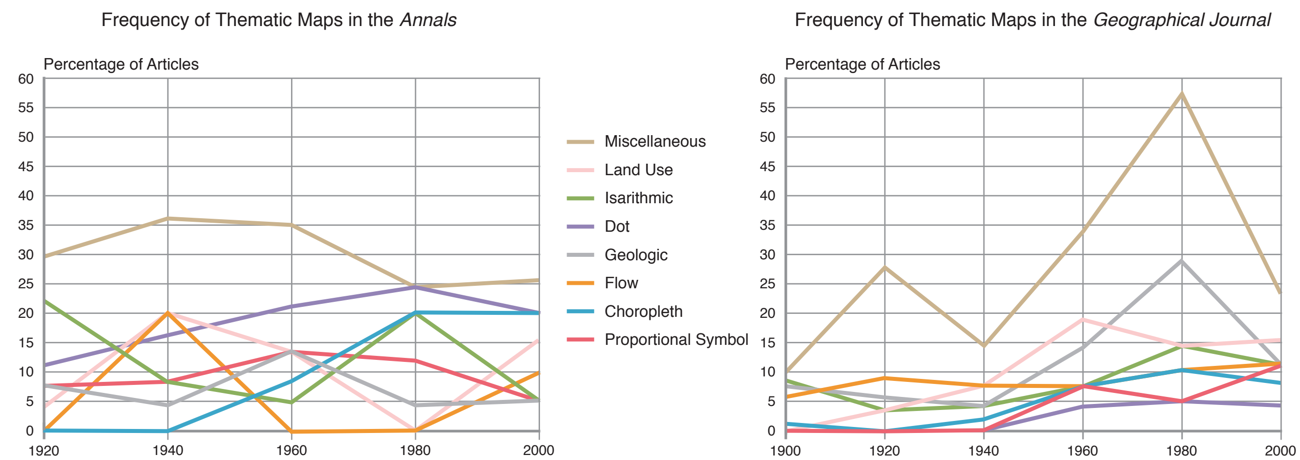



FIG. 951. FREQUENCY OF VARIOUS KINDS OF THEMATIC MAPS APPEARING IN THE *ANNALS OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS* AND THE *GEOGRAPHICAL JOURNAL* IN THE TWENTIETH CENTURY.
After Kessler and Slocum 2011, 305 (fig. 7).

(fig. 952). In a sense he rediscovered the unclassed map. The first choropleth map, produced in 1827 by Charles Dupin, relied on customized, carefully differentiated gray tones rather than a small number of distinctly different areas symbols, each representing a range of values. Even so, almost all choropleth maps produced prior to 1973 were classed. Although Tobler's method created a debate of sorts among academic cartographers (Slocum et al. 2009, 266–68), proponents of classification won the argument insofar as almost all choropleth maps produced at the end of the century were classed.

A third development in choropleth mapping was the replacement of comparatively coarse area shading patterns with more finely textured gray tones. In the early 1900s adding shading symbols to a choropleth map was a laborious process in which dotted stippling had to be created dot by dot and parallel or cross-hatched line patterns were drafted line by line. Statistical mapping became markedly easier in the 1930s, when graphic arts supply houses began to stock line and dot screens printed on a stable transparent adhesive-backed medium. Several firms manufactured these preprinted area symbols, collectively known by the name of the best-selling brand, Zip-A-Tone. A limited selection of gray tones was a handicap for any mapmaker eager for a relatively reliable portrayal of more subtle differences in a broad range of data values.

In the early 1950s computer-based line printers were used to create crude, coarse area shading by mimicking the manual typewriter, which could produce a light shading with simple dots and hyphens and a comparatively darker symbol by overprinting O, X, *, and I. Although

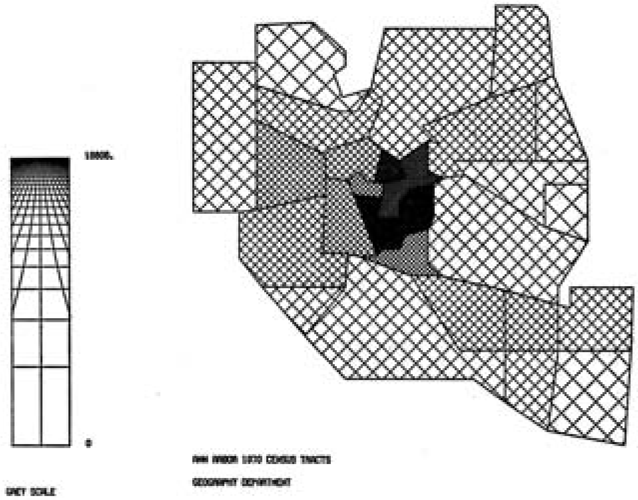


FIG. 952. EARLY VERSION OF AN UNCLASSED CHOROPLETH MAP CREATED USING A LINE PLOTTER. Map of Ann Arbor 1970 census tracts with gray scale to the left.
Size of the original: 11.3 × 14.8 cm. From Tobler 1973, 263 (fig. 1). Permission courtesy of John Wiley & Sons, Inc.

raster-based choropleth maps produced on a line printer were suitable for exploring data or experimenting with category breaks, they were rarely published. By contrast, pen plotters could create a more aesthetically appealing vector-based choropleth map by drawing boundary lines as a series of short straight-line segments and plotting the individual linear elements of parallel-line and cross-hatch shading symbols. Offered by a few vendors, notably Calcomp in the late 1950s, pen plotters became more widely available at university computing centers and government mapping agencies in the early 1970s, and quickly displaced line printer mapping. Even so, pen plotters could not produce smooth tones because the symbol produced was a function of the pen width used for plotting. Dot matrix printers, which emerged in the early 1970s, allowed finer gray tones than either line printers or pen plotters but could not replicate the fine tones of traditional manual cartography. As the name implies, a dot matrix printer used a print head with a small array of identical pens that could be fired in different configurations to create letters, numbers, and other symbols and could be programmed to produce gray tones as well.

Printing technology was hampered by its reliance on a printer control language to orchestrate the movement of the pen or print head. Printer languages compatible with a range of devices fostered the development of other kinds of printer technologies in the 1980s, including the inkjet printer (using liquid ink) and later the laser printer (using dry ink, or toner). Both printer types relied upon a page description language called PostScript to control the transfer of process color (CMYK) inks to the page. Developed in 1982, PostScript was able to convert text, line drawings, and images to a very fine grid with 300 or more dots per linear inch and reproduce its contents on any printer. PostScript not only made it easy to change a document's size and resolution but could also fill regions on a map with aesthetically pleasing smoothly continuous gray tones or colors. During the 1990s, other kinds of printing technologies became available, including thermal wax and dye sublimation, but none of these were as prominent at century's end as the color inkjet printer and the black-and-white laser printer.

Until at least 1980 choropleth maps were generally created using coarse gray-level shading (fig. 953), primarily because of the expense and technical difficulty in utilizing more finely grained gray symbols but also because of a perceived need to help viewers easily match symbols on the map with examples in the key. In the first edition of their textbook *Maps and Diagrams*, widely used in the United Kingdom, Francis John Monkhouse and Henry Robert Wilkinson (1952, 34) stated, "Care should be taken to provide sufficient shading contrast; a balance must be maintained between dark and light tints, and any suggestion of a monotonous grey uniformity over the whole map is to be avoided." After 1990 there was a gradual shift to more finely textured area symbols that differed only in gray value, not in pattern, which computer software and printing devices could easily produce and cartographers considered more aesthetically pleasing.

A fourth development in choropleth mapping was a

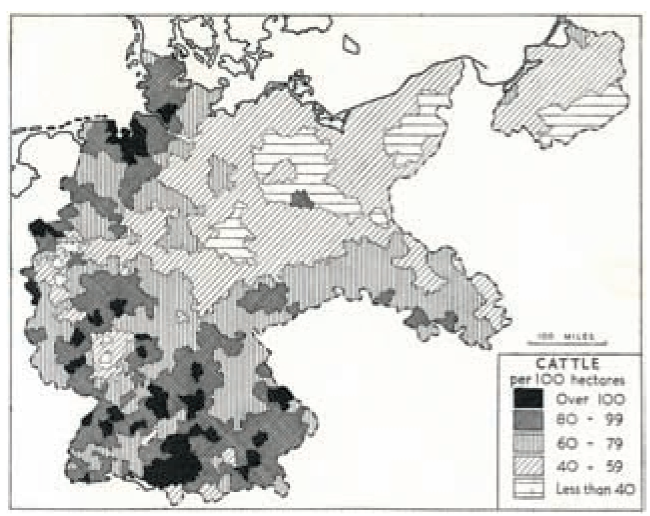



FIG. 953. COARSE SHADING PATTERNS TYPICALLY USED ON CHOROPLETH MAPS UNTIL AROUND 1980. Map shows German cattle distribution.
Size of the original: 10.7 × 13.7 cm. From Monkhouse and Wilkinson 1952, 191 (fig. 104). Reproduced by permission of Taylor & Francis Books U.K.

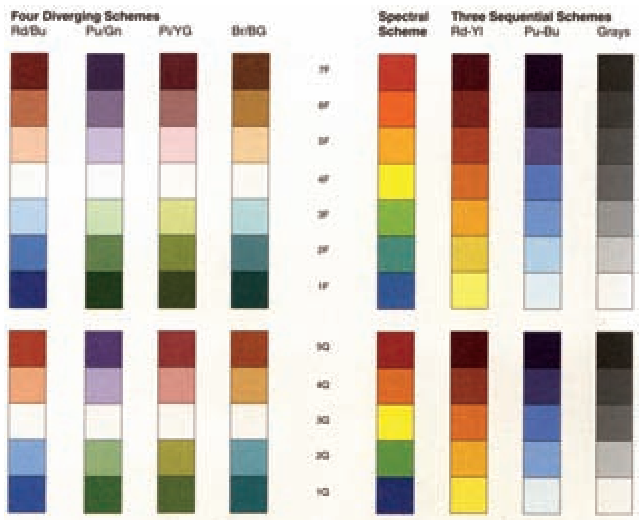



FIG. 954. DIVERGING, SPECTRAL, AND SEQUENTIAL COLOR SCHEMES FOR SEVEN AND FIVE CLASSES. Brewer and her colleagues found that all of these schemes were reasonable for a range of map reading tasks, although the gray scheme was deemed not as pleasant.
Size of the original: 10.6 × 13.1 cm. From Brewer et al. 1997, 418 (part of fig. 3). Reproduced by permission of Taylor & Francis.

revised view of the role of color. Traditionally, shades of a single hue (sequential schemes, almost always rendered in black) were common, although variations could be found in Europe (Funkhouser 1937, 326–28). Research by David J. Cuff (1972) supported the single-hue strategy, but later work by Janet E. Mersey (1990) and by Cynthia A. Brewer and her colleagues (1997) concluded that a careful use of hue variation could improve communication. Figure 954 shows a variety of color schemes found to be effective for choropleth mapping. In diverging schemes, two hues diverge from a common light hue or neutral gray, while spectral schemes span the visual portion of the electromagnetic spectrum. Although spectral schemes had been frowned upon, Brewer and her coworkers found them effective if they simulated a diverging scheme—this strategy was called a partial-spectral scheme. Other factors found to be important in selecting colors for choropleth maps included the kind of data, the names of colors, possible color vision impairments of viewers, and simultaneous contrast.

A fifth development was research dealing with the so-called equal-value grayscale—that is, a progressive sequence of discrete gray tones in which the perceived visual difference between adjoining symbols in the series was constant. For classed black-and-white maps, the consensus among researchers was that the Munsell curve was appropriate, while for unclassed black-and-white maps some cartographers argued that the Stevens curve was more suitable (Slocum et al. 2009, 260–61). Early in the twenty-first century, these concerns faded when Brewer and colleagues provided a software application, available on the Internet, that helped mapmakers choose from a variety of schemes (both black-and-white and color) deemed effective for choropleth mapping (Brewer, Hatchard, and Harrower 2003).

ISARITHMIC MAPPING. Isarithmic maps have been used throughout the twentieth century to represent statistical surfaces, including merely conceptual surfaces interpolated from aggregated data represented by points, for example, the centers of states or counties (Slocum et al. 2009, 281). Although only isolines were often used to represent the surface, visualization could be enhanced when a logical progression of areal shades was added between the isolines to portray relative value—a common example is the wall map on which hypsometric tints representing elevation category are more visually prominent than the lines between them. As with choropleth maps, coarse areal symbols were common on black-and-white isarithmic maps through at least 1980.

A key development in isarithmic mapping was the availability of computer-based software, which relieved the mapmaker of the task of interpolating isolines between known control points. Much of early thematic mapping software developed in the 1950s focused on isarithmic mapping, and by the mid-1970s a wide range of isarithmic mapping techniques had been developed (Rhind 1975). However desirable a generous range of choices, mapmakers were often confused by the need to select not only an appropriate interpolation method but also specify values for its parameters. Although studies of the effectiveness of various interpolation approaches (e.g., Declercq 1996) did not produce straightforward guidelines for selecting an interpolation method, Tobler's pycnophylactic approach (1979) was a notable exception, particularly appropriate for data based on enumeration units like census blocks and tracts. Another problem was that computer-based approaches did not incorporate the specialized knowledge of experts, for example, the meteorologist accustomed to interpolating surface analysis weather maps by hand (Mulugeta 1996, 335).

DOT AND DASYMETRIC MAPPING. Dot maps and dasymetric maps are similar in their use of ancillary information to provide a more realistic portrayal of a geographic distribution, particularly when variation in density is important. The dot map is used to portray raw totals—in principle the dots can be counted—whereas the dasymetric map portrays standardized rates, densities, or other intensity measures (Slocum et al. 2009, 271–80, 318–24). As noted earlier, the dasymetric map is largely an early twentieth-century technique, whereas the dot map has been around since the mid-1800s. According to Robinson (1982, 201), Thure Alexander von Mentzer created the "first true dot map" in 1859.

Dot and dasymetric maps can be viewed as alternatives to proportional-symbol and choropleth maps, respectively. In 1938 Raisz noted that "[choropleth maps] will not give a true picture of distribution, because in most cases it is not at the county or township line where the value changes" (246). More than six decades later Jeremy W. Crampton (2004, 51) extolled the virtues of the dasymetric map, arguing that the choropleth map had returned to predominance only because it was so easily produced with mapping software and GIS.

Before the computer age, dot and dasymetric maps were difficult to produce because of the considerable effort involved in collecting and using the necessary ancillary information. Although computers, at least in principle, eased the development of dot and dasymetric maps, it wasn't until the full development of GIS that the production of dot maps and dasymetric maps became more feasible. Early thematic mapping applications, such as MapViewer (released in 1990), encouraged a crude and potentially misleading form of dot mapping, in which the dots allocated to an areal unit according to its population count or other magnitude measure were placed at random within its boundary. By contrast, automated dot maps created for the 1969 U.S. Census of Agriculture, were true dot maps insofar as the positions of the dots were based on a sixteen-level land use map with approximately one-half million cells (fig. 955) (U.S. Bureau of the Census 1973, 14). Automated dasymetric mapping was a more recent phenomenon than automated dot mapping, with initial developments in the 1990s (Eicher and Brewer 2001) and more extensive elaborations after 2000 (Mennis and Hultgren 2006). A limitation of automated dasymetric mapping is that it required a thorough understanding of both the ancillary data and the requisite GIS software.

PROPORTIONAL SYMBOL MAPPING. A major twentieth-century development in the use of two-dimensional proportional point symbols like circles and squares was the rescaling of their areas so that the perceived difference in relative size for a pair of symbols did not distort the mathematical ratio of their data values. Without per-

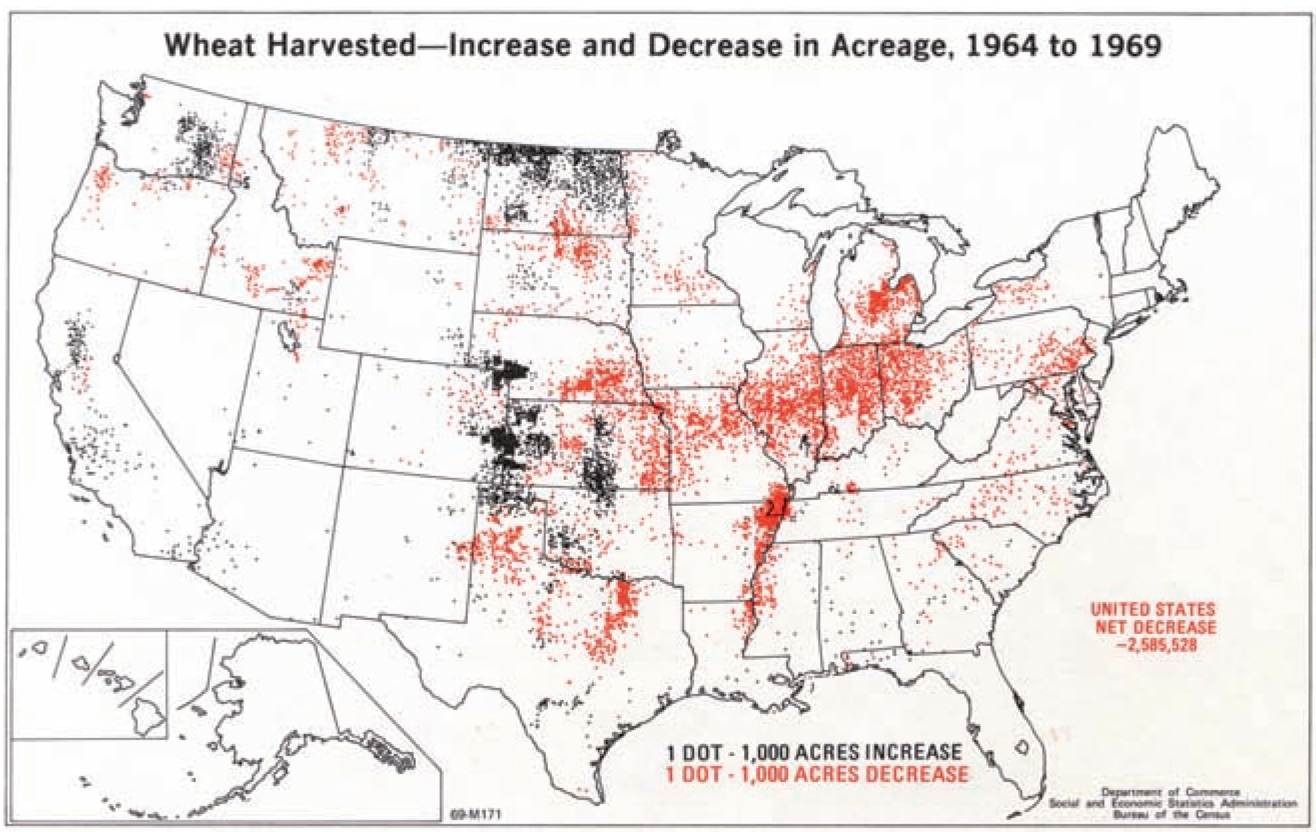



FIG. 955. EARLY AUTOMATED DOT MAPPING.
Size of the original: 12 × 19 cm. From U.S. Bureau of the Census 1973, 118.

ception-based rescaling (or concentrated training in the correct reading of these symbols), a map viewer looking at two symbols will tend to underestimate the size of the larger symbol. James John Flannery demonstrated this effect in his classic 1956 study, and his strategy for rescaling enriched the second edition of Robinson's *Elements of Cartography* (1960), to which he contributed. As the twentieth century came to a close, at least one GIS software company (ESRI) included an option for Flannery rescaling.

Studies similar to Flannery's led cartographers to recommend against using spheres, cubes, and other three-dimensional point symbols because of the difficulty of perceiving correct size relationships, even though these symbols could handle a large range of data values and people often found them eye-catching. The block-pile approach (fig. 956) is an intriguing three-dimensional symbol proposed by Raisz (1938, 238) as a more reliable way to use the limited selection of representative examples in the map key to estimate values represented by three-dimensional symbols on the map.

Early computer programs produced proportional symbol maps exhibiting poor figure-ground relations (e.g., Kern and Rushton 1969) largely because the line-plotting devices used to create smooth symbols and linework were not shaded easily—and certainly not with fine-textured gray tones. By 1990 improvements in hardware and software had made it possible to produce proportional symbol maps using a wide range of design options. For instance, Terry A. Slocum and Stephen C. Yoder (1996) developed software that permitted users to dynamically change the amount of overlap on proportional circle maps.

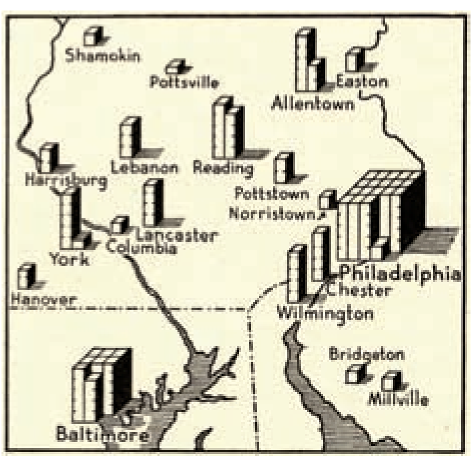



FIG. 956. THE BLOCK-PILE SYSTEM. Erwin Raisz promoted the blocks as an alternative to spheres.
Size of the original: 6 × 6.2 cm. From Raisz 1938, 304 (fig. 182). Permission courtesy of The McGraw Hill Companies, New York.

Although cartographers and graphic designers have long recognized the potential value of proportionally scaled pictorial point symbols (Funkhouser 1937; Raisz 1938), they were difficult to create by hand and rarely used. The increased availability of pictorial symbols in mapping and GIS software in the 1990s promised a greater use of pictorial symbols in the decades ahead. A powerful exemplar is Michael Kidron and Ronald Segal's *State of the World Atlas* (initially published in 1981; in its eighth edition in 2008), which made extensive use of pictorial symbols (fig. 957). Though criticized by cartographers for various deficiencies, this lively thematic atlas was praised for its attention to humanitarian, social, and political issues (Coulson 1982).

CARTOGRAMS. As noted earlier, the first contiguous-area cartogram (by Hermann Haack and H. Wiechel) appeared in the early 1900s. Another important early cartogram was Henry Charles Beck's early 1930s linear cartogram of the London subway system (Garland 1994), which distorted distances to provide greater detail in central city areas, where the stations were closer together and the network more complex (see fig. 483). Beck's cartogram paved the way for similar linear cartograms for mass-transit systems in other cities. And in 1934, Raisz developed the rectangular statistical cartogram (fig. 958), arguably an extension of Émile Levasseur's work in the late 1800s (Funkhouser 1937, 355), even though Raisz mentioned no earlier cartograms.

Prior to the development of computers, the construction of cartograms was a tedious manual process (Dent 1999, 215–17). In the early 1960s Tobler developed the first computer-produced contiguous-area cartogram. In 2004, he reviewed his early work and numerous other cartogram algorithms, many of which appeared after 1990. An intriguing algorithm developed by Daniel Dorling placed a uniformly shaped symbol (typically a circle) at the center of population of each enumeration unit and made the area of the circle proportional to the population. An iterative algorithm, which then moved the circles so that they did not overlap, resulted in a non-contiguous cartogram, so-called because most adjoining areas no longer touched. Typically, the circles served as a base for mapping some other variable, as in figure 959. A particularly efficient algorithm for the contiguous cartogram was later developed using the diffusion process of elementary physics (Gastner and Newman 2005). Dorling and his colleagues used this approach to map a wide variety of social and economic data, first on the web (as the Worldmapper Project) and later as a book (Dorling, Newman, and Barford 2008) (fig. 960).

The difficulty of producing cartograms by hand largely accounts for their relative scarcity. Although computer-based algorithms were available for the century's last

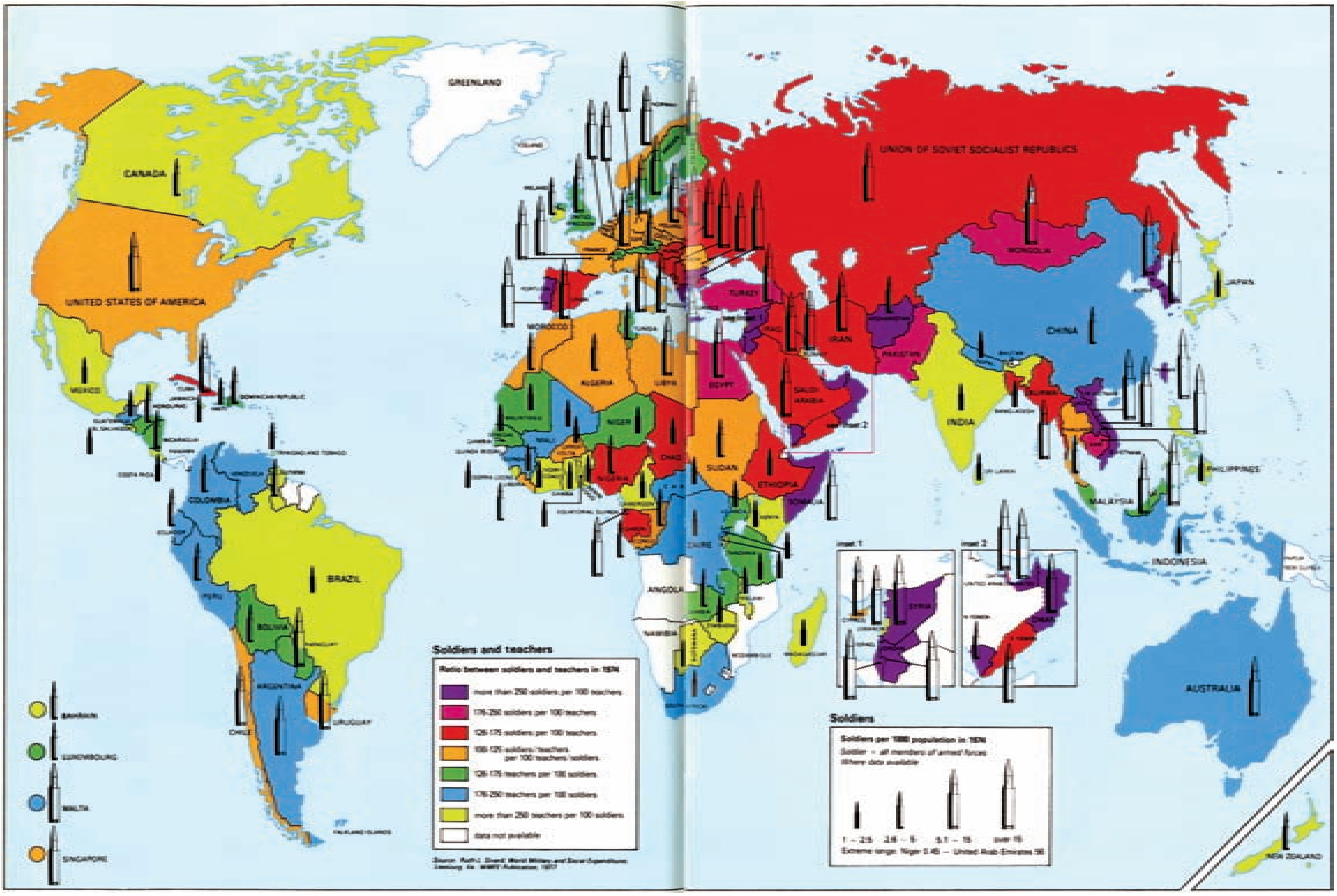



FIG. 957. *BULLETS AND BLACKBOARDS*, PICTORIAL SYMBOLS USED IN KIDRON AND SEGAL'S *STATE OF THE WORLD ATLAS*. Bullets of different sizes are used to symbolize the number of soldiers per 1000 population. Size of the original: 22 × 33 cm. From Michael Kidron and Ronald Segal, *The State of the World Atlas* (New York: Simon & Schuster, 1981), map 29. Copyright © Myriad Editions, Reprinted with permission.

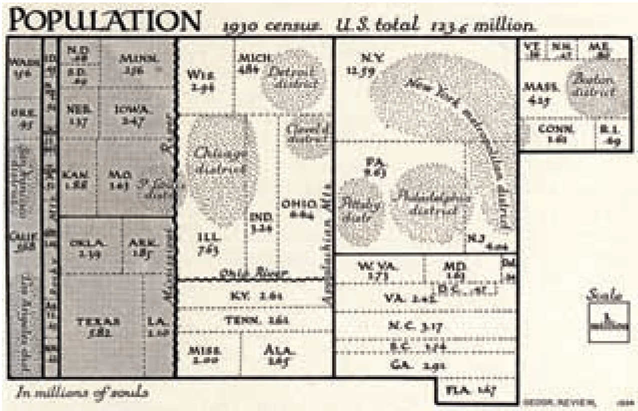



FIG. 958. ERWIN RAISZ'S RECTANGULAR CARTOGRAM. The rectangles represent geographic divisions of the census and states in proportion to the size of their population. The largest metropolitan areas are shown with a stippled pattern also proportionate to population size.
Size of the original: 7 × 11 cm. From Erwin Raisz, "The Rectangular Statistical Cartogram," *Geographical Review* 24 (1934): 292–96, esp. 293 (fig. 2). Permission courtesy of the American Geographical Society, New York.

three decades, map authors were apparently reluctant to use projections on which landmasses and familiar areal units differed radically from their counterparts on equal-area projections. In spite of these technological and social impediments, cartographic textbooks have extolled the cartogram as a logical base map for electoral, epidemiological, and demographic data, and the news media have found them an intriguing device for comparing the electoral and popular votes in U.S. presidential elections (fig. 961). In the early twenty-first century the Worldmapper Project made cartograms more widely available on the Internet.

FLOW MAPPING. Some of the most sophisticated flow maps were created during their initial development in the nineteenth century. Robinson (1967, 105) noted that Charles Joseph Minard's flow maps were at "a level of sophistication that has probably not been surpassed," and the survey of two geographic journals confirmed that flow maps were used frequently in the twentieth century but tended to be simple in nature, generally only

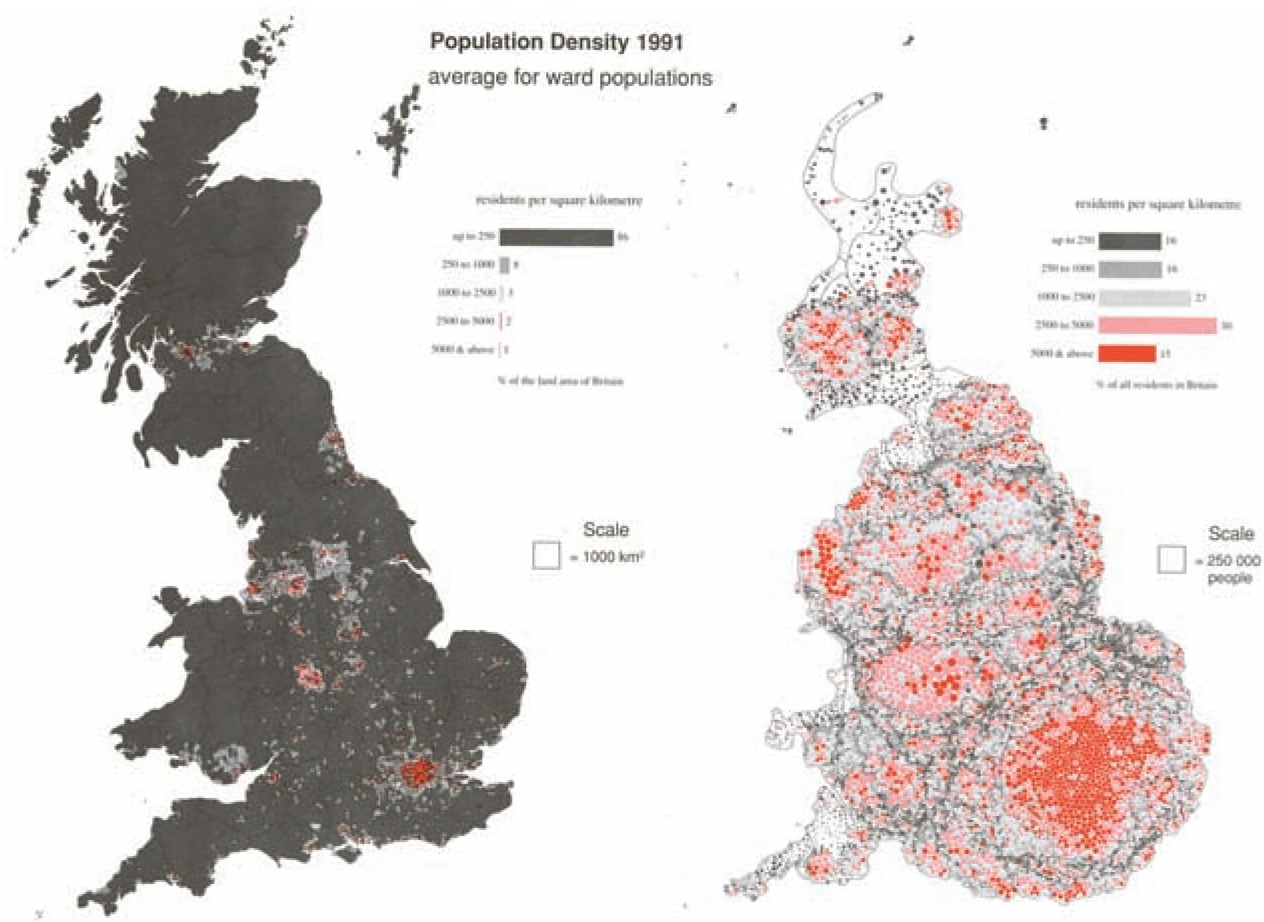



FIG. 959. DANIEL DORLING'S CARTOGRAM APPROACH (RIGHT) COMPARED WITH A TRADITIONAL EQUIVALENT PROJECTION (LEFT).
Size of the original: 17.2 × 24 cm. From Daniel Dorling, *A New Social Atlas of Britain* (Chichester: John Wiley & Sons, 1995), 9. Permission courtesy of John Wiley & Sons, Inc.

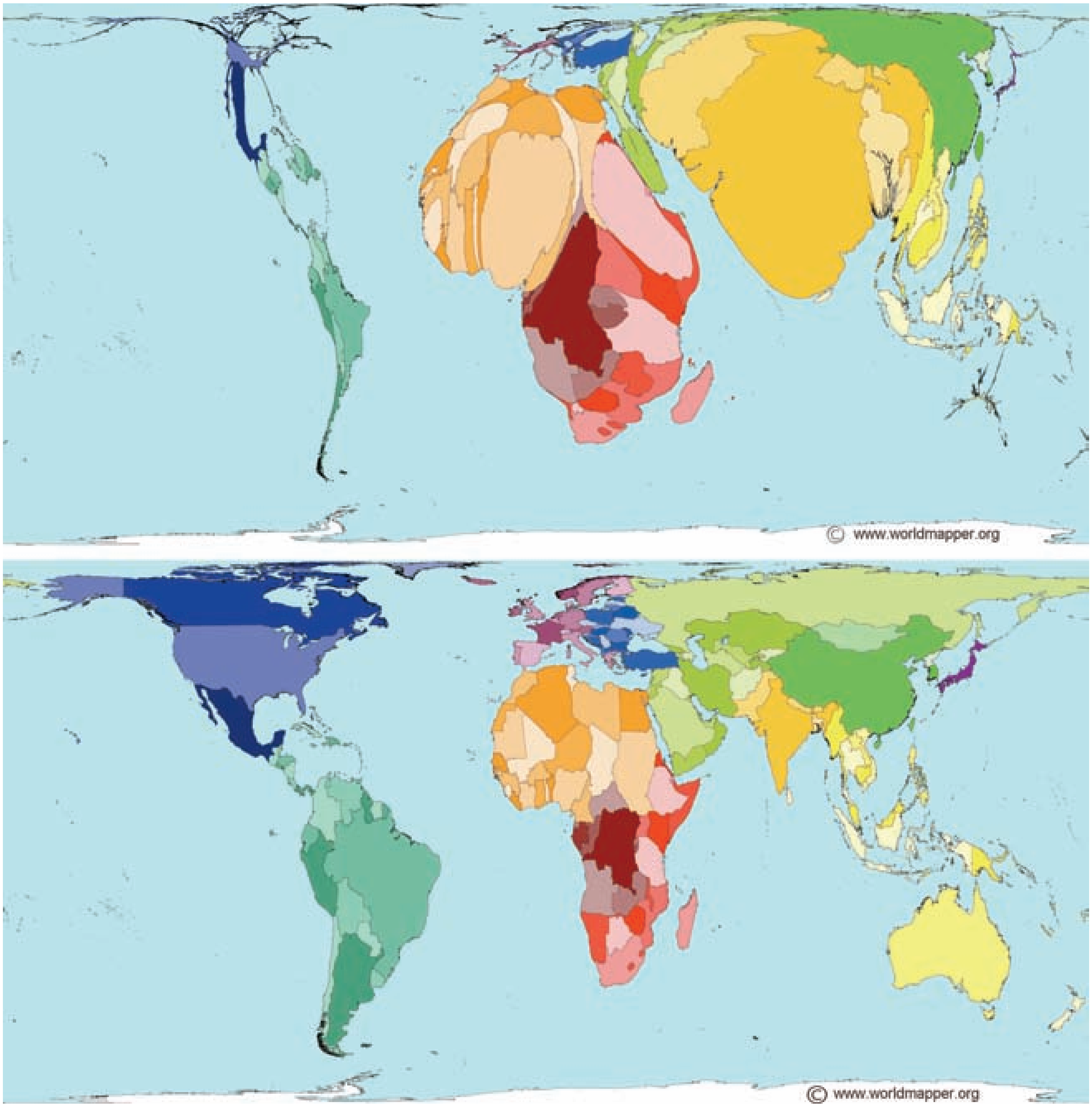



FIG. 960. CARTOGRAM COMPARED WITH TRADITIONAL EQUIVALENT MAP PROJECTION. In the map of infant mortality (top), the size of each territory indicates the number of deaths during the first year after birth. In the map of land area (bottom), the size of each territory represents exactly its land area in proportion to the others. Both maps are taken from the Worldmapper project.
Size of each original: 10.9 × 23.2 cm. © Copyright Benjamin D. Hennig (Worldmapper Project).

showing the direction of routes or flows, with no indication of the magnitude.

Early computer-based flow mapping routines (e.g., Kern and Rushton 1969) were perhaps more simplistic, typically depicting simple as-the-crow-flies connections rather than actual flow routes—in transportation studies, these maps typically consisted of a multitude of "desire lines," each linking an individual's place of residence with his or her place of employment (Potts and Oliver 1972, 8–10). Later work by Tobler (1987) integrated an indication of actual flow routes with a range of design options. Subsequently, computer scientists and infor-


FIG. 961. COMPARISON BETWEEN THE CHOROPLETH AND CARTOGRAM SYMBOLIZATION METHODS. Choropleth (left) and cartogram (right) maps showing the electoral votes cast by state for the 2008 U.S. presidential election candidates.
From "Election 2008," *New York Times*, 1 December 2008.

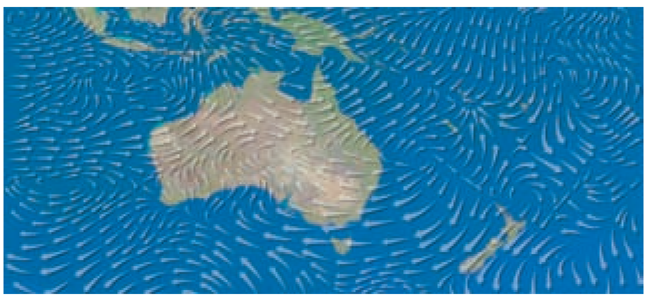


FIG. 962. AN AUTOMATED METHOD FOR FLOW MAPPING. Depiction of wind direction and magnitude over Australia. The method utilizes an energy measure (lower energy equates to higher quality) to improve the position of flow lines.
Size of the original: 8 × 17.8 cm. From Turk and Banks 1996, 458 (fig. 7). © 1996 Association for Computing Machinery, Inc. Reprinted by permission.

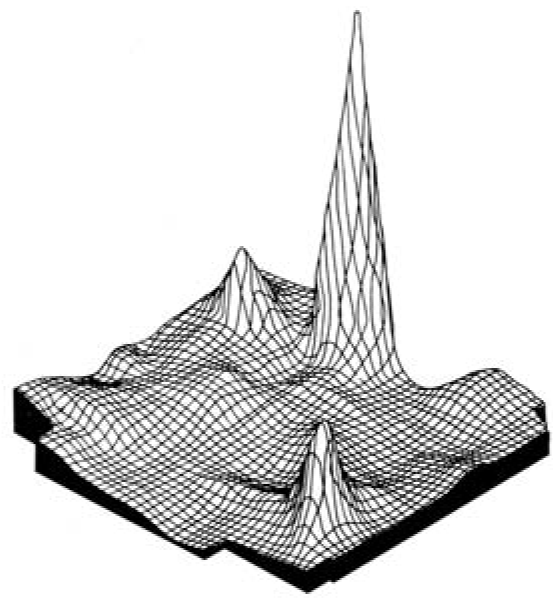


FIG. 963. A 3-D MAP OF POPULATION DENSITY IN CENTRAL KANSAS. A variant of this smoothed statistical surface appeared on the cover of *Science*, 18 November 1966.
Size of the original: 6.8 × 7.4 cm. From George F. Jenks, "Generalization in Statistical Mapping," *Annals of the Association of American Geographers* 53 (1963): 15–26, esp. 19 (fig. 7). Reproduced by permission of Taylor & Francis.

mation visualization experts developed intriguing flow mapping methods. For example, Greg Turk and David Banks (1996) utilized an energy measure, whereby lower energy equates to higher quality, to improve the position of flow lines (fig. 962).

THREE-DIMENSIONAL MAPPING. Maps consisting of obliquely viewed prisms can usually preserve most data-symbol relations insofar as a data value twice that of another is represented by a prism twice as tall; three-dimensional fishnet surface maps, which portray relative slope and a surface's peaks and valleys, can be equally eye catching (fig. 963). In spite of these advantages, neither of these methods was encountered in the systematic survey of the two geographic journals, although they were sometimes discussed in cartographic textbooks. For instance, Raisz included several examples in his 1938 *General Cartography*, and Robinson's classic *Elements of Cartography* used them to depict the three-dimensional nature of the statistical surface.

Before digital computing became readily available in the mid-1960s, the limited use of three-dimensional maps probably reflected not only the difficulty of constructing them but also the fact that low areas were often hidden behind higher areas in the foreground. While rotating the map could sometimes minimize hiding, some readers were confused by an unusual map orientation. Although Jenks and Brown (1966) proposed a crossed-slit anamorphoser (an optical device that transforms photographic images in a fashion similar to a pinhole camera) as an efficient way to construct three-dimensional maps, their novel approach and active promotion of three-dimensional maps did not lead to a notable increase.

Even though computer-based three-dimensional mapping routines, such as SYMVU, released by the Harvard Laboratory for Computer Graphics and Spatial Analysis in 1969, made three-dimensional maps easier to produce, they never became common, probably because of the blockage and orientation problems noted above and their infrequent use in earlier decades. A serious limitation of many early computer-based three-dimensional mapping routines was the lack of suitable options for shading the sides of three-dimensional surfaces, necessary for a distinctive and aesthetically pleasing three-dimensional appearance.

In 1980 Harold Moellering demonstrated how sophisticated computer graphics hardware could be used to explore three-dimensional surfaces in real time. Since others did not have his expensive hardware, he distributed a video with animations of attractive colored three-dimensional prism maps. With the release of software such as 3D Analyst in the late 1990s, users of GIS software were able to create interactive three-dimensional maps, just as Moellering did, and with an extensive range of design options. Although the survey of two prominent geographic journals suggests that three-dimensional thematic maps rarely appeared in print, specialized hardware available at century's end enabled the creation of true three-dimensional computer maps by taking advantage of people's ability to see stereoscopically. Early in the twenty-first century this technology was well received by a broad range of geoscientists (Johnson et al. 2006).

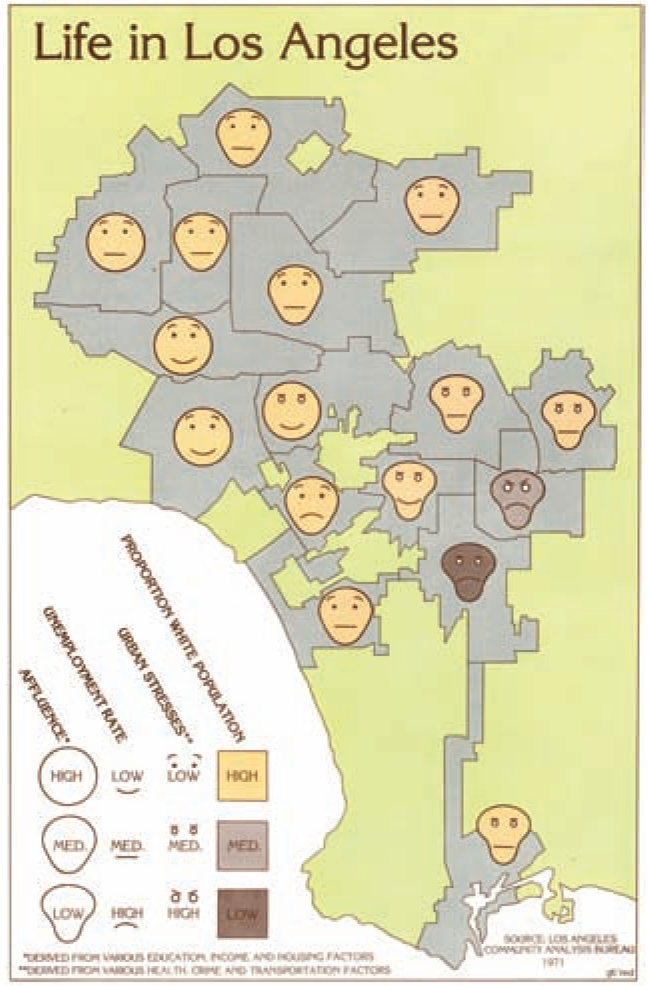



FIG. 964. EARLY MULTIVARIATE MAP THAT UTILIZED CHERNOFF FACES. *Life in Los Angeles* [Northridge: California State University, 1977], by Eugene Turner, 1:264,000. Size of the original: 27.1 × 17.5 cm. Map courtesy of Eugene Turner.

MULTIVARIATE MAPPING. Like cartograms and dasymetric maps, multivariate thematic maps were largely a twentieth-century phenomenon. Robinson's review of the early history of thematic mapping (1982) reported no examples of multivariate mapping in the nineteenth century, and Friendly (2008, 30–36) found only a few examples from the same period, most notable Francis Galton's 1863 multivariate weather chart and selected maps from the U.S. Census Bureau's *Statistical Atlas of the Ninth Census* for 1870. An important question in the design of multivariate maps is whether to use individual maps for each attribute or show all attributes at once on a single map. The various novel implementations of the single-map approach (Slocum et al. 2009, 327–54) include the U.S. Bureau of the Census's bivariate mapping technique (see fig. 85); Herman Chernoff's association of facial features with various attributes in the 1970s (fig. 964); and Christopher G. Healey's use of small three-dimensional bars called pexels, which could be varied in height, spacing, and color, in the 1990s (fig. 965). When separate maps were used for each attribute, the result was termed a small multiple. Although the notion of small multiples had been around since at least the nineteenth century, Edward R. Tufte (1990, 33) championed their use by noting that they "move to the heart of visual reasoning . . . . enforc[ing] local comparisons within our eye span." Tufte (1983, 51), who was a vociferous proponent of multivariate mapping, argued

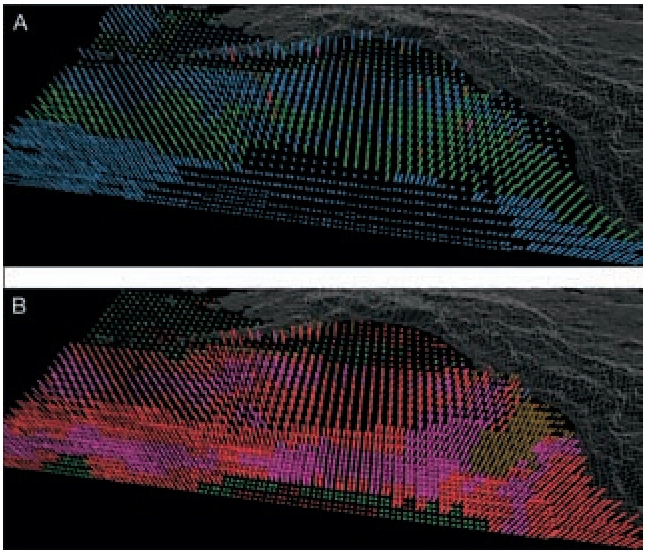



FIG. 965. PEXELS USED TO DEPICT MULTIVARIATE DATA. The northern Pacific Ocean in February (A) and in June (B). Color of the pexels indicates the density of plankton (from low to high density, the scheme is blue, green, brown, red, and purple); height of the pexels depicts the ocean current (a taller pexel equals a stronger current); and spacing of the pexels depicts sea surface temperature (a tighter spacing indicates a warmer temperature).
Image courtesy of Christopher G. Healey.

that "graphical excellence is nearly always multivariate" (fig. 966).

## Design and Construction Issues in Map Animation and Data Exploration

The dynamic nature of animated maps and data exploration software raised new design issues for thematic maps. Mark Harrower (2003), who summarized key characteristics of animated maps and proposed ways to enhance their design, noted that animated maps were often so complex that readers had trouble understanding them. One solution was to filter, smooth, or aggregate the data, for example, when data for a choropleth map were aggregated into only two or three classes, rather than five or more. Other solutions included allowing users to turn data on and off and to control the tempo of the animation. It was clear that animated thematic maps required a simpler design than their nonanimated counterparts.

In a sense, data exploration software has some of the same problems as map animation software because maps are constantly being changed, albeit under the control of the researcher exploring the data. For instance, a researcher might highlight (brush) a set of enumeration units on a map and note where these units appear on both a bivariate scatterplot and a parallel coordinate plot (a graphical method that displays all the data on a single graph). Because researchers interacting with data do not have time to constantly reappraise the design, the design must be intuitive.

In sum, the twentieth century was characterized by dramatic changes in thematic mapping. It began with maps being created entirely with manual methods, evolved to a point at which maps were completed with the assistance of computing technology, and ended with the creation of digital maps produced entirely via the web. The four distinctive eras separated at approximately 1958, 1976, and 1990 indicate accelerated change toward the end of the century. These developments are summarized in figure 967.

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SEE ALSO: Academic Paradigms in Cartography; Atlas: Thematic Atlas; Bertin, Jacques; Cartogram; Census Mapping; Choropleth Map; Dasymetric Map; Demographic Map; Perception and Cognition of Maps: Subject Testing in Cartography; Projections: (1) World Map Projections, (2) Regional Map Projections, (3) Projections Used for Statistical Maps; Robinson, Arthur H(oward); Statistical Map; Statistics and Cartography

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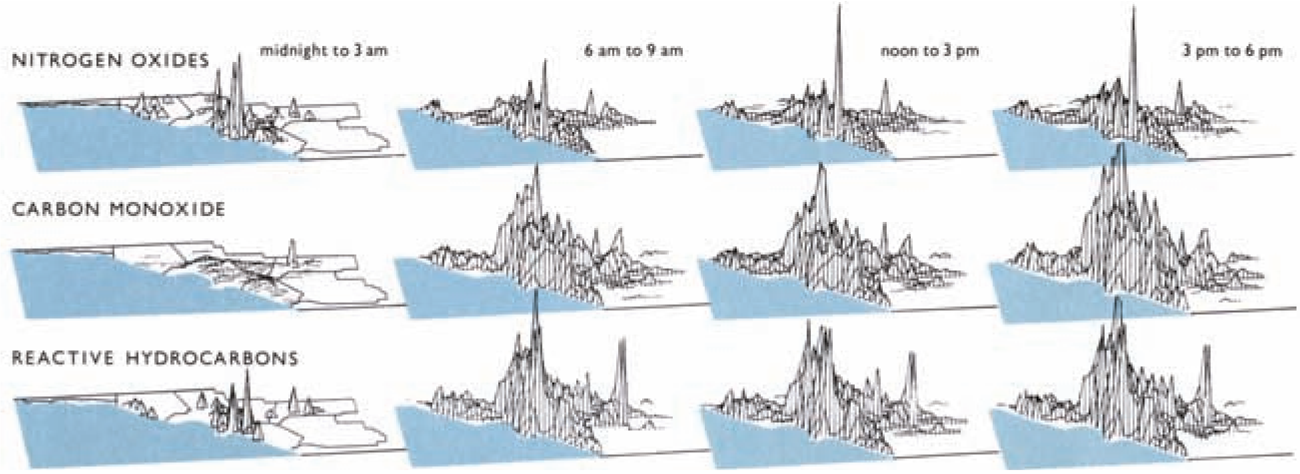


FIG. 966. EXAMPLE OF A SMALL MULTIPLE PROMOTED BY EDWARD R. TUFTE. Size of the original: 6.2 × 17 cm. From Tufte 1990, 28. Permission courtesy of Graphics Press LLC, Cheshire.


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| | | |
|---|---|---|
| Precomputer | 1903 | First contiguous equal-area cartogram |
| | 1906 | *Atlas of Canada* |
| | | Eckert creates six pseudocylindrical projections |
| | 1911 | Semënov-Tyan-Shanskiy introduces dasymetric mapping |
| | 1922 | First edition of *Goode's School Atlas* |
| | | Goode's homolosine interrupted projection |
| | 1925 | Eckert's *Die Kartenwissenschaft* |
| | | First academic cartography department |
| | 1930 | Beck produces pioneering linear cartogram |
| | 1933 | Work begins on *Bol'shoy sovetskiy atlas mira* |
| | 1934 | Raisz develops rectangular statistical cartogram |
| | 1935 | Leroy lettering system appears |
| | 1937 | Zip-A-Tone appears |
| | 1938 | Raisz's *General Cartography* |
| | 1944 | Harrison's *Look at the World* |
| | 1952 | Robinson's *The Look of Maps* |
| | 1953 | Robinson's *Elements of Cartography* |
| | | Term "thematic map" first used |
| | 1956 | Flannery's correction factor developed |
| Mainframe | 1959 | Tobler's "Automation and Cartography" |
| | 1961 | *International Yearbook of Cartography* |
| | 1963-64 | Fisher develops SYMAP |
| | 1964 | *Canadian Cartographer* and the *Cartographic Journal* |
| | 1967 | Bertin's *Semiologie Graphique* |
| | 1969 | U.S. Census Bureau produces automated dot map |
| | | SYMVU developed at Harvard Lab |
| | 1971 | Jenks and Caspall's automated natural breaks classification |
| | 1973 | Tobler produces automated unclassed map |
| | | Chernoff uses faces to depict multivariate data |
| | 1974 | First AUTO-CARTO conference |
| | | U.S. Census Bureau's bivariate choropleth map |
| Desktop | 1977 | First desktop computers |
| | 1981 | Kidron and Segal's *State of the World Atlas* |
| | 1982 | First *USA Today* weather maps |
| Internet | 1990 | Tufte promotes small multiples |
| | 1991 | Launch of the World Wide Web |
| | | Dorling develops cartogram based on uniformly shaped symbol |
| | 1996 | Turk and Bank's flow map based on an energy measure |
| | 1997 | Brewer and colleagues develop new guidelines for selecting color schemes for choropleth maps |
| | 1998 | Healey uses pexels for multivariate data |

FIG. 967. TIMELINE SUMMARIZING DEVELOPMENTS IN THE DESIGN AND CONSTRUCTION OF THEMATIC MAPS IN THE TWENTIETH CENTURY.

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***Thrower, Norman J(oseph) W(illiam).*** Norman J. W. Thrower was part of the cadre of academic cartographers trained in the military during World War II. He was born in Crowthorne, England, on 23 October 1919. He attended art school but was conscripted into the British Army early in the war. Accepted for training in the Survey of India, he spent the war years in India doing mapping and photogrammetry. At the end of his service, he returned to England, where he joined the Directorate of Overseas Surveys and worked on photogrammetric surveys.

In 1947 Thrower immigrated to the United States, where he had obtained a position at the Virginia Geographical Institute at the University of Virginia. Erwin Raisz was one of his instructors and a major influence on his work. While at the Institute he also worked with Richard Edes Harrison and Armin K. Lobeck.

After receiving a BA from the University of Virginia in 1953, Thrower studied under Arthur H. Robinson at the University of Wisconsin–Madison, where he received his PhD in 1958 for a dissertation on cadastral mapping, later published as *Original Survey and Land Subdivision* (1966). In 1957, he joined the geography faculty at the University of California, Los Angeles (UCLA), where his primarily teaching responsibilities focused on overhead imaging, cartographic design, and the history of cartography and exploration.

Although Thrower's best-known contributions are in the history of cartography, he was also involved in modern cartography. He created map illustrations for numerous books, some illustrated with pen and ink sketches; his map *Cyprus: A Landform Study* (1960) was a tour de force in the art of cartography. He wrote on relief representation and the use of satellites in geographic mapping (*Satellite Photography as a Geographic Tool for Land Use Mapping of the Southwestern U.S.*, 1970), and was one of the first to write on animated cartography (articles in 1959 and 1961). During the 1960s he served as map editor for the *Annals of the Association of American Geographers*, for which he authored and edited map inserts. He also edited or advised on several maps and atlases. One of the best known was *Man's Domain: A Thematic Atlas of the World* (1968, 1970, and 1975).

Among the more than 200 items in Thrower's bibliography, the two best known are his edition of *The Three Voyages of Edmond Halley in the* Paramore, *1698–1701* (2 vols., 1981), and *Maps & Civilization: Cartography in Culture and Society* (1996, 1999, and 2007), first published as *Maps & Man: An Examination of Cartography in Relation to Culture and Civilization* in 1972. He also wrote scholarly essays on Samuel Pepys, William H. Emory, Pīrī Re'īs, Sir Francis Drake, and Prince Henry of Portugal.

From 1975 to 1990, Thrower was in charge of a variety of special projects at UCLA. He was president of the California branch of the British-California commission formed to celebrate the 400th anniversary of Drake's circumnavigation of the world (1975–81); director of the William Andrews Clark Memorial Library (1981–87); and director of the Columbus quincentenary program (1989–92). Each of these projects brought celebrated scholars in cartography and history to campus for seminars and colloquia.

Thrower supervised numerous doctoral students at UCLA, including John Estes and John Jensen in remote sensing, Patricia Caldwell on television news maps, and Judith A. Tyner on persuasive cartography.

JUDITH A. TYNER

SEE ALSO: Animated Map; Histories of Cartography; Relief Depiction: Relief Shading; Remote Sensing: Earth Observation and the Emergence of Remote Sensing; Robinson, Arthur H(oward); Terrain Analysis and Cartography

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***Tidal Measurement.*** Most people will be familiar with the twice-daily (or daily at some locations) rise and fall of the ocean tide. These changes in water level have been known since antiquity and are primarily due to the gravitational forces of the moon and sun, the latter force being approximately 40 percent as large as the former. In fact, the ocean's water level can vary for many other reasons (Pugh 1987), but for present purposes "tidal" and "water level" changes are treated as similar.

This article is concerned with how tidal elevations have been measured in the past, primarily during the twentieth century, and how they were made at century's end (fig. 968). (It does not discuss the measurement of tidal currents, which is less relevant to cartography.) It was not until the seventeenth and eighteenth centuries that the amplitudes and timings of tidal elevations began to be measured systematically (Cartwright 1999). Many measurements in the eighteenth century in Europe took the form of observations of the heights and times of high waters (Woodworth 1999; Wöppelmann et al. 2008). Most dock entrances were equipped with what were then called tide gauges, graduated markings on the dock walls to indicate water depth over the dock sill, by means of which extended observations of tidal levels could be made. Alternatively, wooden measuring rods called tide poles or tide staffs would have been used.

Such visual measurements would have been less ac-

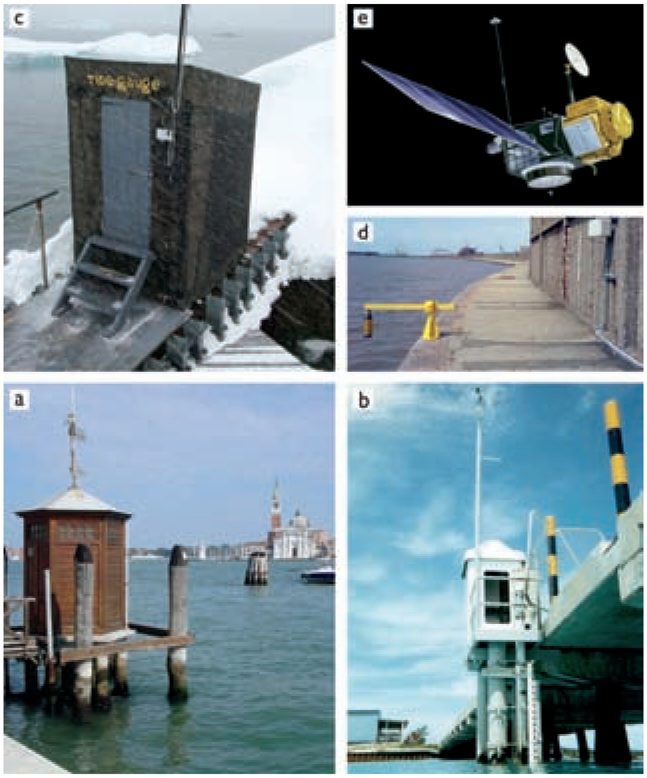


FIG. 968. TIDE GAUGES FOR MEASURING SEA LEVEL FROM AROUND THE WORLD. (a) Float and stilling well gauge at the Punta della Salute, Venice (photo credit: P. A. Pirazzoli); (b) acoustic gauge at Kiribati, South Pacific (photo credit: National Tidal Centre, Australia); (c) float gauge at Vernadsky, the site of the longest sea level record in Antarctica (photo credit: British Antarctic Survey); (d) radar tide gauge installation at Liverpool, U.K. (photo credit: National Oceanography Centre Liverpool); and (e) TOPEX/Poseidon radar-altimeter satellite. This composite figure was constructed by Lea Crosswell of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, and has been copied with permission from John A. Church et al., eds., *Understanding Sea-Level Rise and Variability* (London: John Wiley & Sons, 2010), 7 (fig. 1.5). Permission courtesy of John Wiley & Sons, Inc.

curate in the presence of waves, especially at night during winter. Robert Moray (1665–66) had suggested the use of a stilling-well to dampen the waves and enable more accurate measurement of what is called the still water level. In its simplest form, a stilling-well consists of a vertical tube open at the bottom so that water level inside the tube is, on average, the same as that outside. However the measurements were made, high waters were of greater importance for dock operations than low waters, and the former were easier to acquire, low-water measurements requiring the use of a second measuring scale some distance offshore.

By the 1830s, automatic (or self-registering) tide gauges had been developed that could record the full tidal curve, not just the high and low waters. These instruments took the form of a stilling-well inside of which was a float connected by a wire run over pulleys to a pen that moved up and down as the tide rose and fell, thereby drawing a tidal curve on a rotating drum of paper. The resulting continuous water level measurements could then be expressed relative to the height of a benchmark on the nearby land. The first such tide gauge is often credited to the installation at Sheerness, England (Palmer 1831; Pugh 1987), although the same ideas were being pursued at many places at around the same time. The first self-registering tide gauge in the United States was made by Joseph Saxton for the U.S. Coast Survey in 1851. By the end of the nineteenth century, similar instruments had been installed at ports around the world. Float and stilling-well gauges have provided most of our knowledge of tides as well as the historical record of nontidal water level variations, including the evidence for sea level rise over the past two centuries contained within the global data set of the Permanent Service for Mean Sea Level (PSMSL), established in 1933 and based in Liverpool. These gauges still constitute a large fraction of the gauges in the global network called the Global Sea Level Observing System (GLOSS) (IOC 2006).

New tide gauge technologies developed since 1970 had replaced float-based tide gauges at many locations by century's end. These newer instruments are based on acoustic, radar, or subsurface pressure measurement and, when combined with either telephone or satellite telemetry, have enabled real-time monitoring of water level. Such a capability is especially important to operational flood warning in areas prone to storm surges or tsunamis. At locations where float and stilling-well gauges remained in operation, their clockwork chart recorders were usually replaced by electronic shaft encoders, thereby also enabling real-time monitoring. In 2006 the Intergovernmental Oceanographic Commission (IOC) reviewed each type of gauge, together with standards for measurement, including the essential maintenance of a local benchmark network.

Once a water level record was established for an extended period (e.g., a month or year, or even a lunar nodal period of 18.6 years), the data could be analyzed to extract information on the characteristics of the local tide (Parker 2007). Prior to the invention of digital computers, the fairly simple but time-consuming hand calculations involved in such analyses made use of arithmetical filters designed to isolate the main individual components of the tide. These calculations were made in the world's main hydrographic and oceanographic institutes by large teams of people called "computers." Since the 1960s that sort of computation has been performed readily by a tidal analysis software package. In most tidal analyses, information on the tide is expressed as a sum of harmonic constituents, of which the largest are usually $M_2$ and $S_2$, the main twice-daily tidal components due to the moon and sun respectively. If most of the main constituents are known accurately (typically 50–100 constituents being required), the total tide can be predicted forward and backward (hindcast) for at least several hundred years, a timescale for which the local tide can be considered similar to that at the time of the measurements. (This situation might not pertain to, for example, a waterway the dimensions of which may have changed significantly). These predictions were also taken over by digital computers, although earlier in the twentieth century they were carried out by elegant clockwork machines, which were a form of analog computer (Cartwright 1999, 88–109, 154–77). Tidal predictions have many applications to navigation, port operations, and coastal users, whereas hindcasts are needed for study of the tides during important events in history.

Tidal measurements and analyses enable the definition of the various datums employed in marine (or hydrographic) and terrestrial mapping. For example, mean sea level (MSL) at Newlyn, England, over a six-year period from May 1915 to April 1921 defines Ordnance Datum Newlyn (ODN) to which all heights in the United Kingdom are referred. Similar datums defined in terms of, or constrained by, MSL measurements have been employed for many years in most other countries—the Normaal Amsterdams Peil (NAP) in the Netherlands, for instance, and Nivellement général de la France (NGF) in France—and they were still important at century's end, though destined to be gradually superseded through global height unification and the use of precise geoid information. The tidal constituent information becomes important when secondary datums are defined. For example, the analysis will provide an estimate of highest and lowest astronomical tide (HAT and LAT), the water levels above and below MSL that will not be exceeded by the lunar and solar astronomical forces alone (levels could of course be exceeded due to other factors such as the action of winds and air pressure fluctuations). A number of other, somewhat archaic datums (e.g., mean high-water springs, mean low-water neaps) are defined and listed for each location in the regular tide table publications of national hydrographic offices. In most countries (but not the United States), the reference level used for nautical charts, called the chart datum, has been set equal to LAT, and this procedure was adopted in the 1990s as a standard of the International Hydrographic Organization (IHO), which maintains a working group on this topic. However, other chart datums remained in use by other countries, a significant example being the United States, where mean lower low waters was a reference level for charts. The practice of defining a consistent national chart datum in this way has replaced the use of ad hoc local datums, which largely represented low waters and were sometimes defined relative to dock sill heights (e.g., Liverpool Bay Datum for the Irish Sea).

Some of the other tidal-related datums were of greater utility than others. For example, a tidal-related datum has been used in all countries to determine ownership of intertidal areas, although different countries used different datums (Pugh 1987, 440–43). The United States used mean high water as the legal definition of the shoreline. Besides indicating the legal shoreline, high-water datums (e.g., mean high water or mean high-water springs) are of interest to biological and environmental studies in the coastal zone (e.g., saltmarsh formation).

Many short-term tidal measurements are undertaken during bathymetric surveys of shallow-water areas, often in remote regions. In the nineteenth and early twentieth centuries, the measurements would most likely have employed simple tide poles with a vertical graduated scale, as recommended to captains of British Royal Navy ships at that time, although it is conceivable that they could have comprised an upright stilling-well tube for filtering out wave action (Beechey 1849; Whewell 1849). By century's end many inexpensive gauges of various types could be readily deployed depending on the local environment.

The last few decades of the twentieth century saw the development of bottom pressure recorders, which provided first measurements of tides away from the coast and in some of the deepest parts of the ocean (Cartwright 1999, 206–13) (fig. 969). In addition, the launch of the TOPEX/Poseidon altimeter satellite in 1992 initiated the first precise quasi-global tidal measurements from space, since complemented by data from the Jason-1, Jason-2, and other altimeter missions. These data sets have all been analyzed in a similar way to study coastal tide gauge information, with the result that oceanographers and geophysicists in the early twenty-first century had excellent global maps of the main constituents of the ocean tide useful for diverse applications (e.g., Lyard et al. 2006), and other high-technology methods for tidal measurement were under investigation, e.g., Global Positioning Systems (GPS) on ocean buoys and GPS-reflectometry (IOC 2006). In addition, various forms of ocean instrumentation not only provided measurements of tidal currents but also measured the internal tides that occur at the interfaces of different density layers within the ocean.

PHILIP L. WOODWORTH

SEE ALSO: Coastal Mapping; Figure of the Earth; Law of the Sea; Marine Charting: Overview; Topographic Mapping

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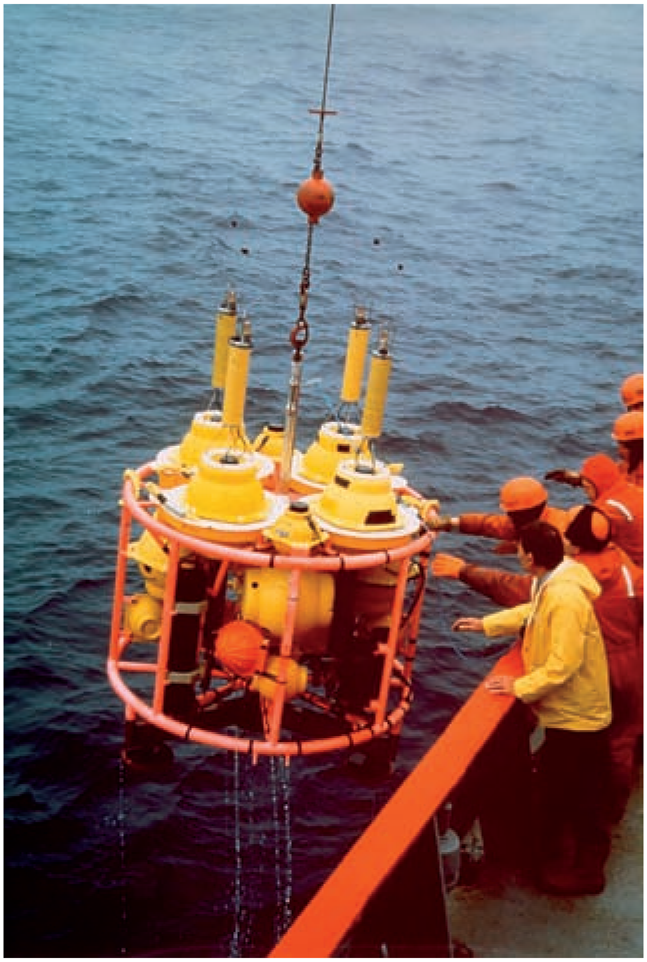

FIG. 969. DEPLOYMENT OF A DEEP-SEA TIDE GAUGE (BOTTOM PRESSURE RECORDER). The recorder sits on the sea bed recording pressure changes due to the tide. Photo credit: National Oceanography Centre, Liverpool.

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***Time, Time Geography, Temporal Change, and Cartography.*** "Time" in cartography can refer to either the mapmaking process, which includes the dates of compilation and printing, or to the mapmaker's attempts to depict time itself on the map and thus represent processes and geographic change. Despite the common assumption that maps do not have a temporal component, cartographic scholars have chastised mapmakers for distilling time out of maps and thereby creating images that falsely portray an eternal present and eliminate the concept of process or datedness (Muehrcke 1998, 160–78; Vasiliev 1997). As cartographic educator Phillip Muehrcke observed, "By making static maps of relatively static features, cartographers may simplify their job, but they largely ignore the fact that time is a vital part of the map user's world." Since most maps are out of date even before they are printed, cartographers have tended to map stable phenomena, which not only "gives their maps greater longevity if not greater utility [but] also shifts the burden of dealing with environmental temporality to you, the map user" (Muehrcke 1998, 162, 160). Until the late 1960s maps were not only produced by hand but also confined to paper, which made updating difficult and slow. As a result, prior to 1970 few maps attempted to depict either time-sensitive data (e.g., current weather conditions) or explicitly represent temporal processes. However, in the last decade of the twentieth century the combined opportunities afforded by the personal computing revolution (for making and viewing maps) and the Internet (for collecting data and distributing maps) made it possible for cartographers to gather and map time-sensitive data, such as real-time traffic conditions, as well as utilize new mapping techniques for depicting time and geographic processes, such as the interactive map.

How cartographers in the twentieth century have conceptualized and represented time is intertwined with (1) the migration to digital map production, (2) the concurrent development of theories and practices related to temporal geographic information systems, and (3) the rapid increase in digital time series geographic data available for mapping (e.g., continuous output from global sensor networks). This history is also paralleled—and in part driven by—a larger interest by geographers in studying geographic processes, and not merely spatial states, in both the human (e.g., phenomenology) and physical (e.g., climatology) sciences. Although beyond the scope of this entry, it is worth noting that Western mapmakers had been experimenting with the explicit depiction of time on maps since at least the middle of the 1700s (e.g., tide maps, travel time maps), and that the maps of some non-Western cultures (e.g., Aztec cosmographies, Polynesian stick charts) have never separated space and time.

Throughout the twentieth century, mapmakers have employed three basic techniques for depicting change on static maps: dance maps, chess maps, and change maps (Monmonier 1990, 36–38). Dance maps emphasize change in position of one or a few entities, such as the westward march of the center of population of the United States, or the migration routes of birds along flyways with corresponding dates. Chess maps show two (or more) time periods side by side, such as before-and-after comparisons, and may show change in position (implied movement), existence (e.g., arrival of a disease), or attribute (e.g., increasing population). On chess maps the reader must infer where the changes have occurred by scanning between the two images, since the changes are not explicitly shown. Both dance maps and chess maps were used long before the twentieth century and include famous examples such as Galileo's nightly plots of the relative positions of Jupiter's moons: a series of small multiples implying, with profound consequences, movement. Change maps are a third technique for depicting time and are created by taking the difference between time periods. They do not map the original data but rather the change itself in those data (e.g., twenty-four-hour temperature change maps). Change maps are somewhat limited because they capture only two time periods and the original data cannot be retrieved.

When time is explicitly depicted on maps it is most often seen merely as an attribute of features in space (e.g., date of a battle). However, geographer Brian J. L. Berry's (1964) space-time matrix elevated the status of time to that of a structuring dimension, on par with space itself, in which all things were located (and thus referenceable) both in time and in space (fig. 970). The frontal axes of his geographic matrix describe location and activity (e.g., land use), while the depth axis samples time at regular intervals. By stacking multiple time slices on top of one another, Berry outlined an approach for representing geographic processes. Other space-time frameworks have been proposed in the years since, including the declaration of David F. Sinton (1978) that the basic components of all geographic information are (1) time, (2) location, and (3) theme, leading to Donna J. Peuquet's "what-when-where" triad model (1994).

Maps depicting isochrones, or lines of equal travel time, have been produced since the late 1800s, reflecting the increased mobility and interconnectedness of

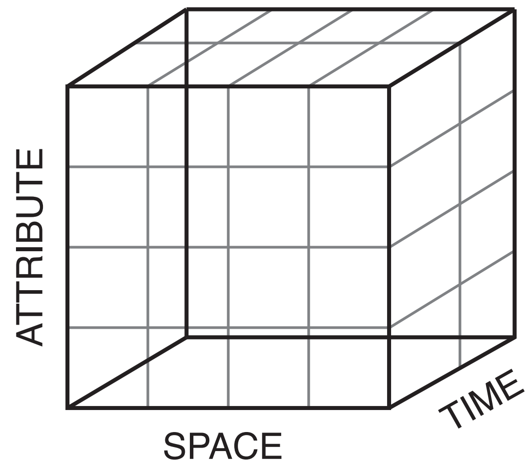


FIG. 970. SPACE-TIME MATRIX. Based on Berry's influential 1964 geographic matrix, this is one framework for representing geographic processes.

the modern era, and the common and intuitive use of time as a unit of distance (e.g., "a day's journey," or "it is five minutes from here"). Examples include Francis Galton's *Isochronic Passage Chart for Travelers* (1881) and Charles Oscar Paullin's *Atlas of the Historical Geography of the United States* (1932). Some of the first academic cartographers to discuss the utility of isochrones—and how to construct them—include Erwin Raisz (1948, 262–64), Waldo R. Tobler (1961, esp. 100–106), and William Bunge (1962, 52–61).

Isochronic maps keep geographic space constant and adjust time to fit space by adjusting the placement of the isolines. By contrast, temporal cartograms transform geographic space in order to hold time constant. For example, Tobler's pioneering work on analytical cartography, beginning in the 1960s, experimented with reprojecting geographic space into both "travel time" space and "travel cost" space so that one unit of distance on the map corresponded to one unit of time or cost. An example focused on airline travel into or out of San Francisco showed Madison, Wisconsin, as 219% as far as Milwaukee to reflect a more than doubling of airline tickets prices despite a mere ninety-mile distance between the two Wisconsin airports (Tobler 1993, unpaginated).

Just as there are different kinds of spatial data (e.g., points, lines, areas) and different levels of measurement (e.g., nominal, ordinal, interval, ratio), so too have geographers and cartographers proposed different kinds of time. Perhaps the most basic is the distinction between linear and cyclic concepts of time, reflected in the two most common designs of temporal legends for animated maps (linear time line temporal legends, and cyclical daily/weekly/yearly temporal legends). Economist Walter Isard (1970), who founded regional science, characterized four types of time: universe time, which is absolute and linear; cyclic time such as diurnal patterns; ordinal time, which records the relative ordering of events; and time as distance, in which the spatial dimension is used to represent time. Geographer Peter Haggett (1990, 142–62) described four types of temporal change in geography: constants (i.e., no change), trends (i.e., linear change), cycles (i.e., recurring patterns), and shifts (i.e., sudden changes). In summarizing this and other work on time, Irina Ren Vasiliev (1997) found five basic categories of time on maps:

1. Moments: the dating of an event in space (e.g., 16 March 1971);
2. Duration: the continuance of an occurrence in space (e.g., how much time it takes for an event to occur, what happens within a certain period of time, or what changes from one time to another);
3. Structured Time: the organization or standardization of space by time (e.g., world time zones);
4. Time as Distance: the use of time as a measure of distance (e.g., travel time maps); and
5. Space as Clock: spatial relations as a measure of time (e.g., temporal cartograms).

*Moments* are based on a notion of absolute time that references events against an external, linear framework against which all things can be placed or referenced. By comparison, *duration* often invokes a sense of relative time in which time has meaning only as a product of relations between moments.

James M. Blaut (1961), who urged fellow geographers to study processes, not spaces, acknowledged that measuring process was more difficult then measuring time and space separately. This call to a new kind of geography took root during the 1960s and 1970s with the development of time geography, a field strongly associated with Swedish geographer Torsten Hägerstrand (1970), and later his graduate students, who were concerned with space-time geographies of individuals (rather than populations) and the way in which space and time create and constrain human behaviors (fig. 971). Despite a waning interest in time geography after 1985, Hägerstrand's map of a space-time path of one individual's movements through a typical day is perhaps one of the most enduring images of this field of study. When used as a tool to forecast future trajectories or behaviors, a cone demarcates all future potential locations of the individual, the size of which is based on the mode of

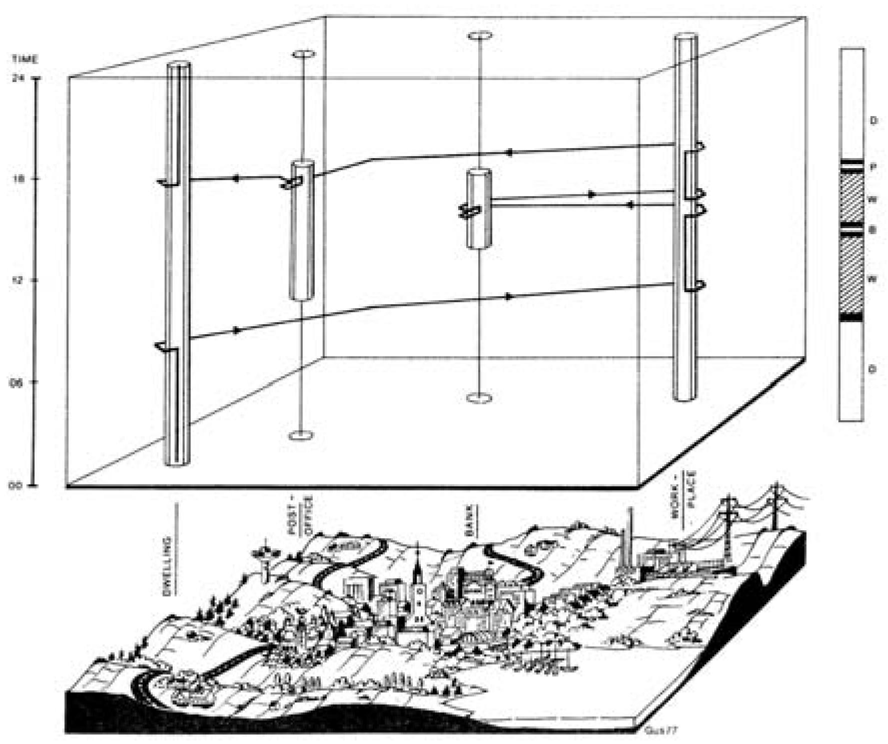


FIG. 971. INDIVIDUAL'S PATH IN A TIME-SPACE COORDINATE SYSTEM. Time geographers often mapped "personal geographies" of individuals in order to better understand how our collective movements across space and time inform place making.
Size of the original: 10 × 12 cm. From Bo Lenntorp, "A Time-Geographic Simulation Model of Individual Activity Programmes," in *Human Activity and Time Geography*, vol. 2 of *Timing Space and Spacing Time*, ed. Tommy Carlstein, Don Parkes, and Nigel Thrift (London: Edward Arnold, 1978), 162–80, fig. 1. Permission courtesy of Bo Lenntorp.

travel. In this instance, the *x*, *y* dimensions are space and the *z* dimension is time.

Since 1970, map animation has become a favorite tool for depicting time on maps. Animations are scale models of both space and time and intuitively use time to represent time (e.g., one second of animation corresponds to one week of data). As early as the 1930s, cartographers experimented with animated map displays, although it wasn't until the development of computer-based techniques in the 1970s that animated maps became relatively easy to produce. The arrival of the affordable desktop computer in the 1970s—and the exponential growth in the power of those computers in the last twenty-five years of the century—coupled with the rise of the World Wide Web since 1994 meant that cartographers finally had a method for producing animated maps and map users a method for finding, retrieving, viewing, and interacting with those maps.

MARK HARROWER

SEE ALSO: Animated Map; Atlas: Historical Atlas; Historians and Cartography; Narrative and Cartography

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**Times *Atlas of the World*.** Widely considered the finest English-language general world atlas of the twentieth century, the *Times* atlas of the world was born out of the tradition of German *Handatlases* of the previous century. In 1895 the *Times* newspaper of London published the first atlas to use its name. It was a new edition of Cassell's *Universal Atlas* of 1893, which was itself an English edition of Richard Andree's *Allgemeiner Handatlas* of 1881, although the German atlas was substantially different. *"The Times" Atlas* of 1895 included 117 plates of maps, of which 60 covered Europe, reflecting the Eurocentricity and colonial aspirations of its time. A handful of thematic maps and a generous place-name index (130,000 items) completed the volume. The subsequent version, *The Times Survey Atlas of the World*, was prepared over fifteen years by the Edinburgh Geographical Institute of John Bartholomew & Son, the beginning of a long association between mapmaker and publisher. This appeared first in parts and then as a complete volume in 1922. Thematic maps played a larger role, relief was portrayed by contours and coloring, and coverage of the non-European world was expanded to 74 of 112 plates. A second volume, the *Index-Gazetteer*, contained 200,000 entries and became a major reference source in its own right.

The changing view of the world following World War II called for a new approach, and between 1955 and 1959 *The Times Atlas of the World, Mid-century Edition* was published in five volumes. It reflected an improved balance in geographic coverage, with a wide selection of world thematic maps and the use of new projections as a special feature. Greater authority was placed on its index of over 200,000 place-names, with the only serious issue the decision to separate the index into five sections. This version represented a major advance in the work itself and atlas production in general, maturing from a fine atlas into a truly premiere cartographic achievement.

The problems associated with maintaining a world atlas in five volumes led in 1967 to the publication of the one-volume *The Times Atlas of the World, Comprehensive Edition*. Expanded coverage of astronomy accompanied improved accuracy in the mapping from satellite observation. A variety of projections, thematic mapping, and statistical information, along with increased front matter made this edition stand out as a well-rounded reference source. *The Times Comprehensive Atlas of the World*, the tenth edition of the 1967 version, was issued in 1999 as the "Millennium Edition," and represented the first entirely new edition since the *Mid-century Edition*. Its computer-generated maps were distinct from earlier editions and exquisite examples of cartography. The front matter, now sixty-seven pages, was a lavishly illustrated tour of the universe, the earth, cartography and its history that could easily serve as a basic text in geography.

The *Times* atlas of the world has appeared in many editions, translations, and formats and continues to be published. The care in its production, authority of its information, and beauty of its presentation have made it the essential geographical reference of the twentieth century.

APRIL CARLUCCI

SEE ALSO: Atlas: World Atlas

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***Tissot's Indicatrix.*** Nicolas Auguste Tissot, a nineteenth-century French cartographer, was a major contributor to the application of mathematical principles to map projection studies in both the nineteenth and twentieth centuries. Prior to his study of geometric distortion, map projection treatises focused on describing specific map projections, their mathematical derivations, and occasionally proposed new projections. Tissot's theorem and visualization method introduced generations of cartographers to the concept of map projection distortion.

Tissot's theorem was developed during the 1850s and outlined in his 1881 publication *Mémoire sur la représentation des surfaces et les projections des cartes géographiques*. The theorem describes two orthogonal directions associated with each point on the spherical or ellipsoidal surface of the earth that also exist at right angles on the flat map. These directions serve as the major and minor axes of what has been referred to as Tissot's indicatrix, Tissot's ellipses, or ellipses of distortion. The indicatrix is the projection of an infinitely small circle on the surface of the earth to an infinitely small ellipse on the map projection plane. Each ellipse describes the map projection distortion at the point and in its immediate surrounding area, since scale and angular changes can be derived for each ellipse (fig. 972). Details on computing the parameters of Tissot's indicatrix are described by Piotr H. Laskowski (1989), and a bidimensional regression approach is described in a 1977 discussion paper by Waldo R. Tobler, later republished (Tobler 1994). Tobler's approach expands the application of Tissot's concept to evaluate differences between two different map projections rather than only evaluating transformations from the sphere to the projection plane.

In visual displays distortion ellipses are enlarged for visibility, often simplified to the outline of an ellipse, and placed repeatedly throughout the map at graticule intersections, as seen in figure 973. The Mercator projection

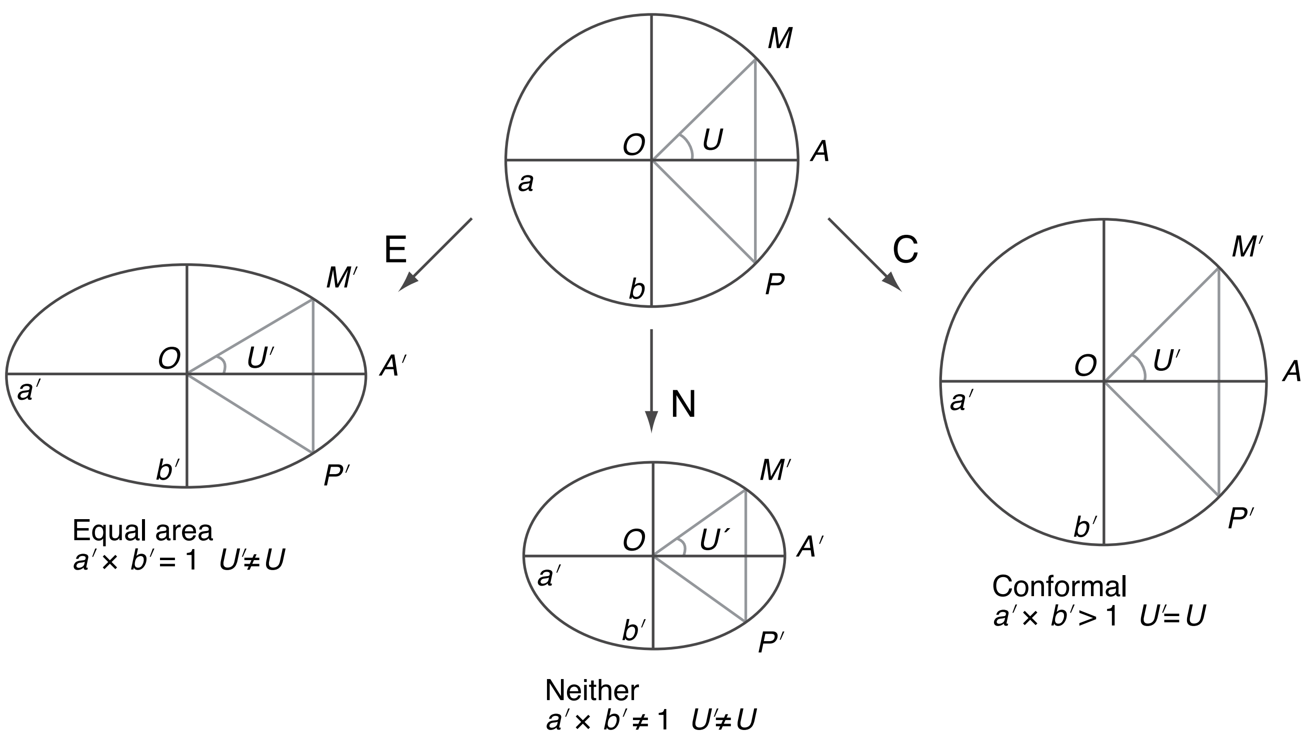


FIG. 972. TISSOT ELLIPSES DEPICTING THREE POSSIBLE OUTCOMES FROM PROJECTING TISSOT'S INFINITESIMALLY SMALL CIRCLE FROM THE EARTH'S SURFACE TO THE MAP PROJECTION PLANE. In the equal area case (E), the axes of the ellipse have changed so that $a' \times b' = 1$, maintaining the same relative area. Angular distortion can be calculated by $U - U'$. In the conformal case (C) the original unit circle has been projected and the angle $U = U'$ and $a' \times b' > 1$. The scale has increased proportionally in both principal directions $a$ and $b$, hence angle $U$ remains the same. In the last case (N), neither property has been retained.

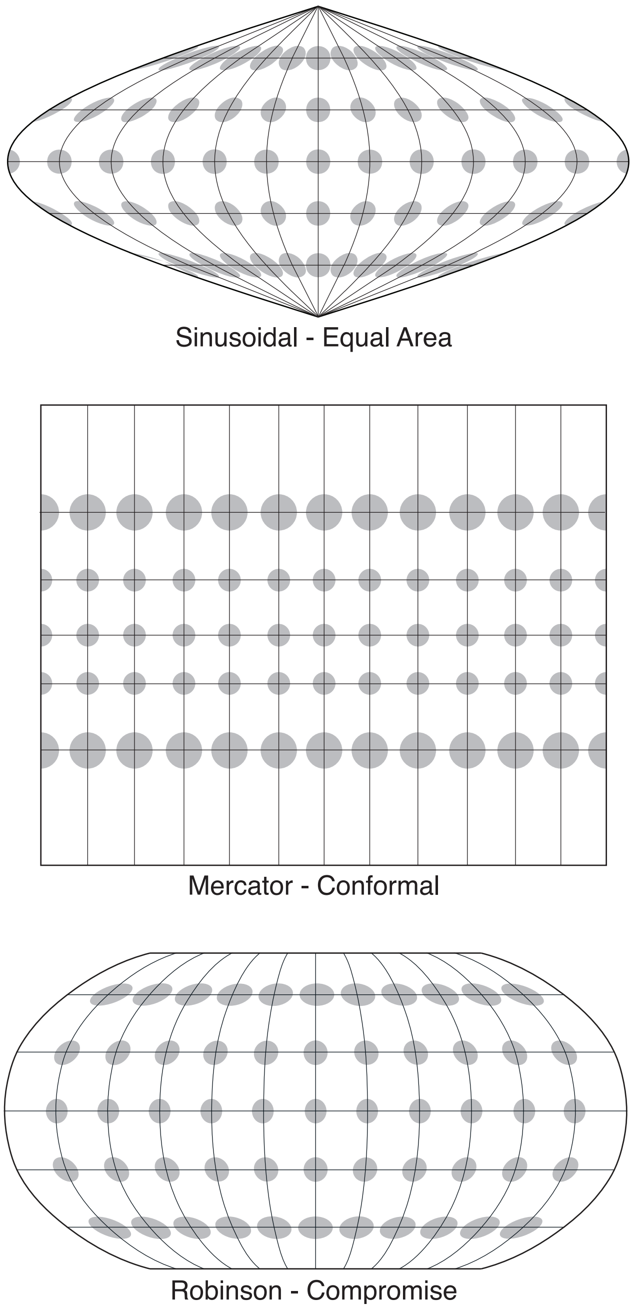


FIG. 973. TISSOT DISTORTION ELLIPSES AT GRATICULE INTERSECTIONS ON THE SINUSOIDAL, MERCATOR, AND ROBINSON WORLD MAP PROJECTIONS.

illustrates the property of maintaining true local angles and shapes known as conformality. Although varying in size, the distortion ellipses have remained circular. The sinusoidal projection, by contrast, illustrates the property of equivalence or equal area. The sizes of the ellipses remain true relative to the globe while varying amounts of angular distortion are evident. The Robinson projection is a compromise, with ellipses displaying both size and angular distortion.

Following the publication of Tissot's work, there were a relatively small number of references to his theorem and indicatrix from 1900 to the late 1960s. With the advent of computers that eased the difficult calculations involved in determining ellipse parameters, the number of references to the use of Tissot's indicatrix for the analysis and depiction of map projection distortion suddenly increased in late 1960s and more than doubled each decade through the remainder of the century. Furthermore, the applications of Tissot's indicatrix have moved beyond traditional use in teaching the concept of map projection distortion to areas such as analytical cartography, geodesy, structural geology, geographic information science, physiology, optics, interactive visualizations, remote sensing, and the Global Positioning System (GPS).

The first major publication to popularize Tissot's indicatrix to a wider audience was *An Album of Map Projections* (Snyder and Voxland 1989). This was a less mathematical and more accessible introduction to map projections for a broader audience described by the authors as "the cartographic profession and other cartophiles" (vii). They underestimated the impact and broad audience of this work, as it has served the large and growing cadre of geographic information science, remote sensing, and related professionals.

Tissot's indicatrix inspired the development of extensions to the concept of an ellipse of distortion. The floating ring, an interactive approach developed by computer scientists, was implemented in an existing visualization system (Brainerd and Pang 1998). Another expansion of the concept of the indicatrix addressed issues related to raster data structures and led to noncircular indicators. A rectangular expression of the indicatrix called grid squares was developed for the specific purpose of exploring raster data structure distortion resulting from projection-to-projection transformations (Steinwand, Hutchinson, and Snyder 1995). This approach was further expanded to raster grids positioned at graticule intersections (Mulcahy 2000). By the end of the twentieth century, Tissot's indicatrix continued to play a significant role in the calculation of map projection distortion, the display of distortion, and in inspiring new directions in map projection research.

KAREN A. MULCAHY

SEE ALSO: Analytical Cartography; Conformality; Mathematics and Cartography; Standards for Cartographic Information; Scale

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***Tobler, Waldo R(udolph).*** Born on 16 November 1930 in Portland, Oregon, Waldo Tobler was first introduced to maps while in high school in Maryland and Switzerland. In 1948, he joined the U.S. Army and worked in an intelligence unit, interviewing German prisoners of war returning from the Soviet Union and working closely with maps and air photos. After his military service, he studied physical geography at the University of British Columbia with J. R. Mackay, but eventually received his undergraduate and graduate degrees at the University of Washington, Seattle, ground zero for geography's quantitative revolution. Fellow graduate student Carlos B. Hagen seems to have been Tobler's source of interest in map projections, a lifelong theme. After completing the MA in 1957 with the thesis "An Empirical Evaluation of Hypsometric Colors," he worked for two years at the RAND Corporation in Santa Monica, California, on overlay graphics for radar scopes as part of the SAGE (Semi-Automatic Ground Environment) early warning system. While at RAND, Tobler published the first English-language paper on automated cartography, entitled "Automation and Cartography" (1959), a pioneering view of the role that the computer could play not only in drawing maps but also in their storage and analysis. Returning to the university, he took graduate classes with John Clinton Sherman and William Louis Garrison, and received a PhD in 1961 for his dissertation "Map Transformations of Geographic Space." Tobler then followed fellow graduate student John D. Nystuen to Ann Arbor, and from 1961 to 1977, Tobler rose through the ranks from assistant to full professor at the University of Michigan. Moving to the new Department of Geography at the University of California, Santa Barbara (UCSB) in summer 1977, he taught there until his retirement in 1994, after which he remained active as Professor Emeritus. Tobler was elected to the U.S. National Academy of Sciences in 1982, awarded an honorary doctorate by the University of Zurich in 1988, and received the Lifetime Achievement Award from Environmental Systems Research Institute (ESRI) in 1999.

A self-described geographical cartographer, Tobler has led major research thrusts in several areas: cartography (especially analytical cartography, map projections, and cartograms); flow phenomena (especially human migration); and geographic interpolation. His publications reflect a strong secondary focus on the history of cartography and a powerful interest in interdisciplinary and inquiry-driven research. Two concepts unify his work. The first is the idea that most real-world phenomena are best represented and modeled as continuous fields rather than as discrete classes or objects. The second is the concept of mapping as a set of mathematical and computational transformations in which the nature of the transformation and its invertibility determine what information is captured, stored, and communicated and how efficiently.

Tobler is also well known for several influential papers. He formulated the "first law of geography"—the notion that all things are similar, but that things closer are more so—in 1970 as an aside in a paper detailing one of the first cartographic animations. He also invented novel map projections as well as the earliest derivation of partial differential equations for area cartograms. He invented and published the pycnophylactic method for smooth two-dimensional mass-preserving areal data interpolation. He also proposed that cartography eliminate classed choropleth maps and instead show continuous quantities by graded shading. At UCSB, Tobler continued his research on flows and cartograms and was involved in building a global demographic information database at one-kilometer resolution—an effort picked up and supported by Columbia University's Center for International Earth Science Information Network.

From a cartographic perspective, Tobler's lasting contribution has been the genesis of analytical cartography, of which it was stated: "If any one paradigm within cartography has an 'intellectual leader,' it is analytical cartography" (McMaster and McMaster 2002, 318). Tobler's 1976 paper, "Analytical Cartography," outlined a scientific, mathematical, transformational, and analytical approach to the subject. By detailing the way he had developed and taught the analytical cartography class (Geography 482) at the University of Michigan in the 1960s and 1970s, Tobler influenced a whole generation of cartographers who adopted the analytical cartographic paradigm. Analytical cartography has been described as "the mathematical concepts and methods underlying cartography, and their application in map production and the solution of geographic problems" (Kimerling 1989, 697). Periodic special issues of journals, research essays, and textbooks have strengthened the intellectual background for the subfield over time, and its pervasive influence on the growing field of applied geography has kept it at the research frontier of geographic information science and systems.

KEITH C. CLARKE

SEE ALSO: Analytical Cartography; Cartogram; Interpolation; Mathematics and Cartography; National Center for Geographic Information and Analysis (U.S.); Statistics and Cartography

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***Toponymy.*** See Geographic Names

***Tooley, R(onald) V(ere).*** R. V. Tooley was born in London in 1898. His career, which spanned much of the twentieth century, saw the study of early maps transformed from an introspective specialist discipline into one that welcomed a wide range of enthusiasts. He was largely responsible for creating a market for separate maps, which allowed the formation of geographically defined collections. This in turn led to the closely related achievement of laying down the cartobibliographical framework (directly or indirectly) for several parts of the world. As a publisher and stimulator of interest in the history of cartography, his indirect impact was even greater.

Tooley's groundbreaking *Maps and Map-Makers* went through eight editions and several reprints between 1949 and 1990. It has now been superseded, but its catholicity—both in countries of production and geographical areas covered—has provided a basis for much subsequent scholarship.

Given its universal scope, *Maps and Map-Makers* was necessarily superficial, in some places comprising little more than lists. His earliest detailed work was a study of the variants of a distinct group of 614 printed maps (Tooley 1939). Surprisingly, this remains one of his most cited publications.

Tooley set out on his own distinctive cartobibliographical road publishing 110 monographs in the Map Collectors' Series (1963–75). He did not invent the genre—there had been occasional listings of published maps since the nineteenth century—but he devised a simple, effective formula that democratized the process. Each of the illustrated chronological listings emphasized the originality (or more usually the lack of it) of each map. Besides the appeal for collectors, this formula provided a springboard for others to dig deeper into the bibliographical niceties or to flesh out the listings with more historical context. It also provided historians (when they chose to take advantage of it) with a better understanding of what they were looking at—possibly a map whose content dated from decades before its stated publication year.

Tooley authored many of the Map Collectors' Series listings (mostly of maps described by region), with some of the larger studies gathered up later in book form. These included his listings of the maps of Africa, Australia, North America, and the West Indies. Best known was what became *Tooley's Dictionary of Mapmakers* (1979), a monumental compilation of entries on more than 20,000 individuals based on his observations over fifty years.

Tooley also acted as publisher for a number of academics and collectors. Several books initially appeared serially in the Map Collectors' Series: Donald Hodson's listing for Hertfordshire, Halina W. Malinowski's for Poland, Rodney W. Shirley's for the printed maps of the British Isles, and R. A. Skelton's *County Atlases of the British Isles*.

The *Map Collector* magazine (1977–96), for which Tooley served as first editor, used the cartobibliographical format sparingly. It was left to Ashley Baynton-Williams's *Map Forum* (founded in 1999) to persevere with the tradition Tooley had established of publishing annotated map listings. Tooley died on 12 October 1986.

TONY CAMPBELL

SEE ALSO: Cartobibliography; Collecting, Map: Europe; Histories of Cartography

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***Topografische Dienst (Netherlands).*** National topographic mapping in the Netherlands started during the Napoleonic period. Surveying and mapping were carried out by staff officers of the Militaire Verkenningen (military survey), part of the General Staff, and stone engraving and printing were executed by the Topographische Inrigting of the Ministerie van Oorlog (ministry of war). Although military maps were offered for sale to other ministries and the public, mapmaking was not formally recognized as a national obligation. During the nineteenth century full coverage was completed at the scales 1:25,000, 1:50,000, and 1:200,000.

This division of responsibility between two separate agencies did not foster timely map revision. Demands for more accurate maps and the introduction of new technology (aerial photogrammetry, modern printing techniques, a new nationwide reference system) required an improved organization of mapping activities. To address these concerns the Topografische Dienst was established in 1932. This new agency included all activities of the two older institutes and was part of the Ministerie van Defensie.

Aerial photography became the basis of a new strategy for aerial triangulation, terrain surveying, and feature delineation (figs. 974–76). The stereographic projection, which is conformal, replaced the Bonne projection, which is equal-area and thus prone to angular distortion. The introduction of offset printing modernized map production, and establishment of a sales department addressed the growing need for maps.

World War II brought this modern development to an abrupt end, and reconstruction after 1945 took several years. The establishment of the North Atlantic Treaty Organization (NATO) brought urgent requirements for military maps with a Universal Transverse Mercator (UTM) grid. This resulted in a huge increase in the production of maps in the 1:25,000 and 1:50,000 series and the introduction of new series at scales of 1:100,000 and 1:250,000 to replace the old 1:200,000 series. Technical innovation developed rapidly, with rectification of aerial imagery as the standard mapping procedure for flat areas (85 percent of the country) and stereoplotting for hilly country and built-up areas. Starting in 1960 rectified photo imagery formed the basis for scribing on plastic materials, and reproduction and printing departments were set up.

Meanwhile, map use by civilian departments grew

FIG. 974. DUTCH TOPOGRAPHER IN THE FIELD NEAR SCHIPLUIDEN, CA. LATE 1970s. Until 2004, topographers used air photos mounted on a board and annotated them with pencils (the topographer used a horse until around 1890, when it was replaced by the bicycle). Preceding field reconnaissance, terrain details were already gathered by stereoscopic interpretation as much as possible. By 2010, topographers used laptop computers mounted on the handlebar of their bicycles.
Image © Kadastermuseum, Arnhem, the Netherlands.


FIG. 975. TERRAIN SURVEY (CALLED A "MINUTE"), 1:25,000. Before the use of aerial photography, topographic reconnaissance was surveyed and drawn on the basis of reduced cadastral maps. The drawing of the terrain details was performed in the field and the coloring done during the night's lodgings (1840–1930). This detail is in the vicinity of the old fortress town of Heusden in Noord Brabant.
Size of the entire original: ca. 55 × 80.2 cm; size of detail: ca. 13.4 × 17.9 cm. Image © Nationaal Archief, The Hague, the Netherlands.

rapidly, especially for agricultural research, soil improvement, and regional planning. From 1953 onward, demand for large-scale base mapping was met by enlarging photogrammetric plots at 1:12,500 to a produce a map series at 1:10,000. From 1950 onward all military map series were overprinted with the national grid, which was designed to meet civilian needs. The cycle of map revision was progressively shortened from ten years in the 1960s to ten, seven, or five years (depending on the region) in the 1970s, and to between eight and four years in the 1990s.

A serious problem for national mapping arose in 1966, when a change in military policy led to cancellation of the 1:25,000 military map series. Thereafter, 1:25,000 civilian maps could no longer be produced as a by-product of military mapping. Still not formally recognized and subsidized by the government, the series had to become financially self-sufficient. A long period of interdepartmental discussion about financing began, and the Ministerie van Defensie covered the deficit for the time being.

A second problem arose when the government decided to move the agency from Delft to Emmen, a town on the other side of country. Years of uncertainty resulted in a decrease in the number of staff members and a serious decline in map production. In 1984 a new building became available, and the move yielded the beneficial results of a rejuvenated staff, modern accommodations, and new equipment.

Increased use of maps by governmental institutes as well as a contract with a large publishing firm to market the agency's topographic atlases slightly improved the


FIG. 976. ANNOTATED PHOTOMAP, 1:10,000. This became the source for scribing the topographic basemap, 1:10,000 (1930–2005).



financial situation. In the meantime, the production process began to be automated. Between 1984 and 1990 a first road map database was established and parts of the related map were produced by photoplotting.

In 1990, the 175th anniversary of its oldest predecessor, the Topografische Dienst launched a program to convert its 1:10,000 map series to a completely digital vector-format database by 1997. This decision was a turning point: new software and equipment were introduced, and within two years all hand labor was replaced by electronic data capture and editing technology. At the same time, a new kind of management agreement substantially altered the agency's relationship with the Ministerie van Defensie. This restructuring allowed greater independence, including the ability to invest in new equipment, contract out digitizing, and develop new markets. Full conversion of all maps series—from 1:10,000 to 1:250,000—into digital form was reached in 1997. The 1:10,000 vector database (TOP10vector), although still not officially authorized, was now available as a national core database.

The end of the twentieth century marked the end of an era in Dutch topographic mapping. Decreasing military needs and budgets and increasing civil demands for two-year updates and improvement of the core database led to a review of the agency's position as a public agency. After a thorough investigation two decisions were made: to establish a specific military survey within the Koninklijke Landmacht (army) and to transfer the Topografische Dienst out of the Ministerie van Defensie.

In 2004 the Topografische Dienst was integrated with the Dutch Kadaster, an independent organization regulated by law that was responsible for the national reference system, for land registry, and for large-scale mapping. Officials hoped that the strong position of the Kadaster in research and development of information and communication technology would guarantee the future of topographic databases as an essential part of the Netherlands' national geoinformation infrastructure.

P. W. GEUDEKE

SEE ALSO: Colonial and Imperial Cartography; Topographic Mapping: (1) Western Europe, (2) Indonesia

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***Topographic Map.*** There has been a lack of unanimity regarding the definition of the topographic map (see Larsgaard 1984, 3–9). Whereas the United States Defense Mapping Agency (1973, 253) stated that a topographic map is "a map which presents the vertical position of features in measurable form as well as their horizontal positions," Francis John Monkhouse (1965, 311) defined the topographic map as "of fairly large scale (e.g. 1:63,360)" depicting "not only landforms, but all other objects and aspects both of natural or human origin." The topographic map served a multitude of purposes during the twentieth century but broadly speaking shifted from almost a purely military raison d'être to the support of the expanding civilian market centered on tourism and leisure. At one extreme, the topographic map had to fulfill the requirements of the military in providing accurate, current, and measurable delineation of topography and at the other, to provide the untrained eye with an intuitive visual impression of the landscape.

The topographic map was the most frequently used of all types of maps as well as the most exacting and expensive to make due to the requirements of such a diverse range of users. Topographic maps were largely issued by national mapping agencies (NMAs). Individual sheets formed part of a series whose content and style of depiction was determined by its specifications. The specifications would in turn be determined by user requirements in light of the production and future revision costs. The nature of the terrain and complexity of the cultural element of the landscape would also have a significant influence on the specifications.

By the end of the century, the general aims of the topographic map had not changed fundamentally from that presented by Major Charles Frederick Close in his textbook (1905, 1): "A topographical map should depict all the surface features which can be legibly drawn; all the accidents of the surface should be shown which distinguish it from a level, featureless plain. The amount of information presented on a topographical map is thus conditioned by two principal factors, the complexity of the surface features, and the scale of the map." During the twentieth century, topographic maps at scales generally larger than 1:100,000 became the backbone of almost all government mapping programs.

Perhaps the most significant transformation of the topographic map was not in its appearance but in its coverage. The expansion of empires prior to the twentieth century presented vast areas of virgin territory to the topographer. Much of Australia remained unexplored, and by 1930 still no detailed accurate topographical maps had been published as part of a map series. Even in Europe, where the Royal Geographic Society (RGS) had embarked on mapping at a million scale during World War I, the map sources varied alarmingly in scale and quality. This was particularly the case where sheets covered border areas in remote parts of the continent. For example, maps of various scales published by Norwegian, Finnish, and Russian agencies were used by the RGS, and the result, though not immediately obvious to the map user, was a map that varied in accuracy and detail in line with the international boundaries (fig. 977).

Similar situations existed throughout the rest of the world. In Canada, Labrador's interior and northern areas and large stretches of the Yukon and Canadian Rockies in British Columbia remained completely unmapped. Latin America had newly independent states that possessed largely reconnaissance maps completed during the nineteenth century and splendid national atlases that were more statements of national sovereignty than maps suitable for military strategists and government administrators. Some countries such as Chile and Argentina had embarked on overambitious topographic surveys that were unrealistic in terms of completion date. So poor was the compilation material available to the American Geographical Society that it took twenty-five years to complete its million-scale Hispanic map at a cost that far exceeded any previous map series undertaken by a private organization (Pearson and Heffernan 2009). By 1933 only Argentina, Chile, Peru, and Uruguay had made any significant progress in the publication of national series mapping (Platt 1933).

Completion of a topographic map series was prohibitively expensive even for relatively wealthy nations. By 1906, the U.S. Geological Survey (USGS) had completed topographic sheets for about one third of its territory (over a million square miles) with an average of 35,000 square miles of surveying each year. The cost was enormous, rising from an average cost per square mile in the early 1890s of $4 to $10 by 1907. The cost for topographic mapping was in the region of $350,000 per


fig. 977. DETAIL FROM THE MILLION-SCALE MAP *NORDKAP AND ROMANOV*, 1916. Compiled by the Royal Geographical Society under the direction of the Geographical Section, General Staff (GSGS 2758) and printed by the Ordnance Survey (Provisional Edition, North R 35 & 36). Variations in topographic detail conform to the international borders (superimposed over original) reflecting the quality of the source materials. Norwegian topographic maps at a scale of 1:100,000, which covered a small part of the Norwegian territory, were combined with 1:2,000,000 scale atlas mapping of Russia.
Size of the entire original: 60.2 × 57.7 cm; size of detail: 22.7 × 23.5 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

annum (Wilson 1907, 13). Even for a country with the resources of the United States, completion of a national topographic map series was a constant drain on finances and proceeded at a snail's pace. It became an issue of national pride when, in 1950, it was declared: "Despite the fact that the United States is one of the most advanced nations of the world . . . it has lagged far behind other forward-looking nations in completing topographic and geologic maps of its area" (U.S. Congress, House, Committee on Public Lands 1950, 2). By 1944, even though mapping had been ongoing for sixty-five years in California, 17 percent of the state remained unmapped; of the mapping that had been done, 44 percent was deemed obsolete and only 13 percent of acceptable standard.

The topographic mapping inherited from the czars by the Soviet Union remained inadequate and very uneven (Komkov 1967). Vast expanses of interior regions were not mapped. Maps were published so slowly that they were obsolete when made available. Maps of a given territory were not in agreement either with regard to planimetric positions or to content and design. The inherent beauty of the issued maps and the high quality of the engraving belied major weaknesses in their accuracy and currency. To address these deficiencies required considerable political will. The newly formed Soviet Union viewed topographic maps as the basic maps of the state, necessary for tackling economic, scientific, and defense issues and "a compulsory prerequisite for the progress of the productive forces of the state and the strengthening of her defensive capability" (Komkov 1967, 254). The Soviet Union embarked on an ambitious program of mapping at scales that were to become the de facto standard around the world using the sheet lines and numbering system of the International Map of the World (IMW).

At the beginning of the twentieth century maps were typically engraved. All the map elements—lettering, relief hachuring, roads, buildings, rivers, and woodland—interweaved intricately in a black-and-white graphic of great complexity (fig. 978). Producing such a map took an inordinate amount of time but also required time and skill on the part of the map reader. Other map elements that we might expect on a modern topographic map were often absent. For example, legends were not always present and cartesian systems for geographical referencing were not available. Longitudes and latitudes were provided, but these were typically relative to one of many different prime meridians before the Greenwich meridian became the international standard.

The twentieth century saw important developments in symbolization on topographic maps. The development of lithography during the late eighteenth century continued during the nineteenth century to facilitate the publication of color maps together with the ability to produce maps with continuous tonal variation. This had a profound effect on the development of hill shading, allowing the incorporation of fine shading or model photography. Furthermore, the move toward color printing opened up the possibility of moving away from the use of text to identify feature types (associated with monochrome maps).

Implementation of these new opportunities was by no means worldwide. Many countries, particularly in Europe, had already commenced topographic series with well-defined specifications. A move away from hachuring to contouring, for example, would incur considerable cost at a point when the first series of topographic maps was yet to be completed. Dramatic changes in specifications would be expensive. The Ordnance Survey of Great Britain made rapid and radical changes to its one-inch map series during the first quarter of the twentieth century, transforming the monochrome and hachured Old Series one-inch map (1:63,360) to the new Popular Series. Sanction was received in 1897


FIG. 978. DETAIL FROM THE 1:80,000 SERIES TYPE 1889, *CHÂTEAUDUN*, 1899. Published by the Service géographique de l'armée (sheet 79) following revision. A beautifully crafted map but of a complexity that demands lengthy study, especially for an untrained eye.
Size of the entire original: 30.2 × 42.9 cm; size of detail: 15.6 × 9.9 cm. Image courtesy of the Cartothèque, Institut géographique national.

from the Treasury for the publication of an experimental one-inch map in color (Mumford 1980, 201–7) and subsequent series of Ordnance Survey one-inch series demonstrated a shift toward effective use of color to develop standard topographic symbols for road classes and various point symbols such as bus and railway stations (fig. 979). Replacement of the rather heavy treatment of relief through hachuring combined with light brown contouring provided more space for symbolization. Other national mapping agencies were not as quick to change their symbols to take advantage of these new design opportunities.

One problem associated with this ever-increasing richness of possibilities was the lack of standardization between topographic map series of different countries. Though most topographic maps had adopted a de facto standard with water features rendered in blue, relief in brown, and cultural features in either red or black, the divergence of style between series was striking. One noteworthy attempt to establish an international standard for small-scale topographic mapping was proposed by Albrecht Penck in 1891. His idea was to map the land areas of the world at a scale of 1:1,000,000 through the collaborative efforts of the national mapping agencies around the world. It could be argued that his IMW marks the beginning of the modern period of cartography with the establishment of Greenwich as the prime meridian, the meter as the unit of measurement, and the creation of a global sheet numbering system. The final specifications published in 1913 also specified the type of projection and the symbols and lettering styles to be implemented. Though this ambitious project took nearly a century to complete, its impact on the topographic map should not be underestimated, not least due to its role as a focus for international cooperation. Later initiatives to standardize on map specifications such as the adoption of the North Atlantic Treaty Organization (NATO) international standards could use the precedent set by the IMW.

Though topographic maps rather than topographic mapping is the focus here, the impact of aerial photography on cartography cannot be ignored. As Norman J. W. Thrower (2008, 173) argues, "The use of aerial photographs . . . has wrought changes in cartography comparable perhaps only to the effect of printing in the Renaissance." Aerial photography provided opportunity to map areas that had until then remained inaccessible. Furthermore, it is easy to demonstrate the improvement in quality and accuracy by comparing two topographic maps of the same geographical area.

The military value of photography had been recognized during World War I, when photography and aircraft combined to obtain ground measurement to produce new maps or revise outdated ones (Newcombe 1920; MacLeod 1919, 396–403). Commercial applications of aerial photography for reconnaissance and mineral exploration demonstrated the efficiency of these techniques as a replacement for such outmoded methods as plane table surveys. For example, Colombia had attracted considerable interest from petroleum companies that had funded and conducted significant aerial surveys as a basis for geological studies and for the location of oil-related boring operations during the 1920s. The location of oil fields was not the sole reason for the surveys. Many were conducted to assess and plan the infrastructure of the oil production operation, including pipelines, roads, navigable waterways, and railway routes. It was


FIG. 979. DETAIL FROM *TRURO AND ST AUSTELL*, 1:63,360, 1934. Published by the Ordnance Survey, Fifth (Relief) Edition, sheet 143. Between the wars topographic maps began to place greater emphasis on the needs of the road user and tourist with color symbols being applied to road classes. (See also fig. 1007).
Size of the entire original: 70.3 × 95.3 cm; size of detail: 11.8 × 19.3 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

claimed that surveys initiated by the petroleum companies "involved more time and money and have covered more ground and made more important contributions to the cartography of Colombia than all the other survey work that has been done there since the Conquest" (American Geographical Society 1932, 56).

Raye R. Platt's world index of topographic map coverage (Platt 1945) reveals the state of map coverage at the outbreak of World War II. Large tracts of South America, Africa, the Soviet Union, and Australia remained unmapped. Wartime had demonstrated to the major powers that the coverage and quality of the topographic maps remained unsatisfactory. Major revision mapping programs were initiated by NMAs during the postwar recovery years, and new map series of overseas territories that lacked adequate mapping were initiated by colonial powers such as Great Britain and France. Collaborative mapping agreements such as the Inter-American Geodetic Survey, signed in 1946, encouraged the development of self-sufficiency in the topographic mapping capabilities of Central and South American countries. While the Institut géographique national (IGN) made major inroads on the mapping of France's African territories, the Directorate of Overseas Surveys (DOS) (founded as the Directorate of Colonial Surveys in 1946) spent the next forty years mapping over six million square kilometers of Britain's overseas territory (Parry and Perkins 1987; McGrath 1983).

The primary aim of the DOS was to produce usable maps, often of remote and inaccessible areas, in quantity as quickly and as cheaply as possible. Experimental mapping was undertaken where circumstances permitted. The development of orthophotographs and orthophotomapping presented an alternative to the conventional line map for many overseas territories. In areas of inaccessible swamp, desert, and forest that contained features that were indistinct or too ephemeral to be represented by the standard techniques of conventional topographic mapping, the photomap offered a better alternative. Though photomosaics had been shown to be superior to conventional maps in such circumstances, their major limitation had been their inability to be selective in the detail they recorded. Experiments by the DOS attempted to introduce some degree of selection and to change the emphasis in the visual impact made by the various features of the landscape so as to enhance the value of the photomosaic as a topographic map substitute. The introduction of a shadow line between the vegetation classes through displacing positive and negative components enhanced the differentiation between the categories. The sheets of Aldabra Island at a scale of 1:25,000 (fig. 980) were prepared by the DOS and demonstrated this method of rapid vegetation mapping and the value of the technique for mapping shallow water detail. The DOS claimed that it achieved savings in the region of 25 to 30 percent on the cost of equivalent conventional topographic mapping.

The progress made by the French IGN and British DOS decreased substantially during the 1980s as government support for these agencies dwindled. By 1987, the mapping of large tracts of Africa was over twenty years old, and many newly independent countries were without sufficient mapping capabilities (Parry and Perkins 1987). However, progress was made in some parts of the world through mapping aid programs. Furthermore, major progress was made with high-quality mapping projects by developing countries such as Chile, Brazil, and Mexico.


FIG. 980. DETAIL FROM *ALDABRA ISLAND (WEST SHEET)*, CA. 1:25,000, 1969. An experimental photomap produced by the Directorate of Overseas Surveys (from aerial photography flown June 1960) for the Royal Society's expedition 1967–68. Photomapping became a cost-effective method of mapping remote and inaccessible areas.
Size of the entire original: 77 × 90 cm; size of detail: 19.1 × 19.8 cm. Image courtesy of the Syndics of Cambridge University Library (Maps.12[2].96.9-10). © Crown Copyright. Reproduced by permission of the Ordnance Survey.

The impact of the space race began to be felt during the late 1960s as the USGS, in cooperation with the U.S. National Aeronautics and Space Administration (NASA), used rectified photography from Apollo 9 to publish its space photomap at 1:250,000 of Phoenix, Arizona. This was an experimental prototype and the first map of its type to be sold commercially. Space imagery was combined with selected elements of a conventional medium-scale topographic map to improve the currency and accuracy of the conventional map. It is evident that the photography has neither the resolution nor the geometric fidelity that would normally be applied to such a use; however, the imagery was virtually orthographic and therefore easily fitted to the Universal Transverse Mercator (UTM) map projection. The conventional line map of the same area was printed on the reverse side of the photomap, the anticipated advantage being to present the relatively uncluttered line map as a working base and the photomap as a ready source of additional and more recent information not shown on the line map.

In a century tarnished by major wars in which topographic maps performed a vital role, the postwar mapping of Antarctica demonstrated how such activities can be the catalyst for international cooperation. Map coverage was rather fragmentary before World War II, relying heavily on primitive surveys by explorers and whaling expeditions. Mapping of the area gained momentum with the growing interest of the United States and the first major expedition in 1946–47 of the U.S. Navy's Operation Highjump. The International Geophysical Year in 1957–58 marked the pivotal point in the mapping of Antarctica as it kick-started a period of international cooperation, formalized by the creation of the Special (later Scientific) Committee on Antarctic Research (SCAR) in 1958, which in turn led to the Antarctic Treaty of 1959. SCAR sought to standardize the mapping of Antarctica and encouraged the free exchange of information between the various mapping authorities. Thus began a period of mapping with an agreed specification in relation to projections, sheet lines, sheet numbering, scales, symbols, and datums. The Antarctica 1:250,000 Reconnaissance Series was based on ground and aerial surveys dating from 1957 to 1960 and trimetrogon photography flown in 1959 (see fig. 45). The international nature of the series is demonstrated by the metric contour interval with bar scales in statute miles, kilometers, and nautical miles. By the end of 1968, topographic mapping of Antarctica had witnessed significant contributions from Australia, Belgium, France, Japan, New Zealand, Norway, the Soviet Union, the United Kingdom, and the United States. The satellite image map largely replaced the conventional line map for the mapping of the Antarctic during the 1980s. The National Oceanic and Atmospheric Administration (NOAA)/USGS Antarctic Mosaic Project using AVHRR (Advanced Very High Resolution Radiometer) images from NOAA satellites combined with Landsat imagery for areas above 80°S expanded the coverage rapidly. By 1987, 20 percent of the continent had been mapped at 1:250,000 scale or larger (Parry and Perkins 1987).

While bodies such as the United Nations continued to report rather inconsistent progress in the extension of topographic maps to worldwide coverage (see *World Cartography* vols. 10, 14, and 17), governments of the developed world concentrated their mapping resources on the revision and densification of their survey networks. Some countries, such as West Germany, Austria, the Netherlands, and France, embarked on ambitious large-scale mapping programs at 1:5,000 scale to meet the growing demand for larger-scale data to aid the better management of ever-decreasing resources. Furthermore, the demand for more efficient map production during the latter half of the century naturally focused attention on the potential benefits of automating the map production process. Beyond the purely economic considerations, military and civilian organizations were also eager to capitalize on the capacity of this new technology to provide topographic maps tailored to specific requirements. NMAs throughout the developed world invested heavily in this expensive technology, convinced that major economies could be made.

Mapping agencies were fixated on reducing the cost of producing facsimiles of conventional topographic maps. Examples of early experimentation abound. The experimental map of Petersborough, Ontario (fig. 981), was produced to appraise the applicability to medium-scale topographic mapping of the automatic drafting system, normally used for much larger-scale engineering mapping. Stereo compilation was performed on a Zeiss Planimat equipped with Wang digitizers and recorded directly onto magnetic tape. The map states that the four models took a total of 190 hours, while the automatic drafting on a Gerber 1232 system with optical exposure head took 26 hours, and the manual preparation of the peel coats took 32. Though recognizable as a topographic map, this attempt fell well short of the traditional finished product.

To digitize the entire large-scale topographic map coverage of a country was an enormous undertaking, requiring capital investment on an unprecedented scale. The Ordnance Survey of Great Britain embarked on a program to digitize its base scales with a view to automatically deriving its smaller-scale topographic maps from this same data set. However, the subjective nature


FIG. 981. DETAIL FROM AN EXPERIMENTAL MAP OF PETERBOROUGH, ONTARIO, CANADA, 1:25,000, NOVEMBER 1971. The map was produced within the Photogrammetry Office, Department of Transportation and Communications, Ontario, in cooperation with the Department of Energy, Mines and Resources, Ottawa, Canada. It claimed to be "untouched-by-human-hands" with the exception of the peel coats used for the areas covered by vegetation and water bodies.

Size of the entire original: 61.5 × 43.3 cm; size of detail: 19.2 × 9.8 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries. © Queen's Printer for Ontario, 1971. Reproduced with permission.

of the cartographic generalization, along with the individual nature of the design of its 1:25,000, 1:50,000, and 1:250,000-scale map series, thwarted attempts at automating the generalization process. Automation of the medium-scale topographic maps would rely on raster-based production systems designed specifically for each scale.

Like any emerging technology, the early pioneering attempts at automating topographic map production met with mixed reviews. Critics argued that the loss of cartographic excellence was too high a price to pay for the economic advantages that automation brought. However, arguments against automation diminished as public- and private-sector consumers shifted away from printed maps to digital map data. Furthermore, some argued that delays in the completion of suitable topographical databases were partly due to the dominance of early research and development being the responsibility of professional cartographers who "saw the conversion of their labours into elegant printed maps as a natural process and the appropriate one for their users" (Bickmore 1987, 53). Creating a topographic database to cater to this demand became more of the focus for NMAs such as the Ordnance Survey, which also had to deal with new issues of pricing policies and copyright for digital data. Mapping agencies had to break away from their traditional analog thinking in order to come to terms with the digital age and regard themselves as spatial data warehouses where sales of paper topographic maps were but a minor part of their business.

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SEE ALSO: Photogrammetric Mapping: Orthophotography and Orthophoto Mapping; Projections: Projections Used for Topographic Maps; Relief Depiction; Remote Sensing: Satellite Imagery and Map Revision; Scale; Topographic Mapping: Overview

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## *Topographic Mapping.*



*Overview of Topographic Mapping.* Over the course of the twentieth century, topographic mapping underwent enormous changes in the areas of the world covered, in the methods used to collect the information, in design, in drawing and reproduction techniques, and in the transformation from maps on paper to maps on digital databases. If one class of maps could be said to encapsulate all the major changes in mapping during the

FIG. 982. THE EXTENT OF TOPOGRAPHIC MAP COVERAGE ABOUT 1900.

century, topographic mapping probably has the strongest claim.

At the beginning of the twentieth century, topographic mapping existed for most of Europe, with the exceptions of Scandinavia, the Balkans, and Spain, which had only partial cover. Outside of Europe, only India and Java were completely covered, with patchy cover elsewhere (fig. 982). By the end of the twentieth century, topographic mapping covered most of the world, although it was often out of date.

At the beginning of the twentieth century, the exact nature of topographic mapping was far from properly defined. Much of what was regarded as topographic mapping could, equally well, have been defined as military mapping. This confusion was inevitable, as topographic and military mapping shared a common ancestry in the survey of France undertaken by the Cassini dynasty (Thrower 1996, 110–16). By the end of the century there was a clear consensus that military maps and topographic maps were different types of maps, although military maps were frequently still topographic maps with the addition of a military grid. One of the earliest twentieth-century definitions of a topographic map was provided by the British Colonial Survey Committee (1906, 5), which describes it as "an accurate representation of a portion of the earth's surface showing all the accidents of the surface, both natural and artificial, which can be depicted on the scale selected." Both Arthur R. Hinks (1913, 10) and W. M. Beaman (1928) noted the importance of scale, with Beaman also noting that the map is designed to portray "certain selected features" (161). In other words, since a topographic map cannot show everything, what a topographic map shows is a function of the scale of the map and a deliberate process of selection.

When George M. Wheeler carried out his study of national mapping agencies in 1885, there were only twenty-one national topographic surveys, including the U.S. Geological Survey (USGS), capable of producing topographic maps. With the exception of the USGS, all were originally military surveys. Furthermore, the surveys of Prussia, Saxony, Bavaria, Austria-Hungary, France, Switzerland, Holland, the Netherlands East Indies, Italy, Sweden, Norway, Russia, Belgium, and Denmark remained under military control until well into the twentieth century. And even those of Britain, Spain, India, Württemberg, Baden, and Portugal, which were in the civilian sector, were under the direction of a military officer. Moreover, the few national mapping agencies founded between the Wheeler study and the start of the twentieth century were either military surveys, as in Chile and Thailand, or primarily cadastral surveys, as in Egypt, Sudan, and New Zealand. This same pattern was repeated in the first half of the twentieth century and was particularly apparent when Britain established survey departments in its African colonies. Although survey departments were nominally under the governor of the respective country, the Colonial Survey Committee in London dictated mapping policy, and this, in turn, was controlled by representatives of the British War Office. This military presence within the national mapping agencies undoubtedly had a major impact on the evolution


FIG. 983. DETAIL OF A FRENCH ENLARGEMENT TO 1:50,000 OF A 1:80,000 MAP (*CORTE*, CORSICA, 1936). A typical example of late nineteenth and early twentieth century, this style of European topographic mapping persisted in some countries until well after World War II.

Size of the entire original: 47.8 × 73.0 cm; size of detail: 9.5 × 22.6 cm. Image courtesy of Peter Collier. Permission courtesy of the Cartothèque, Institut géographique national.

of topographic mapping in the early years of the twentieth century. It also accounts for much of the topographic mapping being broadly similar in appearance, since it was designed to meet very similar perceived needs.

By the start of the twentieth century, innovations in color printing, which had permitted the production of colored atlases and tourist maps, had not yet brought about a similar transformation in official topographic mapping. Many topographic maps were still printed only in black and white and were little different in appearance from maps produced early in the nineteenth century (fig. 983). There had been some use of color printing in the late nineteenth century, most notably for the mapping of Java, which used the Eckstein process. In 1892 a committee in Britain approved the design for a colored military map at 1:63,000 for use by the British Army. When the Treasury gave the Ordnance Survey permission for the experimental production of colored topographic maps, the design for the military map was simply adopted for civilian use (Seymour 1980, 201).

Introduction of color printing for topographic maps encouraged a diversification in the design of the maps. While in the late nineteenth century it would have been difficult to distinguish the products of the various national mapping agencies on their general appearance, by the outbreak of World War I most had developed a distinctive appearance. These differences were most marked in the choices of methods for relief depiction. The five states with Alpine areas (Austria-Hungary, Germany, France, Italy, and Switzerland) all responded differently to the challenge of representing these areas on topographic maps. The maps produced during this period are among the most attractive topographic sheets ever produced, due in part to the use of flat-color printing, with a separate ink for each color used on the map—in some cases, eight or more inks were used.

While the first half of the century witnessed increased diversity in the appearance of topographic maps, the second half experienced an increasing homogenization in their appearance due largely to the division of the developed world into Cold War power blocs. In the Soviet Bloc the imposition of the so-called 1942-System meant that all military and most topographic maps adhered to a single standard (fig. 984). Although there was some movement away from that standard with a reassertion of national identity after 1989, much of the topographic mapping of the former Soviet Bloc states still betrays this common origin.

In the West, the NATO powers had the same need for standardized mapping so that soldiers from any member state could use maps produced in any other member state. Since military maps are frequently topographic maps with the addition of overprints, the mapping styles of member states invariably converged. For example, Danish, German, Belgian, and British maps contain many similarities but retain some individuality.

Another factor that led to homogenization on a more global scale was the mapping carried out by organizations such as France's Institut géographique national and Britain's Directorate of Overseas Surveys, as part

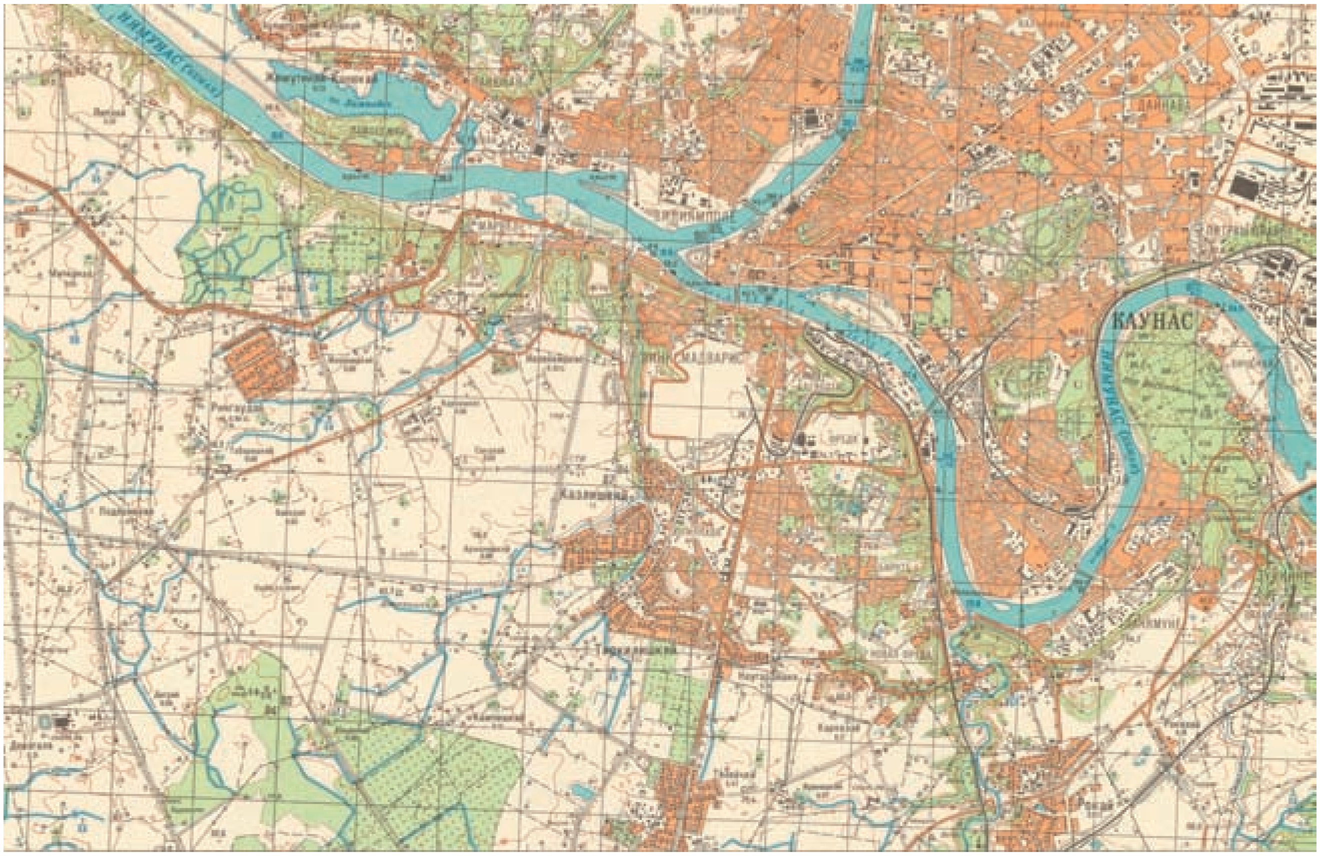


FIG. 984. DETAIL OF A RUSSIAN 1:50,000 MAP, *KAUNAS*, LITHUANIA, 1988 (SHEET N-34-48-B). This is a typical example of the 1942-System style.

Size of the entire original: 43.3 × 35.5 cm; size of detail: 20.7 × 32 cm. Image courtesy of Peter Collier.

of their overseas aid programs. Many of these programs were started while France and Britain were colonial powers and continued through the first decades after independence. The result was a distinctly French style of mapping in France's former colonies, which had its origins in the mapping carried out in French North Africa in the early years of the century. The style adopted by the Directorate of Overseas Surveys changed through time, with the newly independent countries requiring variations on the basic style. However, most of the mapping came to resemble Ordnance Survey maps, albeit with sparser detail.

The Survey of India also influenced the look of topographic mapping in countries where imperial India had played a role. For example, the mapping of Iran, Iraq, and Afghanistan resembled Indian models. An interesting exception is Malaysia and the earlier Malay states, whose topographic mapping was broadly similar to that of the Ceylon Survey.

The development of the four-color printing process also played a role in the homogenization of maps. With only cyan, magenta, yellow, and black it is possible to create many different colors, which are rarely pure because of the limitations of the technology. Once the four-color process was introduced into topographic map production, the process itself dictated that the resultant maps should increasingly resemble each other.

An additional factor that influenced the look of topographic maps was their increasing association with tourism. The growth of mass tourism at the beginning of the century made maps all the more important. Initially, the main use was for walking or cycling, with maps of popular tourist areas including footpaths or *Wanderweg*. In the 1920s the British Ordnance Survey was among the first national mapping agencies to recognize the sales potential of special tourist editions of topographic maps, especially when marketed with attractive covers. In the second half of the century it became normal to add specifically tourist-oriented material to map sheets, such a scenic routes, car parks, viewpoints, and tourist attractions. These were usually added in a distinctive color.

In most countries, plane table methods dominated detail survey work at the beginning of the century and continued to do so until well into the middle of the century, when air survey became the dominant technique. By the beginning of the century the Militärgeographisches Institut in Vienna had started to use stadia tacheometry for new surveys (Kretschmer 1991, 11), and the technique grew in importance for detail surveys of small areas until the 1970s, when it started to be replaced by the use of total stations, which incorporated an electronic distance measuring system with a digital theodolite, enabling the coordinates of positions surveyed to be obtained directly. Conventional stadia tacheometry, using a theodolite or level, was a rapid technique when used on flat or gently sloping sites but required more complex calculations to determine distances and heights if the telescope of the theodolite needed to be elevated or depressed. Self-reducing tacheometers, introduced after World War II and using vertical or horizontal staffs, made measurement much simpler but at a much greater capital cost for the equipment. One organization, the British Ordnance Survey, continued to use chain survey methods, imposed by the survey director, Major Thomas Colby, in the 1820s and not phased out until the 1960s, by which time they were used in conjunction with air survey and tacheometry.

In the years following World War II the relative costs of ground and air survey techniques continued to move in favor of air survey, largely because wage inflation was much greater than inflation in instrument and photographic costs. The effect of the changes in relative costs was to decrease the size of an area that could be surveyed more economically on the ground than with air survey. The introduction of total stations had a major impact on surveying for topographic mapping, reducing the time taken for detail work, and, at the same time, increasing the accuracy compared with tacheometry. For a short time, total stations increased the size of areas that could be surveyed more economically by ground survey. The incorporation of firmware on total stations to carry out resection made location in the field much simpler by removing the need to traverse into a site to be surveyed. Moreover, the ability to directly record the eastings, northings, and heights of the surveyed points meant that data captured in the field could be readily added to existing digital map databases. Introduction of differential GPS (Global Positioning System) in the 1990s meant that on-site control could be acquired by GPS, and GPS could also be used to collect detail. However, GPS data collection is rarely as cost-effective as using total stations and cannot be used in woodland or in dense urban areas, where trees or structures interfere with signals from the satellites.

Early experimental work in photogrammetric methods had started to influence detail survey work after the Canadians used panoramic cameras to create maps of the forest and lakes on the Canadian Shield. Canada's use of similar techniques on the boundary survey in the Yukon led to their adoption and development in the first decades of the twentieth century (Collier 2002, 157–58). In the Alps, terrestrial photogrammetry had been used during tunneling work but not for topographic mapping until after the development of the first successful automated plotting instruments. The lead here was taken by the Deutscher und Österreichischer Alpenverein, which produced topographic maps for walkers and climbers.

Following World War I there were concerted efforts to apply air survey techniques to detail survey work. The main thrust of continental European work was to develop instrumental methods capable of producing large- and medium-scale mapping. In the United States, Britain, and the British Empire, there was much greater interest in the development of simple graphical or optical techniques. Surveyors with the Survey of India were among the first to introduce the kinds of techniques that they had developed for military mapping in Mesopotamia during World War I (Collier and Inkpen 2001; Lewis and Salmond 1920). With a focus on medium-scale mapping and access to a large skilled but low-wage labor force, the Survey of India was well suited to the exploitation of the simple graphical techniques used in Mesopotamia.

In continental Europe, where the main focus was on the development of instrumental techniques for large-scale mapping, instrument designers initially went up a blind alley in attempting to modify the prewar plotting instruments, which had been designed for terrestrial photogrammetry. Success remained elusive until designers recognized the need for a different concept—the use of goniometers (Collier 2002, 165–67). The first instruments were still very expensive and complex to operate, making them unsuited to volume production of medium-scale topographic maps. The development in 1930 of the multiplex plotter, a cheap and easy-to-use instrument, made possible a rapid expansion of instrumental photogrammetry for topographic mapping. Following its initial use in Germany and Italy, the multiplex was rapidly adopted by the USGS and the Tennessee Valley Authority in the United States. Its more widespread adoption had to wait until the end of World War II.

In parallel with the development of instrumental methods of air survey, there was great interest in the development of accurate and cheap graphical methods. In the United States, James Warren Bagley had pioneered the use of radial line plotting techniques, but it was Martin Hotine's work in Britain that provided both the theoretical and practical basis for the widespread adoption of radial line plotting (Hotine 1927; Collier 2002, 165). In 1936, Charles Wood Collier, working at the U.S. Soil Conservation Service, developed the slotted-templet method, which reduced the need for ground control and speeded up the whole mapping process. This method was, as David Landen, a USGS researcher, noted, "one of the most important inventions in photogrammetry" and made possible the "mass-production of photogrammetric maps at low cost and great speed" (1952, 884).

Following World War II, both multiplex and slotted-templet became standard techniques for topographic mapping in Anglophone countries that lacked adequate map coverage. While the British Ordnance Survey did not make use of either technique, both British military survey and the Directorate of Colonial Surveys (later the Directorate of Overseas Surveys) made extensive use of the techniques into the early 1970s. Indeed, it could be argued that the mapping of Britain's colonial and former colonial territories in Africa would have been impossible without multiplex and slotted-templet techniques.

From the mid-1960s a new generation of less-expensive precise plotters started to replace multiplex for original medium-scale topographic mapping. One of the most successful, the Kern PG2, was designed to be used with wide-angle photography and also the super-wide-angle photography that was becoming available and could be used economically for mapping at scales between 1:10,000 and 1:100,000. This flexibility made it attractive to many national mapping agencies and commercial mapping companies. With suitable modification, it could even be used to directly scribe contours, reducing reproduction costs.

The development of photomapping, initially by the USGS, provided a cheaper alternative to conventional line maps. Some mapping agencies, such as in Sweden, decided to replace line maps at a particular scale with photomaps, while others, as in the German province of Nordrhein-Westfalen, used photomaps in addition to line maps at 1:5,000. Other countries, such as Botswana and Australia, made extensive use of photomaps for some areas while retaining line maps in others. Innovation in photogrammetry, primarily the introduction of digital photogrammetry, led to a much more widespread adoption of photomaps, both as alternatives to line maps and as backdrops for GIS (geographic information system) operations. This dual function helped reduce costs still further.

The combination of the Cold War and the application of cost-effective photogrammetric techniques meant that the worldwide provision of up-to-date topographic mapping peaked by about 1970. Much of the mapping in the former colonial territories was paid for out of the aid budgets of a number of first-world countries, not just by the former imperial powers. The provision of topographic mapping was seen as a necessary first step in the economic development of the former colonies, but Cold War politics also played a role in the willingness of the funding nations to meet the costs. The Arab-Israeli War of 1973, and the resultant oil crisis, led to a relative decline in the funding available to carry out new mapping or to maintain existing coverage. Countries like Britain cut back on their aid programs and on their own ability to produce the mapping. At the same time, the former colonies had poorly developed domestic mapping capacities to replace the capacity no longer provided by donor countries. This combination of circumstances led to a period of stagnation in which little new mapping was produced and existing coverage was allowed to go increasingly out-of-date. The situation was made worse by political instability and civil wars, which reduced still further any mapping work. By the 1990s much of the world's topographic mapping was out-of-date.

Introduction of digital photogrammetry in the 1990s had a number of benefits for topographic mapping. First, because it was cheaper than analog or analytical photogrammetry, it led to cost reductions in data capture. Second, it required significantly less skill and experience on the part of the operator to achieve acceptable results than did earlier methods. Photogrammetry ceased to be the preserve of the specialist. Overlaying a digital version of a line map on the stereo model made the revision process much quicker and simpler because the operator could easily see what new or changed information needed to be added to the existing map. Superimposition had been possible with analytical photogrammetric instruments, but had not been widely adopted because of equipment cost.

Satellite imagery did not play a major role in topographic mapping, although Landsat imagery was used for 1:250,000 mapping in Antarctica, and SPOT (Système Probatoire d'Observation de la Terre) imagery for 1:100,000 mapping in Yemen. In general, the resolution was too poor for significant use in developed countries with good map coverage, while developing countries lacked the technical capability to use the data. In 1999 the launch of the first high-resolution commercial satellite, IKONOS, initiated a new era in which satellite imagery could become a significant factor in topographic mapping programs.

The end of the Cold War led to a revival of topographic mapping in Europe, as the countries of the former Soviet Bloc started to replace the homogeneous secret mapping of the 1942-System with openly published mapping in more diverse styles (fig. 985). Some countries, such as Poland, chose to retain a style that was still broadly similar to the 1942-System, while others, such as Hungary, developed a national style (Collier et al. 1996).

The craft of topographic map production was likewise transformed during the early twentieth century. Cartographic drafting was still a skilled craft, requiring a high level of technical experience to produce results with the required quality. All linework was hand drawn, as


FIG. 985. DETAIL OF A 1:250,000 MAP OF *CAPE COLONY*, *ORANGE RIVER MOUTH*, 1907 (SHEET 127-E). An example of the much lighter style of mapping that was to become the norm in the twentieth century.

Size of the entire original: 63 × 53.4 cm; size of detail: 15.5 × 23.2 cm. Image courtesy of Peter Collier.

were symbols, hachures, and lettering. In most national mapping agencies this was to remain the case until the second half of the twentieth century. Various drawing media were used, such as paper, tracing linen, and Bristol board. The midcentury development of plastics led to the introduction of new drafting media, such as Astrofoil and Permatrace, which not only were lightweight and dimensionally stable but allowed easy correction of drafting errors. New styles of drafting pens, most notably Graphos and Rotring, made it much easier to produce high-quality linework of consistent density and thickness. However efficient, these new drafting techniques were rapidly replaced in many organizations by scribing and peelcoats. By midcentury, the photonymograph had already transformed lettering by allowing easy phototypesetting of lettering onto stripping film that could be applied to drawings. In the 1990s, the move to digital techniques largely removed the need for conventional drawing or scribing within national mapping agencies and with it the need for traditional craft skills.

At the start of the century engraving was still commonly used to produce printing plates for topographic mapping, although lithography was gradually becoming more widely accepted. In some countries, such as Austria, heliogravure on copperplates was the preferred method of reproduction because of the high quality of the resultant linework. The innate conservatism of managers and skilled workers at national mapping agencies meant that traditional reprographic techniques survived even when lithographic methods did not lead to noticeably inferior products. Britain's Ordnance Survey did not abandon engraving until the mid-1920s. The reluctance to give up a craft-based—and expensive—method of printing plates seems all the more strange insofar as most mapping agencies were under constant pressure to control costs. Some organizations, such as the Survey of India, had been using photolithographic techniques since the middle decades of the nineteenth century, driven to adopt this approach by the number of sheets that needed to be produced each year. In the early twentieth century a new technique, heliozincography, started to replace photolithography. The Vandyke process was also introduced for situations in which it was not necessary to change scale between drawing and printing plate. World War I, and the demand it generated for rapidly produced maps, also played a key role in the changes in reprographic techniques.

Doubtless the most important transformation of topographic mapping in the last quarter of the century was from an analog product into a digital process. As with so much else in topographic mapping, this transformation had been pioneered in military mapping. But in the civilian sector, issues such as aesthetics, which was a minor consideration in military mapping, became considerably more important. Some national mapping agencies, most notably the Swiss, were not prepared to move to digital mapping until they were convinced that the final product was at least as good as the traditional analog map.

The move to digital mapping raised a number of major problems, which different national mapping agencies chose to address in different ways. One problem related to the move from a sheet-based system of topographic mapping to the use of a seamless database. In some mapping agencies, it had been normal practice to edge match between adjacent sheets, while others had regarded each sheet as a separate entity. Where sheets had been edge matched, the move to a seamless cover was largely unproblematic. However, where the system was sheet based, any difference at the sheet edge needed to be reconciled during the digitization process—often a time-consuming and costly task. A second problem related to differences in the levels of accuracy within the sheets. These differences had arisen as a result of piecemeal revision using different revision techniques over many years. Most organizations adopted a policy of digitizing what was on the maps and attempting to remove errors during subsequent revisions. Only the Survey of Israel decided that it would be impossible to carry out such a process with any guarantee of obtaining a database of uniform quality. Survey officials decided that the only solution was to completely remap the country using photogrammetric methods directly into a digital database.

The move to digital mapping allowed the extensive use of these products as bases for GIS work. At the end of the century, electronic cartography had created a new market for topographic maps as the map interface in handheld and vehicle-mounted navigation systems, which made topographic maps more pervasive than at any other time in their history.

PETER COLLIER

SEE ALSO: Coastal Mapping; Coordinate Systems; Ordnance Survey (U.K.); Photogrammetric Mapping: (1) Instrumental Photogrammetry and Stereocompilation, (2) Orthophotography and Orthophoto Mapping; Plane Table; Projections: (1) Projections Defined for the Ellipsoid, (2) Projections Used for Military Grids; Tidal Measurement; Topographic Map

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*Topographic Mapping in Canada.* As the twentieth century began, Canada was one of few industrialized countries without topographic surveys. Only some maps showing township patterns and major topographic features in parts of eastern Canada and the Prairie Provinces existed. In 1903, a topographic mapping unit was established in the Department of Interior, and terrestrial phototopographic techniques were employed to compile maps of the Rocky Mountains in parts of Alberta and British Colombia at 1:63,500 scale with one hundred foot contours. In 1908, the Geological Survey of Canada organized its Topographical Survey Division. These two civilian mapping organizations were combined in 1936 into the Topographical Survey, but by that time only 161 map sheets at a scale of one mile to one inch (1:63,360) were published, a modest beginning toward compilation of the 12,992 (revised later to 13,488) sheets necessary to cover Canadian territory.

It was realized that the Eight-Mile Series, compiled during World War II (1944), with 220 sheets covering all of Canada, was in no way adequate for postwar defense purposes and economic development. To counter this, the postwar National Topographic System (NTS) mapping program was created. It had two main thrusts: the Four-Mile and its successor the 1:250,000 series, and the One-Mile and its successor the 1:50,000 series. In 1947 the Canadian government directed the completion of all 913 sheets of the 1:250,000 series within twenty years. The sheets were completed in the autumn of 1970 on the Universal Transverse Mercator projection with contour intervals of 20, 50, 100 and 200 meters, depending on topography. The 1:25,000 series was added to the NTS in 1953 but was stopped in 1978 after 690 sheets had been published due to provinces starting to map at this or larger scales. The One-Mile and the 1:50,000 series were the largest scale at which complete coverage of the country was entrusted to the Topographical Survey (fig. 986). The military collaborated in topographic mapping with the civilian Topographical Survey and also produced military town plans at 1:25,000 for the cities considered at risk during the Cold War period. In October 1965, the government decided to end the military work on NTS maps.

Increased demands for NTS map series and aeronautical charting resulted in the termination of the Three-Mile, Two-Mile, and 1:125,000 series. The last new sheet was produced in 1957 and revision was stopped in 1972. The Topographical Survey concentrated its efforts on 1:50,000-scale mapping. This enormous and audacious undertaking was made possible by wartime and postwar advances in aviation, photogrammetry, and electronics. High-resolution vertical photography from high altitude of all of Canada was now feasible. Shoran, Aerodist, Tellurometer, airborne profile recorder (APR), inertial survey, Global Positioning Systems (GPS), and the helicopter made the rapid establishment of geodetic control required for mapping possible and economical. Development in Canada of the analytical stereoplotter by Uno Vilho Helava, of the Gestalt Photomapper by Gilbert L. Hobrough, and of computer programs for adjustment of large aerial triangulation blocks by Gerhardus H. Schut and J. A. R. Blais played a major role in Canadian topographic mapping. Canadian universities ensured an adequate supply of highly qualified surveying engineers.

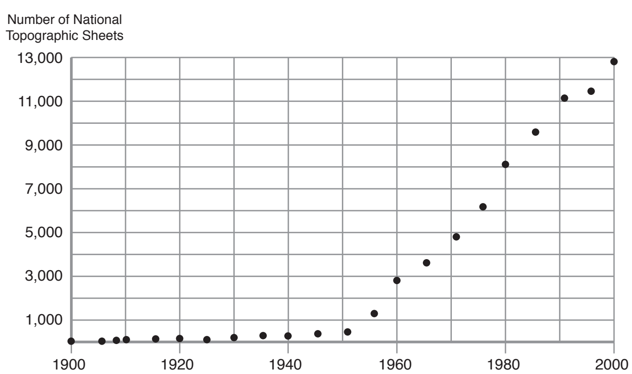


FIG. 986. RATE OF CANADIAN TOPOGRAPHIC MAP PRODUCTION OF ONE-MILE AND 1:50,000 SHEETS DURING THE TWENTIETH CENTURY.
After Leslie J. O'Brien and L. M. Sebert, "Photogrammetry and Federal Topographic Mapping," in *Mapping a Northern Land: The Survey of Canada, 1947–1994*, ed. Gerald McGrath and L. M. Sebert (Montreal: McGill-Queen's University Press, 1999), 76–115, esp. 108 (fig. 3–13).

In the period prior to and immediately following World War II, the Royal Canadian Air Force played a major role in providing aerial photography for mapping. By the late 1940s, however, aerial survey companies composed of wartime-trained personnel were established and provided high-altitude aerial photography for this ambitious mapping program, initially using war surplus aircrafts, and by 1970 switching to Learjets capable of taking aerial photography from a 40,000-foot altitude. Private companies were contracted to establish geodetic control by Shoran trilateration and a grid of Shoran-controlled photography combined with APR. These provided the geodetic control needed for photogrammetric compilation at 1:250,000. Today Canada uses the North American Datum 1983 (NAD83) and the Canadian Geodetic Vertical Datum 1928 (CGVD28) as its horizontal and vertical reference coordinate systems, respectively.

To address the operational imbalance between acquisition of aerial photography, control survey data, and the map compilation, the concept of an Aerial Survey Database (ASDB) was developed. The ASDB consists of diapositives of aerial photography on which pass-points are marked and a list of corresponding $x$, $y$, $z$ coordinates determined by aerial triangulation. Thus any area covered by the ASDB could be mapped immediately.

Military requirements had an influence on Canadian topographic map design. In 1950 the change to metric scales was made. Changes in map design were made by a civilian-military committee as dictated by changing requirements and the introduction of computer assisted cartography. The contour interval was 10 to 40 meters, depending on topography. North of the Wilderness Line, in underdeveloped northern Canada, monochrome 1:50,000 maps were produced. In the Arctic and Hudson Bay lowlands orthophoto maps were produced. Map revision was carried out in cycles of five years (cities and suburbs), ten years (rural areas), fifteen years (south of the Wilderness Line and settlements and communications routes north of the line), and thirty years (remaining areas north of the Wilderness Line).

In addition to the NTS, there are mapping programs in each province. Provincial mapping is contracted with industry. The overall provincial coverage is at 1:10,000 for populated areas and 1:20,000 for the

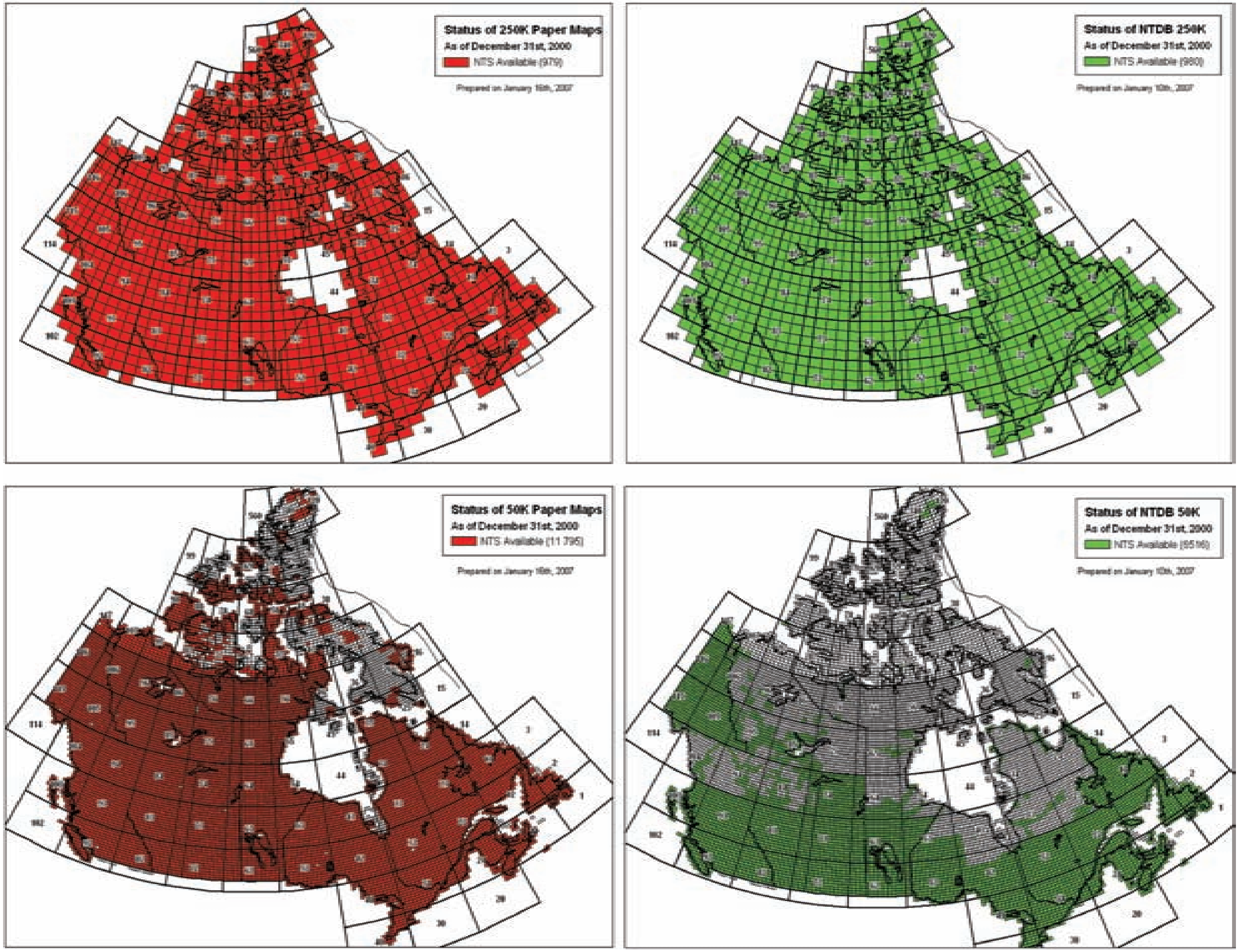


FIG. 987. STATUS OF 1:250,000 AND 1:50,000 MAP COVERAGE OF CANADA (PAPER AND DIGITAL) AT THE END OF THE TWENTIETH CENTURY.

Map data courtesy of Natural Resources Canada; maps created by Costas Armenakis.

rest, in monochrome style. Municipalities are mapped at 1:1,000, 1:2,000, 1:2,500, and 1:5,000. Several provinces also use orthophotomaps. In the early 1980s digital mapping became the norm with the objective of creating digital topographic databases as the foundation for provincial geospatial information systems. A digital terrain elevation model is an integral part of these databases.

In addition to the mapping of its own landmass, Canada has also provided topographic mapping to developing countries in Africa, Asia, the Caribbean, and South America through the Canadian International Development Agency (CIDA). Topographic mapping projects, mostly at 1:50,000, were carried out by Canadian geomatics companies and were inspected by the Topographical Survey.

Rapid development of computers and information technology had a profound influence on the provision of topographic information as map users began requesting terrain information in digital form. This led to the development of the National Topographic Data Base (NTDB), for which all terrain features are recorded in their true geographic position without regard to cartographic symbolization. National standards for digital mapping were developed in collaboration with the provinces and industry.

The first 1:50,000 map compiled by digital photogrammetric and computer-assisted cartography methods was published in December 1977. The following year, digital mapping was systematically introduced at the Topographical Survey as a standard production method. Contracts for digital mapping were also issued to industry.

The Sherbrooke Institute of Cartography was established in 1985, and renamed the Canada Centre for Geomatics in 1988. Digitization of all 913 maps at 1:250,000 was completed in 1990 thus creating the 1:250,000 digital NTDB. This database was expanded to topographic features at the 1:50,000 scale. The NTDB meets national mapping and geographic information systems (GIS) requirements. The NTDB data are available as complete NTS map data sets for specific regions or as topographic themes. As of 2000, all 981 of the 1:250,000 data sets were available in both digital and paper form. There are more 1:250,000 files (981) than paper maps (913). This is because the NTDB data cover exactly the geographical limits of the NTS geographic coverage definition; however, the NTS paper maps in several instances cover larger areas to accommodate for some extensions. At the 1:50,000 scale, 11,795 maps out of the possible 13,488 were produced, and 6,516 NTDB files out of 11,526 were completed (fig. 987).

Satellite imagery has been increasingly used since 1972 to both locate where revision is necessary and to provide metric data. The use of remote sensing techniques for 1:50,000 topographic mapping was started in 1988 with SPOT (Système Probatoire d'Observation de la Terre) data, followed by data from the IRS (Indian Remote Sensing) satellite in the late 1990s, followed by the use of Landsat 7 orthoimage national coverage for updating, beginning in the early 2000s.

The realization that the increasing range of information technology applications rely on geospatial databases led to the development in 1997 of the Canadian Geospatial Data Infrastructure (CGDI) as the geographic component of the information highway. The emergence of the World Wide Web (WWW) in 1994 was the enabling agent for the CGDI. The CGDI is an interagency (federal, provincial, and territorial governments, industry and academia) effort to enable easy, timely, consistent, and harmonized access and discovery of geographic information and services through a cooperative, interconnected infrastructure of the CGDI participants. Natural Resources Canada (NRCan) launched the GeoConnection program in 1999 within the CGDI framework. Its objective is to foster knowledge about Canada, enable better policy decisions, and provide Canadian geographical information and tools using Internet-based content and services. At the end of the century, using new Internet technology, the digital topographic data could be searched, ordered, and downloaded, and thus opening the way to interactive and dynamic mapping.

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SEE ALSO: Military Mapping of Geographic Areas: Canada and the Polar North

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*Topographic Mapping in the United States.* Throughout the twentieth century, the existence of topographic maps as a national public good has been recognized and supported in the United States in the most tangible way—with appropriations by the Congress. Annually since

1888, these appropriations have been made to the budget of the Department of the Interior for the preparation of topographic quadrangle maps by the U.S. Geological Survey (USGS). The impetus for this program came from the legislative directive establishing the USGS in 1879 that charged its director with "the classification of the public lands and examination of the Geological Structure, mineral resources and products of the national domain" (United States, Department of State 1879, 394). This charge required a topographic base map, and a national program was begun to achieve this objective. Other nations recognized the value of topographic maps by forming similar organizations, such as the Ordnance Survey in Great Britain and the Institut géographique national in France, and these nations exported that recognition to many parts of the world during the colonial era of the nineteenth and twentieth centuries.

In the United States it was understood that to conduct such a mapping program on a national basis required a significant amount of coordination and cooperation to determine the map requirements for federal, state, and local agencies. It was also evident that such a program could not produce all of the required mapping in even a few years time. As experience proved, to complete national coverage of the United States required nearly 100 years, and at the end of the once-over coverage many of the previously prepared maps were out-of-date and required revision. In fact, many quadrangle maps were revised before the final map was produced. To effect this cooperation and coordination, the Board of Surveys and Maps of the Federal Government (renamed Federal Board of Surveys and Maps in 1936) was established in 1919 and continued until the Bureau of the Budget (now the Office of Management and Budget) issued Circular A-16 in 1953 (rev. 1967 and 1990) to assign responsibility for coordinating federal mapping to the USGS and responsibility for the coordination of geodetic surveying to the Department of Commerce's Coast and Geodetic Survey.

Under Circular A-16, the USGS annually canvassed federal and state agencies for their map requirements. The requirements almost always exceeded topographic map production capabilities, so priorities had to be established. The USGS augmented the federal topographic mapping program by establishing a cooperative venture whereby states contributed funds to be matched with federal dollars, on a 50/50 basis, to prepare topographic maps that met both federal and state needs. Funds leveraged in this manner expedited the national mapping program.

The early years of topographic mapping in the United States are well documented (Birdseye 1928; USGS Centennial 1979). At the beginning of the 1900s, topographic maps were produced entirely by field methods (fig. 988). The mapmaker started with a blank manuscript and made the necessary observations to generate the map. Planimetry was compiled in the field by sightings, and vertical angular measurements were taken to produce the contours that represent the differences above or below sea level. The concept of sea level, considered to be the zero contour from which all other contour values are determined, is not a constant value, and it varies by as much as 1.5 meters along the eastern coast and by as much as 0.5 meter from the east coast to the west coast. To establish a local mean sea level, a series of observations at established tide gauges were made over a period of nineteen years, and a value for local mean sea level was determined. Early in the century, a value of 0.0 feet was accepted at an established tide gauge near Galveston, Texas, as the primary benchmark for the United States, and Sea Level Datum of 1929, later called the National Geodetic Vertical Datum of 1929, was established. Measurements from satellites beginning in 1957 produced a new series of more precise observations that were used to calculate a new datum, the North American Vertical Datum of 1988 (NAVD88), based on a tide

FIG. 988. SURVEYING WITH PLANE TABLE AND ALIDADE. USGS topographer George Stanley Druhot in Fullerton, California, 1932. In the second car behind Druhot, a stadia rod is visible.
Image courtesy of the Photographic Library, U.S. Geological Survey, Menlo Park.

gauge at Point Rimouski, located in the mouth of the St. Lawrence River. These later changes in the datum resulted in adjustments to the level network from −40 centimeters to +150 centimeters in the conterminous United States and from −94 centimeters to +24 centimeters in Alaska. All benchmark values in the United States have been adjusted to the NAVD88.

The original geodetic datum for calculating horizontal position of control points on the earth's surface in the United States (also accepted by Canada, Mexico, and the countries of Central America) was based on the Clarke spheroid of 1866, with its point of origin at Meades Ranch survey station in Kansas. All previously established control stations based on observations and calculations were adjusted to this North American Datum of 1927 (NAD27).

As the ability to make more precise angular and distance measurements continued to improve and more information on the shape of the earth became available, a new datum was determined, the North American Datum of 1983 (NAD83). Still in use today, NAD83 has an earth-centered (geocentric) origin. All NAD27 positions were recalculated to NAD83. As the earth is a nonrigid body, it undergoes crustal movement along the tectonic plates, i.e., the intersection of the North American and the Pacific plates, thus continuously affecting the interrelationships of horizontal positions within the United States, especially on the western coast.

During the twentieth century, production of the national topographic base map series was affected by these datum shifts, and it was recognized that the map scale originally selected for the topographic series was not sufficient, and that larger and larger map scales were necessary to adequately portray surface conditions. When the program began, a scale of 1:250,000 was selected for the base map, and its format was one degree of latitude by two degrees of longitude. Over the succeeding years, map scales were enlarged to 1:125,000 (30′ × 1° format), then to 1:62,500 (15′ × 15′ format), and a final decision was made to map the conterminous United States at 1:24,000 (7.5′ × 7.5′ format) (fig. 989).

The 1:24,000 scale and 7.5′ × 7.5′ format results in quadrangle maps that range in area from about sixty square miles in southern Texas to fifty-three square miles along the northern tier of states. The published map sheets measure approximately 30 × 24 inches (76 × 61 cms). At 1:24,000 it takes nearly 55,000 quadrangles to cover the conterminous United States. In Alaska, the


FIG. 989. DETAIL FROM *WASHINGTON WEST*, 1:24,000, 1951.
Size of the entire original: 66.2 × 49.6 cm; size of detail: 9.7 × 17.3 cm. Image courtesy of the Historical Topographic Map Collection, U.S. Geological Survey.

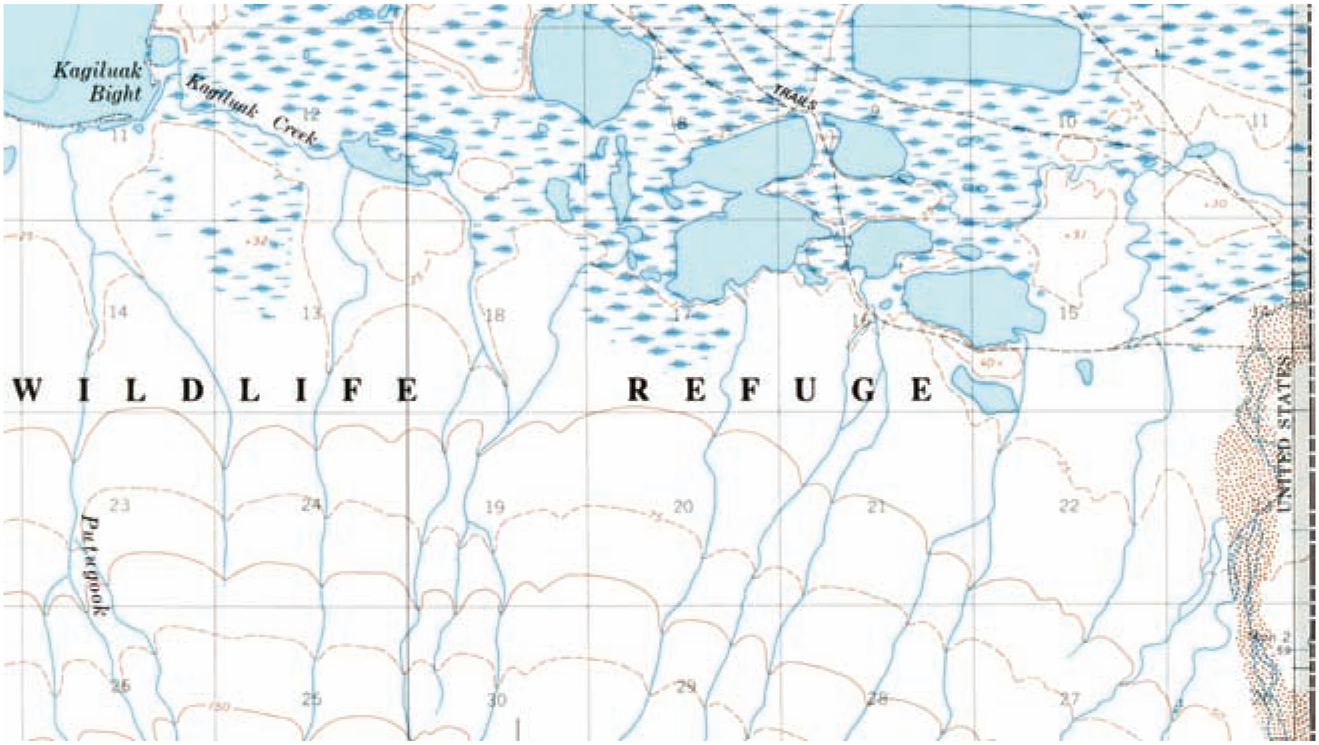


FIG. 990. DETAIL FROM *DEMARCATION POINT (C-1)*, ALASKA, 1:63,360, 1988. Showing Beaufort Sea coast at the U.S.-Canadian border.

Size of the entire original: 53.7 × 41.5 cm; size of detail: 9.7 × 17.3 cm. Image courtesy of the Historical Topographic Map Collection, U.S. Geological Survey.

accepted scale is 1:62,500, with varying formats because of the rapidly converging meridians. Some of Alaska is covered at true inch-to-the-mile scale, 1:63,360 (fig. 990), and some of the developed areas at 1:24,000.

Contour intervals were selected, usually ranging from five to forty feet and up to even eighty feet in areas of steep terrain. To properly depict the slopes, some quadrangle maps have dual contour intervals. For example, in some cases in the western United States where mountains erupt from the desert floor, an interval of five feet is necessary to portray slopes for the flatter areas and either a forty- or eighty-foot interval is appropriate for the mountain areas.

As the production of topographic maps progressed from being exclusively a field operation, attempts were made to combine the use of surveying-type instruments with terrestrial photographs to speed up completion. The photoalidade, the vertical sketchmaster, and the panoramic alidade were developed and are described in a USGS circular (Thompson 1952). While the use of these devices enhanced the production process, the major revolution in the production of topographic maps occurred with the introduction of photogrammetic instrumentation and techniques that allowed the use of precision aerial cameras to obtain photographs. Aerial camera lenses were improved by minimizing distortions caused by imperfect grinding and assembly of lenses composed of several elements. Improvements were also made in the optical systems and in the mechanical systems of photogrammetic plotting instruments. Photogrammetric plotters ranged from relatively simple direct optical projection systems that were used to produce the three-dimensional model necessary to draw contours, to a combination of optical and mechanical projection for model formation, to fully analytical plotters that used computer-controlled photo stages to produce the stereomodel. Direct optical projection plotters using colored filters (red and blue) in the projection system allowed the viewing of successive pairs of overlapping aerial photographs using a pair of similarly colored eyeglasses. The separate images presented to the brain could be interpreted as a single three-dimensional model.

By using a hand-operated tracing device, the plotter operator was able to trace images on the ground—of roads, railroads, building outlines, drainage patterns, ponds, lakes, woodland outlines, and other map-worthy detail, for example—to form the base. The measuring mark on this tracing device allowed height measurement and permitted the operator to keep this measuring mark in apparent contact with the ground, generating a line of equal elevation, forming a contour. As the mark could be set at each succeeding contour value, the entire set of contours for each stereomodel was generated.

While the introduction of photogrammetric methods significantly improved production rates, certain field operations were still necessary. Basic horizontal and vertical control had to be established by on-the-ground surveys, although the necessary density (spacing) of this control was lessened by the application of processes such as aerotriangulation and, later, analytical aerotriangulation. Also, the collection of map information not imaged on the compilation photographs, such as names and boundaries, had to be obtained in the field.

In the early 1960s, another process was developed and introduced to produce a map base. Because the vertical aerial photograph is a perspective image containing displacements in the positions of ground features, a single photograph cannot serve as a map base. It also contains variations in the scale, for example, hills and mountains closer to the lens are of a different scale than those objects at lower elevations. A new instrument, the orthophotoscope, allowed the perspective aerial photograph to be converted to an equivalent orthographic view of the ground, thus removing displacements due to relief and variations in image scale. The resulting image could then be used to make accurate angular and distance measurements directly on the orthophotograph. The conversion from a perspective view to an orthographic view was accomplished by a scanning process. A stereomodel was scanned through a scanning slit, which exposed incremental parts of the image to a negative held below the scan slit. The scan slit was moved in the *x-y* and *z* directions, which removed the displacement due to relief and accounted for changes in scale in the image. During the scanning process, profiles of the terrain were generated that could be used to produce additional topographic information. Later developments allowed the production of orthophotographs from automatic image correlation devices, with closer data spacing so that more accurate elevation data were obtained.

The technology to produce both an image-based map and topographic information was available in 1980. At that time there were approximately 20,000 7.5-minute quadrangle maps not yet completed, so a decision was made to prepare those base maps from orthophotographs. The topographic data needed to complete these maps was scheduled to follow immediately. The use of orthophoto bases permitted the acceleration of the mapping process so that by the mid-1980s the nation was finally covered by a complete set of 1:24,000, 7.5-minute topographic maps, a significant milestone in the history of topographic mapping in the United States. The nation had been covered once, but a significant number of maps, especially those in and around urban areas, were out-of-date and no longer adequately represented conditions on the ground. Major production efforts were directed to the revision of those out-of-date maps. Although early studies had shown that a revision cycle of no less than ten years was necessary, this criterion was almost never met. New aerial photography was obtained for those areas needing revision, and intensive efforts were devoted to revision.

At about this same time, technology that allowed the use and manipulation of map data in digital form was becoming available. A major effort was undertaken to digitize both the planimetric features and the elevation data of quadrangle maps. This led to an ever-increasing number of users who combined the base map data with other data sets—i.e., thematic, climatic, and environmental—to provide the basis for multidisciplinary studies.

Because base map data and other thematic data in digital form could, in effect, occupy the same positional space at the same time, more accurate and meaningful analyses could be made, as opposed to graphic map data that required features to be displaced in order to be most readable. The existence of topographic map data in digital form also contributed to the development of systems allowing the combination of disparate spatial data sets known as geographic information systems (GIS). The future uses of topographic data as the basic framework for GIS were nearly limitless as the proliferation of computer users continued into the twenty-first century. The early recognition of the value of topographic information has given the United States a most valuable asset.

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SEE ALSO: Gannett, Henry; U.S. Geological Survey

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*Topographic Mapping in Latin America.* Soon after the Latin American revolutions during the first half of the nineteenth century, the parts of the dismembered Iberian Empire in America were reorganized into national states. Maps of the new countries began to be published, mostly compiled by foreign travelers, naturalists, and other professionals from various sources. Sometimes the Latin American governments paid the mapmakers and acknowledged their work as official cartography. An example was V. Martin de Moussy's atlas of Argentina, *Description géographique et statistique de la Confédération Argentine*, with a three-volume text (1860–64) and an atlas volume (1869). Meanwhile, newly created civil topographic offices, such as the Departamento Topográfico in Buenos Aires (1826) and the Comisión Topográfica in Montevideo (1831), took charge of measuring lands, public services, and urban infrastructure planning.

Some military offices undertook large-scale topographic surveys for the Creole elites. Military institutes and schools, directly involved in the territorial organization of the new states, included training for topographic mapping among their courses. The topics covered included occupation and mapping of indigenous territories, development of communications networks, cadastral plans, and cartography of border regions. It was hardly coincidental that Chile organized its Servicio Geográfico del Ejército in 1881 during the War of the Pacific, and that Argentina institutionalized the Oficina Topográfica Militar in 1879 during a military campaign against the southern indigenous territories in northern Patagonia.

By the turn of the century, the former *milicias* (militias) had become professional national armies. Absorbing the former cartographic offices, they undertook to produce and systematize topographic information. Although most offices had operated in disorganized and anarchic ways, some merger and reorganization into governmental ministries took place. Both the Chilean and Argentinean offices were reorganized repeatedly and stabilized when they assumed management of state cartographic policy. In Argentina, the División Técnica del Ejército changed and became the Instituto Geográfico Militar in 1904. In Chile, the Instituto Geográfico Militar, created in 1922, was an autonomous bureau controlled by the Chilean army.

The reorganization processes mostly involved progressive centralization of cartographic responsibilities aimed at creating new national topographic maps based on field surveys. The results were intended to replace the old geographical maps, mostly copied and redrawn from selected secondary sources. However, limited financial resources, institutional instability, and the huge extent of some national territories were serious impediments. In fact, two decades into the twentieth century, "save for a small amount of survey conducted by the Instituto Geográfico Militar of the Argentine Army, and some small parts of Uruguay and Chile, South America was, to the topographic surveyor, virgin territory" (Pearson and Heffernan 2008, 4) (fig. 991). Thus, the American Geographical Society's map of Hispanic America project, a contribution to the 1:1,000,000-scale International Map of the World, began in 1920 by compiling "provisional sheets" from secondary sources (figs. 992 and 993), pending production of new topographic maps based on modern surveys by local agencies.

Meanwhile, in Uruguay the Departamento Nacional de Ingenieros was absorbed by the Servicio Geográfico Militar, founded in 1913. The aim was to replace the recompilations of preexisting maps, published since 1908 by the Tercera División del Estado Mayor del Ejército, with a national topographic map based on planimetry and altimetry.

Similarly, in Peru the Estado Mayor del Ejército (established in 1901) absorbed two earlier cartographic offices and later gave way to the Servicio Geográfico del Ejército (1911). The latter became the Instituto Geográfico Militar in 1939 and, finally, the Instituto Geográfico Nacional in 1981.

In Ecuador, the Servicio Geográfico Militar (established 1928) was elevated to Instituto Geográfico Militar in 1947. In 1978 it assumed technical and scientific responsibility for planning, coordinating, and controlling the national mapping and geographical data archive. Although administratively autonomous, it was subordinate to the army general command.

Other national mapping agencies with military profiles were the Dirección del Servicio Geográfico Militar (Paraguay), Instituto Cartográfico Militar (Dominican Republic), and Instituto Geográfico Militar (Bolivia). In Latin America the army was most often capable of technical instruction and field surveys, mainly because of its financial, human, and technical resources, but also due to its relatively early consolidation and stability.

After a period of military governments, political events of the late twentieth century resulted in some institutional changes from military to national. Nonetheless, when the Peruvian Instituto Geográfico Militar became the Instituto Geográfico Nacional it retained affiliation with the Ministerio de Guerra, its responsibility for producing and updating the national map, and its role as cartographic support for the army. In Argentina the Instituto Geográfico Militar became the Instituto Geográfico Nacional in 2009. Although managed by a civilian woman, its structure and mission remained the same.

In Guatemala, though, the civil designation meant a deeper transformation. The Comisión Geográfica, founded in 1946 under the control of the Ministerio de


FIG. 991. *ARGENTINE REPUBLIC: EXTENT AND CHARACTER OF EXISTING SURVEYS.* In 1932 coverage of Argentina by existing surveys was concentrated around urban centers and along international boundaries and rivers. See also figure 94.

Size of the original: 16.4 × 11.4 cm. In *A Catalogue of Maps of Hispanic America, Volume IV: Maps of the Argentine Republic, Chile, and Uruguay* (New York: American Geographical Society, 1932), facing 1. Permission courtesy of the American Geographical Society, New York.

Guerra, Marina y Aviación, not only became the Instituto Geográfico Nacional in 1966 but also moved to the Secretaría de Comunicaciones, Obras Públicas y Transporte.

In Colombia, the Instituto Geográfico Militar (created 1935) was a dependency of the Estado Mayor General del Ejército. In 1940, it moved to the Ministerio de Hacienda y Crédito Público as the Instituto Geográfico Militar y Catastral. In 1950 it became the Instituto Geográfico Agustín Codazzi, which in 1999 joined the Departamento Administrativo Nacional de Estadística and assumed responsibility for georeferencing and cadastral work for tax purposes.

In Mexico, the Instituto Nacional de Estadística,

TIERRA DEL FUEGO
ATLANTIC
PACIFIC
OCEAN
OCEAN
TIERRA DEL FUEGO
MAP ROOM COPY

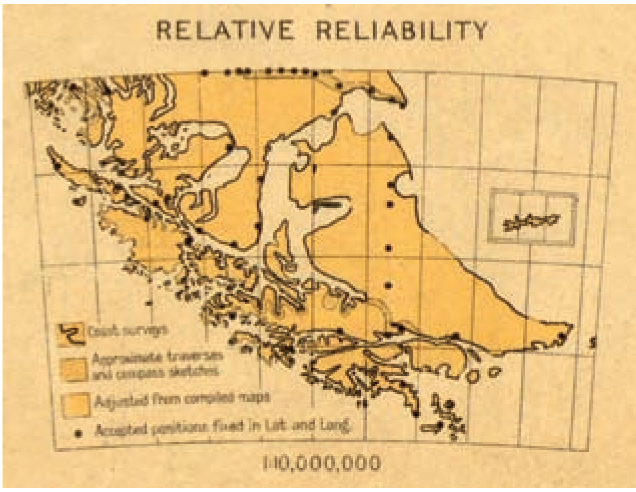


FIG. 993. RELATIVE RELIABILITY FROM *TIERRA DEL FUEGO*, 1930. This graphic detail of figure 992 shows that the points corresponding to accepted positions fixed in latitude and longitude match the international boundary between Argentina and Chile.
Size of the detail: ca. 5.4 × 7.1 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries. Permission courtesy of the American Geographical Society, New York.

Geografía e Informática followed a somewhat different pattern. Established as a decentralized agency in the Secretaría de Programación y Presupuesto, it handled geographical information of a financial nature. However, following the demise of the Comisión Geográfica Exploradora (1878–1914), various military bureaus worked on topographic surveys. After some interruptions, in 1939 the Comisión Geográfica Militar (later renamed Servicio Geográfico del Ejército and Departamento Cartográfico) was created. In 1942, it undertook to produce a 1:100,000-scale topographic map of the Mexican Republic based on aerial photographic surveys and a revised geodetic network.

On the other hand, the Instituto Geográfico de Venezuela Simón Bolívar (IGVSB), created in 2000, resulted from major restructuring of the former Dirección de Cartografía Nacional (which had been attached to the Ministerio de Obras Públicas after its creation in 1935 by the amalgamation of the Oficina de Cartografía Nacional, attached to the Ministerio de Relaciones Interiores, and the Servicio Aerofotográfico, attached to the Ministerio de Obras Públicas). As an autonomous agency attached to the Ministerio del Ambiente y de los Recursos Naturales, the IGVSB took control of the official cartography of the country. Its particular responsibilities were map production and official territorial information (topographic cartography, cadastre, geophysics, geodesy, and remote sensing).

Several other Central American countries displayed similar patterns of development. In fact, during the first cartographic week of Central America, Semana Cartográfia de América Central (celebrated in Guatemala in 1956), and the second (celebrated in San Salvador in 1957), the recommendation was made that all cartographic and geographical institutions should become national institutes for geographical, geodetic, geophysical, and other similar studies and activities. In Costa Rica, the Instituto Geográfico Nacional (1944), attached to the Ministerio de Obras Públicas y Transportes, had resulted from the reorganization of the former Instituto Físico Geográfico (1889). Two other agencies with similar institutional profiles were the Instituto Nicaragüense de Estudios Territoriales (attached to the Ministerio de Obras Públicas Nicaragua) and the Instituto Geográfico Nacional "Tommy Guardia" (Republic of Panama).

The national mapping agencies took over production and publication of official cartography, which usually meant authorized maps. Their founding mission statements noted the strategic value of official cartography and the importance of controlling the production and the circulation of "scientific portraits" of the national territory.

In countries like Argentina the interest in establishing an official cartography emerged in the nineteenth century. The first general official map of the Republic of Honduras on a scale 1:1,000,000 was developed in 1867–68, although it had restricted circulation (and was not reprinted for wider distribution until 1968).

Governments wished to produce official and scientific cartographic documents to support their territorial claims in anticipated diplomatic conflicts. For example, in 1921 the Peruvian government entrusted production of the national map to the Servicio Geográfico del Ejército. The Congress of Ecuador reacted in 1922 by commissioning the army staff to create an official topographic map.

The basic policy was that the official map should match the country's territorial claims, be taught in schools, and be the public geographical image of the country. The work of the national mapping agencies was regulated by legislation. Some regulations directly affected data gathering. In Mexico, for example, aerial photography

(*Facing page*)
FIG. 992. *TIERRA DEL FUEGO*, 1:1,000,000 (NEW YORK: AMERICAN GEOGRAPHICAL SOCIETY OF NEW YORK, 1930). Provisional edition, this map of Tierra del Fuego and its later editions remained in use until the late twentieth century.
Size of the original: ca. 63.3 × 74.2 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries. Permission courtesy of the American Geographical Society, New York.

with metric cameras by private citizens was closely regulated by the Ley de Información Estadística y Geográfica (1980).

In other cases legislation focused on organizational structure, internal functioning, or coordination among various offices producing geocartographic information. For example, the Costa Rican mapping agency had been governed by the Ley Orgánica del Instituto Geográfico Nacional N° 59 since 1944. From 2000 the IGVSB was governed by the Ley de Geografía, Cartografía y Catastro Nacional.

Legislation sometimes affected the cartographic images themselves. In Argentina, a 1946 government decree required maps of the Argentine Republic to show "all continental and insular parts of the state's territory" and the Antarctic sector over which the country had sovereignty (Ley de la Carta, No 12.696 [now 22.963], art. 19). The resulting fictional territorial image, through strong educational policy, became so familiar to the national audience that it strengthened Argentinean territorial claims.

The definition of international borders, often a source of controversy among neighboring countries, required high-accuracy topographic mapping. A major precedent was the monumental work on the United States–Mexico border (1849–57). Elsewhere in Latin America such surveying mostly occurred in limited areas of conflict, such as the Chile-Argentina boundary in Tierra del Fuego.

Earlier cooperative topographic surveys of boundary areas involved drawing accurate maps in the field. Each party then submitted its map to a binational commission that compared them for possible revision and eventual joint acceptance. Agreement on demarcation also involved fieldwork to place markers and design of map symbols representing the boundaries. Toward the mid-twentieth century aerial photographic surveys and photogrammetric methods replaced field measurement. The 1:100,000-scale map of the Washington Award, made in 1932 from controlled aerial photographs, supported field demarcation in 1933–35 of the Honduras-Guatemala border (Pineda Portillo 1998, 61).

Apart from improving accuracy, the new methods facilitated accelerated topographic coverage of Latin American nations. In Guatemala, for example, a geographical commission under the control of the Ministerio de Guerra, Marina y Aviación was created in 1946. Its mission was to conduct an aeronautical mapping program, complete geodetic measurements, and employ photogrammetric methods on topographic maps at scales of 1:50,000, 1:100,000, and 1:250,000. Aerial photography also enabled survey of areas where topography and other physical features restricted fieldwork, such as Amazonia and the Andes.

Private topographic surveys were undertaken for specific purposes. Companies needing to extend railroads for extracting minerals, moving materials to factories, or transporting products to market carried out topographic surveys and produced accurate topographic maps. The Tela Railroad Company (United Fruit's Honduran subsidiary) was one such example. Other private associations had cartographic departments that collaborated with national topographic agencies. In Argentina, the Automóvil Club Argentino provided useful information to correct maps published by the Instituto Geográfico Militar.

Topographic mapping in twentieth-century Latin America involved wide-ranging practices and processes. Despite that heterogeneity, some common patterns were evident throughout the region. One was the formation of official national mapping agencies, which developed more or less coordinated plans for training topographic surveyors, made progress in national topographic surveying, and published topographic sheets. Additionally, the transformation of topographic mapping into national and official cartography implied political control over mapping and cartographic images. Also, the concurrent processes of defining and fixing international boundaries among the Latin American states led to the collaboration of multinational commissions on maps drawn in the field for establishing accurate boundaries based on large-scale topographic surveys. At the same time, topographic mapping was also linked to private interests, such as investors and different kinds of companies in need of topographic maps for production, commerce, and communication.

CARLA LOIS

SEE ALSO: American Geographical Society; Holdich, Thomas Hungerford; Inter-American Geodetic Survey; Road Mapping: Latin America

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*Topographic Mapping in Africa by the British.* Prior to 1900 there had been no significant British effort to map any of the African colonies, even those with a long-standing British presence. How the African colonies were to be mapped had been the subject of considerable debate both in government circles (Collier 2006a) and in the Royal Geographical Society (Collier and Inkpen 2003). Geographer Thomas Hungerford Holdich had long advocated that the Indian model, which used locally recruited and trained staff, should be adopted in the African colonies. The Anglo-Boer War (1899–1902) had highlighted many of the problems created by a lack of adequate mapping, and the matter needed urgent attention. E. H. Hills, head of the Topographic Section, General Staff, advocated forming a Department for African Mapping (McGrath 1976b, 14). For diverse reasons Hills's proposal was not accepted (McGrath 1976a, 7).

By 1900 most African colonial territories already had a survey department, usually involved in a range of work that included cadastral mapping, surveying mineral concessions, and providing cartographic support for public works. There were, however, concerns regarding the efficiency of these departments and whether they were actually providing the kinds of maps that the British government required. The British Ordnance Survey was fully stretched by domestic needs, and the Intelligence Division of the British War Office was capable of little more than compilation from existing mapping. As noted above, Hills's proposal for a department for African mapping had not been accepted; instead, the mapping was to be carried out within the colonies by their own survey departments but under the direction of the imperial power (Collier 2006a). The Colonial Survey Committee was constituted in August 1905 to oversee the mapping programs of the colonial survey departments in Africa, although its scope was subsequently broadened to cover all colonial territories. The committee, which consisted of a representative of the Colonial Office, the director general of the Ordnance Survey, and the officer in charge of the Topographical Section of the General Staff (subsequently renamed the Geographical Section, General Staff [GSGS]), determined that topographic maps should be at scales of 1:62,500, 1:125,000, 1:250,000 (fig. 994), 1:500,000, and 1:1,000,000. The committee followed Holdich's advice in recommending that locally recruited staff be used to carry out survey operations (Great Britain, Colonial Survey Committee 1906). While the local survey departments were responsible for observing the control networks and carrying out detailed surveys, the War Office drawing room compiled and printed the maps.

The Gold Coast was the first colony fully mapped at 1:125,000. All the maps were published by August 1908 (Great Britain, Colonial Survey Committee 1909), but little use had been made of native surveyors during this work. The Gold Coast survey was financed largely

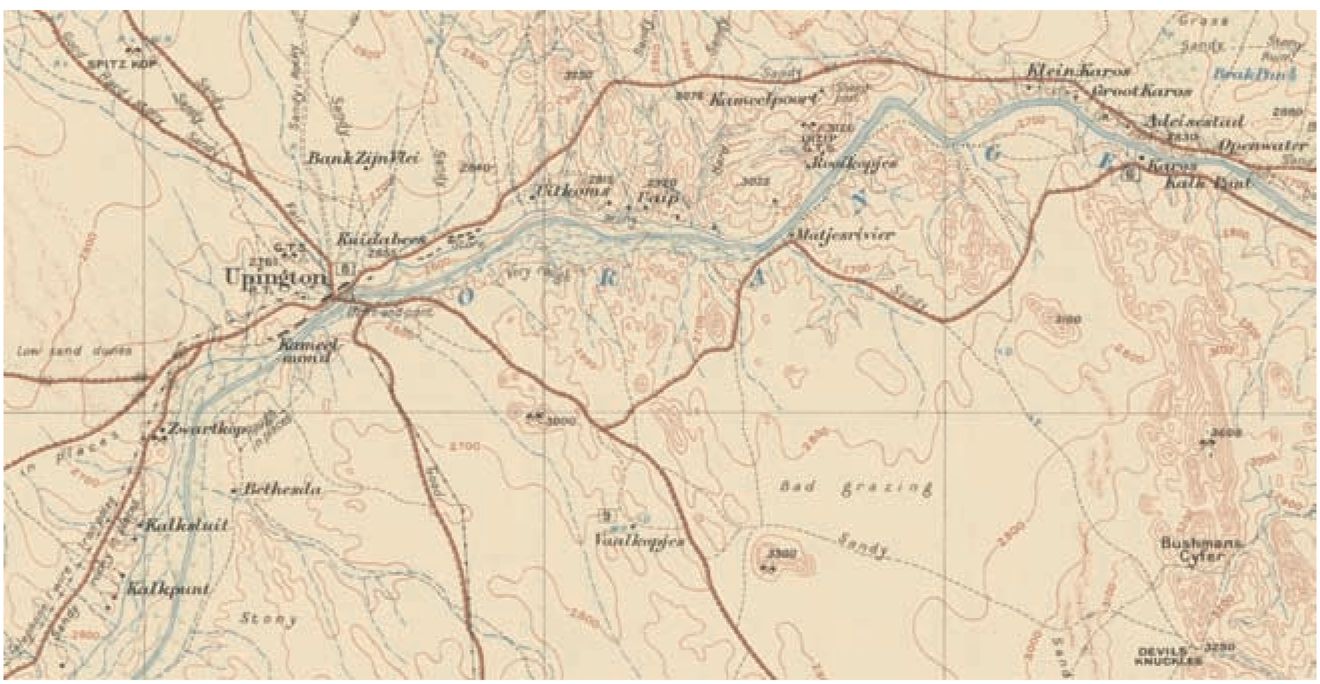


FIG. 994. DETAIL FROM 1:250,000 SHEET, *CAPE OF GOOD HOPE*, *UPINGTON*, 1913. Sheet South-H-34/D. Size of the entire original: 61.3 × 60.0 cm; size of detail: 10.9 × 21.4 cm. Image courtesy of Peter Collier.

by the revenues generated from carrying out boundary surveys of mining concessions, and the colony was able to employ a detachment of Royal Engineer surveyors in addition to its own survey department. The detachment was withdrawn once the topographic survey work was completed. Progress was much slower in other colonies, which lacked the Gold Coast's mineral resources.

Following the outbreak of World War I, all military personnel were withdrawn from the colonial survey departments. In addition, a number of surveyors volunteered for military service. The resulting personnel shortage severely limited the ability of survey departments to carry out topographic mapping. For example, in Kenya, where 1,188 square miles of 1:125,000-scale mapping and 8,000 square miles of 1:250,000-scale mapping had been completed before the war, just 1,500 square miles of 1:250,000-scale mapping was completed in 1915, and no further topographic mapping was carried out until 1920 (Great Britain, Colonial Survey Committee 1924, 29). Even so, for colonies in a war zone the British Army continued to meet its own needs for mapping or paid the local survey department to carry out the work.

In most of the African colonies the interwar years were ones of financial hardship, and the budgets of survey departments were severely restricted. Topographic mapping was seen as less important than cadastral mapping and the mapping of mineral concessions, both of which produced short-term financial returns. There was little increase in the total area covered by topographic mapping, and much of the existing coverage was increasingly out-of-date. Despite a number of proposals from the colonial survey departments to use air survey methods, Royal Engineer Brigadier H. S. L. Winterbotham, the outgoing head of the GSGS, on a tour of inspection of colonial departments, rejected most of these proposals in favor of 1:250,000 and 1:125,000 mapping by ground survey (McGrath 1976b, 47).

The outbreak of World War II once again brought most mapping activity to a halt. The exceptions were colonies in war zones, where, once again, the British Army assumed responsibility for mapping. The chief beneficiary of this policy was Kenya, where military surveyors drawn from the survey departments of the Gold Coast, Nigeria, Rhodesia, Tanganyika, and South Africa mapped its border areas with Abyssinia and Italian East Africa.

While topographic mapping was at a virtual standstill due to the war service of survey personnel, the British government recognized that the demand for mapping had not diminished. Planning for the postwar development of the African colonies was under active consideration in 1941, and these discussions ultimately led to the founding in 1946 of the Directorate of Colonial Surveys, later renamed the Directorate of Overseas Surveys (McGrath 1983). In addition to the more general need for topographic mapping in the African colonies, a number of specific development projects, notably, the Volta (Akosombo) and Kariba Dams, the Tanganyika "Groundnut Scheme," and the Central African Rail Link required topographic mapping before they could proceed (McGrath 1983, 61ff.).

Martin Hotine, the first director of the Directorate of Colonial Surveys, had maintained an interest in African mapping since his work on the 30th Meridian Arc in the early 1930s. He had also played an important role in the development of radial line techniques during his time as experimental officer for the Air Survey Committee in the 1920s (Collier 2006b). The topographic mapping needs of the African colonies provided Hotine with a perfect opportunity to put his ideas into practice. Radial line techniques enabled the Directorate of Colonial Surveys to make rapid progress with planimetric mapping. Slotted template adjustments required relatively sparse networks of control points, and radial line plotting needed only a straight edge and a pencil to compile plots ready for field checking. Called Preliminary Plots, these maps were printed in monochrome and intended to meet mapping needs until a contoured and multicolored edition of the topographic map could be produced (fig. 995).

Hotine was keen on the use of form lining based on simple parallax height measurements to provide height data for the maps, but colonial customers were not content with anything less than properly observed contours. Changing the name from form lines to "contours B" did nothing to reassure the colonies about the quality of the product (McGrath 1983, 109–10). However, the Directorate possessed few photogrammetric instruments, and contouring required a much denser network of control points. Even if contours could not be provided, there was still a need for some form of relief portrayal on the maps. Different approaches were used in different countries. In East Africa the favored approach was the use of simplified hachuring to show the position and shape of hills. In parts of West Africa, such as Sierra Leone and the Cameroons, hill shading was used (fig. 996). While hachuring could be carried out by any of the photogrammetric staff as part of the normal plotting process, specially trained staff created hill shading using stereoscopic examination of aerial photographs. Contoured editions replaced the hachured or hill-shaded maps once sufficient instrumental photogrammetric capacity became available.

The British Military Survey became actively involved in topographic mapping in Kenya following the outbreak of the Mau Mau rebellion in 1952. This mapping continued even after the rebellion had ended and Kenya had achieved independence.


FIG. 995. DETAIL FROM 1:50,000 PRELIMINARY PLOT, *KENYA*, 2d ED., 1954. Sheet A-36/F-I-NW. These sheets were produced very rapidly by radial line methods, but lacked vertical control for contouring, hence the use of hachures to depict relief.

Size of the entire original: 75.0 × 59.1 cm; size of detail: 12.4 × 23.2 cm. Image courtesy of Peter Collier.

Following the successful experiments with photomapping in the United States, it was recognized that the method would be more suitable than line mapping for some African countries. The Okavango Swamp in Botswana was the first area to be mapped in this way (fig. 997) (Macdonald 1996, 147). Subsequently, photomapping covered other areas of Botswana and the whole of Gambia.

At the same time that the Directorate was producing topographic mapping for the African colonies, it also had a program designed to train staff for the local survey department in the expectation that, ultimately, the colonies would become completely independent. By the early 1980s financial constraints in Britain, together with the colonies' increasing self-reliance, meant that the Directorate was carrying out little new topographic mapping in Africa. In 1984, with the closure of the Directorate and the transfer of its residual functions to Ordnance Survey International, Britain's main role became the provision of technical advice and training.

PETER COLLIER

SEE ALSO: Directorate of Overseas Surveys (U.K.); Holdich, Thomas Hungerford; Military Mapping by Major Powers: Great Britain; Military Mapping of Geographic Areas: (1) North Africa, (2) Sub-Saharan Africa

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FIG. 996. DETAIL FROM 1:50,000 MAP OF SIERRA LEONE, *BAUYA* SHEET, 1964. Sheet 75. These maps lacked height information for contouring but relief was shown using hill shading derived from inspection of the aerial photographs.
Size of the entire original: 78.5 × 58.8 cm; size of detail: 13.8 × 11.1 cm. Image courtesy of Peter Collier.

FIG. 997. DETAIL FROM 1:50,000 PHOTOMAP OF THE OKAVANGO SWAMP IN BOTSWANA, 1970. *Republic of Botswana*, sheet 1922C2. An early attempt at photomapping by the Directorate of Overseas Surveys.
Size of the entire original: 78.0 × 65.0 cm; size of detail: 19.6 × 16.6 cm. Image courtesy of Peter Collier. Permission courtesy of the Botswana Department of Surveys and Mapping, Gaborone.

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*Topographic Mapping in Africa by the French.* Mapping in Africa commenced soon after the French invasion and colonization of Algiers in the 1830s and was extended eastward after Tunisia fell under French control. Reconnaissance mapping initiated at a scale of 1:400,000 was replaced by conventional topographic mapping in 1855. The mapping of Algeria was regarded as an extension of Carte de France on the other side of the Mediterranean, on the same projection and with the same sheet size. Initially issued in the style of Type 1880 maps, the series was originally intended for publication at 1:80,000 but in 1881 the scale was changed to 1:50,000. By the start of the twentieth century most of the areas that had been opened up to white settlement had been mapped. At that time this coverage represented the only systematic topographic mapping anywhere on the African continent. With interruptions, the 1:50,000 mapping of the coastal strip was extended about 100 miles inland by the 1930s (France, Service géographique de l'armée 1938, 43–45).

In the 1930s the Service géographique de l'armée adopted photogrammetric methods based on instruments designed by Georges Poivilliers and rapidly extended their use to Algeria and Tunisia, which became the first parts of Africa to be mapped using instrumental aerial photogrammetry. Depending on the density of settlement and intensity of land use, areas not covered by 1:50,000 mapping were originally mapped at 1:100,000 or 1:200,000. Derived maps at 1:100,000 and 1:200,000 were also published for most areas originally mapped at 1:50,000.

In Africa south of the Sahara the French approach to mapping was to establish outstations of the Service géographique de l'armée, such as the Service géographique de l'Afrique Équatoriale Française et du Cameroun in Yaoundé, subsequently renamed the Institut géographique national (IGN) Annexe de Yaoundé. Similar organizations were established in Brazzaville, Tananarive (Madagascar), and Dakar. In concert with the IGN in Paris, the Dakar center was responsible for the French West African colonies, while Yaoundé and

Brazzaville were responsible for French Equatorial Africa and Cameroon, respectively. The relationship between these outstations and the parent organization in Paris was based on the Service geographique de l'armée supplying and paying for all European personnel, with the outstation paying, recruiting, and training all local personnel. This approach continued after the creation of the IGN in 1940 (Sallat 2003). The U.S. Department of the Army (1963, 44) clearly considered them the responsibility of the parent organization, whereas the Service géographique de l'armée (1938, 121) treated them as autonomous. Whatever the precise relationship, the French strategy was quite different from the British approach of establishing a survey department in nearly every colony under the guidance of the Colonial Survey Committee. The Ordnance Survey had no direct role in colonial mapping except through the service of its director general on the Colonial Survey Committee.

With the exception of some 1:200,000 mapping started in 1922 in what became Burkina Faso and Niger and some 1:100,000 mapping in Madagascar (Parry and Perkins 2000, 73, 131, 153), topographic mapping of sub-Saharan Africa started only after World War II. Louis Hurault, director of the IGN, epitomized the prewar situation, describing a sketch map at 1:1,000,000 (fig. 998), published just prior to the war, as "drawn up

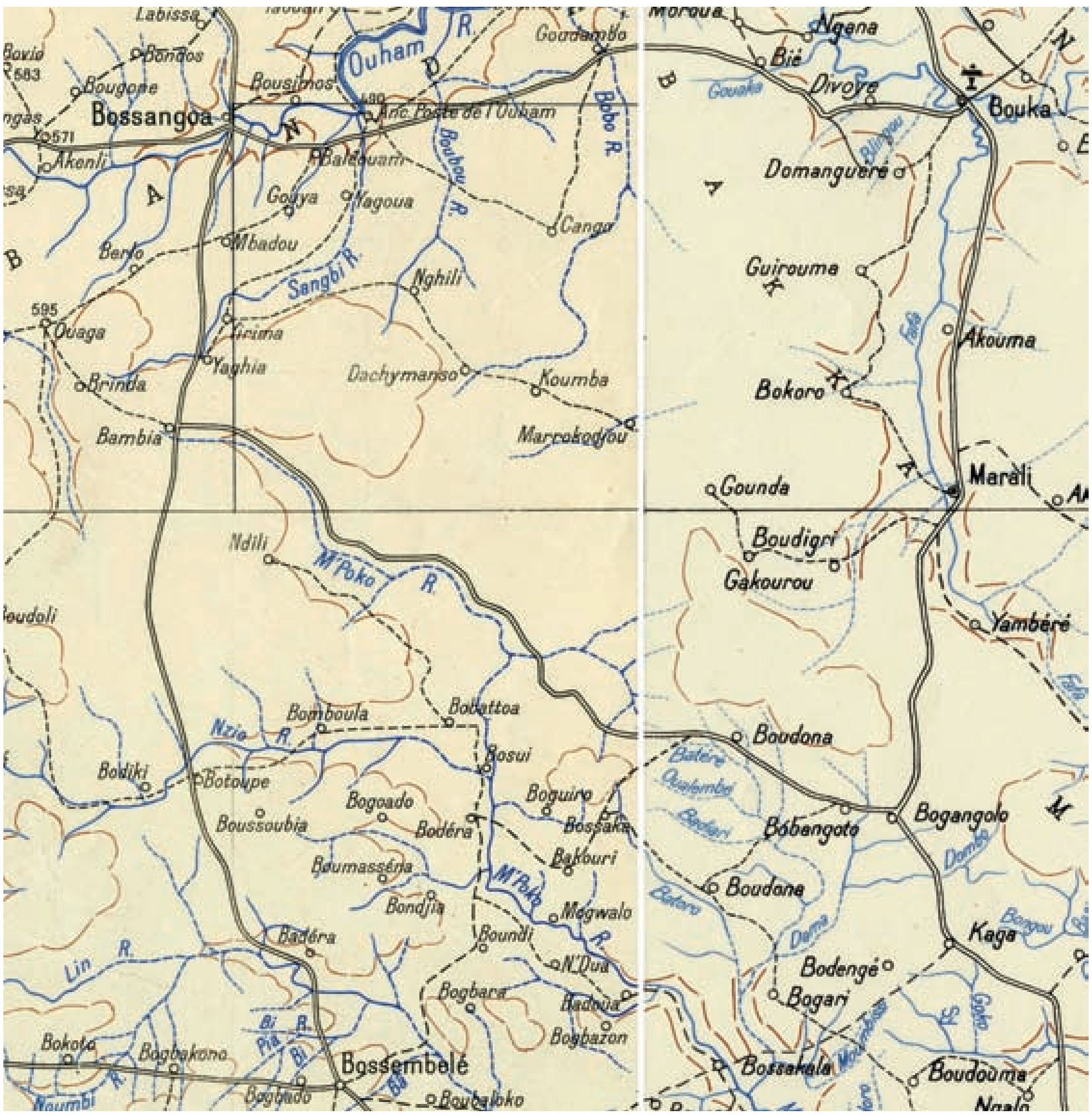


FIG. 998. DETAILS FROM 1:1,000,000 MAPS OF THE UBANGUI DISTRICT IN FRENCH EQUATORIAL AFRICA. Taken from two adjacent sheets (N.B. 33, *N'Gaoundéré*, 1937 [left], and N.B. 34, *Bangui*, 1935 [right], Ministère des travaux publics et des transports), these maps were compiled from itinerary survey records and other miscellaneous sources.
Size of the combined details: 15.1 × 14.8 cm. Image courtesy of the Cartothèque, Institut géographique national.


FIG. 999. DETAIL FROM SKETCH MAP AT 1:1,000,000 OF THE UBANGUI DISTRICT, 1946. Covering the same area as figure 998, this map was compiled from aerial photography and illustrates the major improvement in accuracy and data content once aerial photography entered widespread use in Africa.

Size of the entire original (in Hurault): 14.2 × 14.6 cm. From Hurault n.d., pl. VI. Permission courtesy of the Cartothèque, Institut géographique national.

from itinerary survey records obtained from many different sources, complemented by miscellaneous, often verbal, information" (Hurault n.d., pl. V). The Ubangui District was an area of savannah and riverine forests that would have lent itself to conventional topographic surveys by plane table, had the resources been available. It did not present the same problems for surveyors as the rainforests of Gabon or the Cameroons.

In the postwar period, the French approach to control for topographic mapping in Africa was unusual in depending on astronomical observations rather than networks based on triangulation. Hurault (n.d., 55) considered this approach faster and cheaper than triangulation but sufficiently accurate for mapping at scales of 1:100,000 and 1:200,000. The French extended the use of aerial photogrammetry to sub-Saharan Africa immediately after World War II (figs. 999 and 1000). Although the French initially followed normal Western practice in using film cameras for aerial photography, concerns about its dimensional stability led to film being abandoned in the early 1950s in favor of glass plate cameras, such as the Poivilliers-S.O.M. with a magazine holding ninety-six glass plates (Hurault n.d., 62–63). The heavier glass plate cameras, together with the need to carry several magazines, was probably a factor that led the French to use converted Boeing B-17s

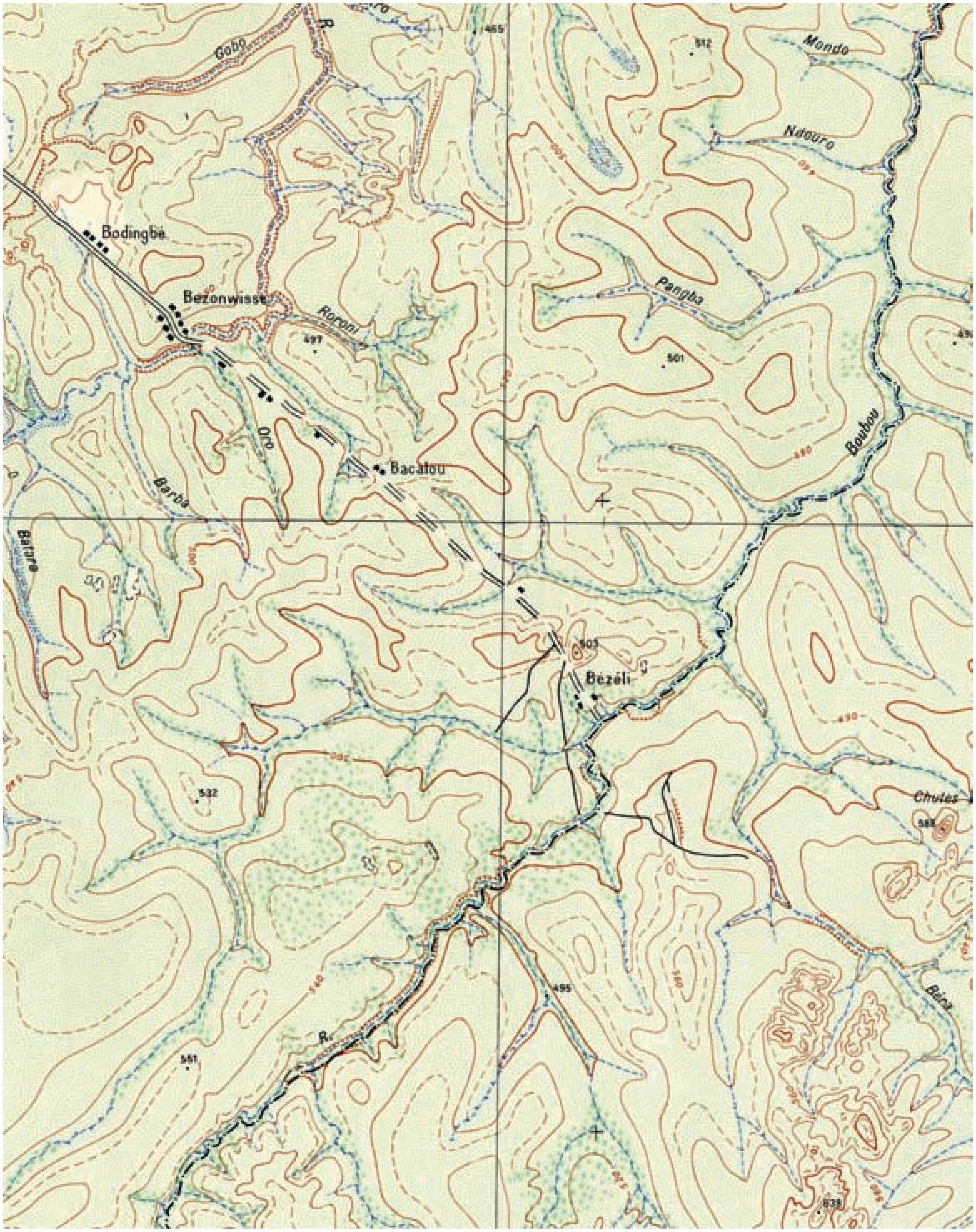


FIG. 1000. DETAIL FROM THE 1:100,000 MAP OF THE UBANGUI DISTRICT, 1950. *Métima* sheet, Ministère des travaux publics et des transports. Plotted photogrammetrically on a framework of astronomical fixes and barometric heights. This is the area of the rectangle in figure 999. Size of the entire original: 69.5 × 63.9 cm; size of detail: ca. 19.4 × 15.4 cm. Image courtesy of the Cartothèque, Institut géographique national.

for photographic work rather than the Douglas C-47 widely used elsewhere.

With few exceptions, the French aimed to produce mapping of their African colonies at three scales. Mapping at the two smaller scales, 1:500,000 and 1:200,000, was intended to provide complete coverage of all colonial territories. In practice, 1:500,000 coverage was achieved for all colonies by the 1970s, with the former French Cameroon completed in 1976, shortly after responsibility for mapping was passed to the government of the Republic of Cameroon, independent since 1960. In most cases mapping at 1:200,000 was also completed by the 1970s, but the mapping of some countries took many years to finish. In Burkina Faso (then known as Upper Volta), for example, the French had started 1:200,000-scale mapping in 1922, using ground survey methods. Air survey methods were introduced in the early 1950s, both to map the previously unmapped areas and to revise existing ground-surveyed sheets, with the final sheets being published by 1960. But by the late 1980s many of the maps were already out of date, and some were no longer available.

In the case of Guinea, where 1:200,000 coverage was completed in 1957, the earliest sheets had been compiled from ground survey in the 1930s and 1940s and were already out of date. These maps had not been revised by the end of the century.

Madagascar was unusual in sub-Saharan Africa in having a survey office established as early as 1896, and 1:100,000-scale mapping initiated in 1906. It is not clear why a scale of 1:100,000 was chosen for Madagascar, insofar as this scale was not used elsewhere in sub-Saharan Africa. Unfortunately, the Service géographique de l'armée (1938), the main published source on French mapping, is silent on the issue.

The French intended to cover all settled and developed areas with 1:50,000 mapping, but progress at this level of detail was very slow in most colonies, and only completed in Togo. In Congo-Brazzaville only 44 of the 570 sheets needed for complete coverage were produced.

France withdrew from direct mapping activities in most former colonies during the 1970s and 1980s. For the remainder of the century there was little systematic effort to extend the area of coverage provided by the French or to revise existing mapping. In many cases no stocks of printed maps were held, and there was little provision for reproduction of existing sheets. While not limited to the former French colonies, this situation was more acute there than in areas controlled by the British, partly because of the highly centralized approach adopted by the French. It could be argued that the British approach, based on the establishment of a survey department in most colonies, produced a greater independent capacity to maintain the currency of the mapping. However, the financial status and stability of the independent government may, ultimately, have been the decisive factor, irrespective of the original colonial power.

PETER COLLIER

SEE ALSO: Institut Géographique National (National Geographical Institute; France); Military Mapping by Major Powers: France; Military Mapping of Geographic Areas: (1) North Africa, (2) Sub-Saharan Africa

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*Topographic Mapping in Africa by the Germans.* Following the great exploratory expeditions of the mid-nineteenth century, Germans started around 1884 to make topographic maps of Africa. Their surveys were limited to the protectorates of the German empire in German Southwest Africa (Namibia), German East Africa (Tanzania), Cameroon, and Togo. The civil land survey was responsible for maintaining cadastral and topographic records as well as for surveys and mapping. The Reichskolonialamt in Berlin sent cadastral surveyors to the colonies. Civil servants, military personnel, missionaries, and civilians supported these efforts. The large land and mining companies hired their own surveyors and produced large- and medium-scale maps of economically important areas within their designated concessions. No native African personnel were trained; the staff was entirely German.

Mapping consisted largely of route surveys but included local triangulation for cadastral surveys. From the beginning of the twentieth century, terrestrial photogrammetric methods were also used in East and Southwest Africa. Triangulation was carried out mainly along the borders in concert with the relevant international border commission. The Reichskolonialamt commissioned the Kolonialkartographisches Institut of the Berlin-based publisher Dietrich Reimer (Ernst Vohsen), under the leadership of cartographers Paul Sprigade and Max Moisel, to convert colonial survey records into maps. Map coverage was produced for Togo at scales of 1:200,000 (10 sheets) and 1:500,000 (2 sheets), for German East Africa at 1:300,000 (36 sheets), and for Cameroon at 1:300,000 (34 sheets). These maps set the style of German colonial mapping, with its distinctive form lines and subtle shading (fig. 1001). In addition to the aforementioned maps, there were several topographic

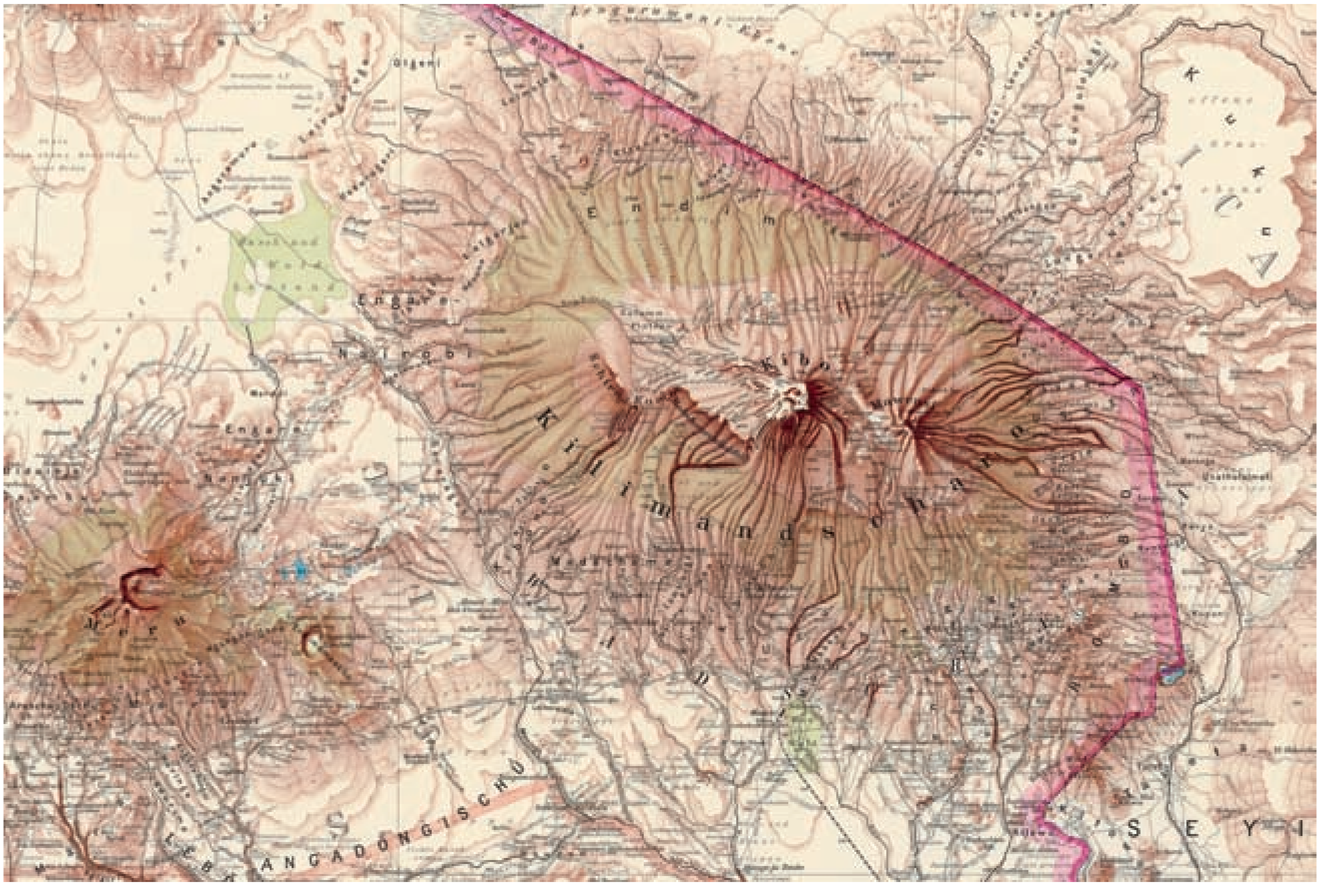


FIG. 1001. DETAIL OF MOUNT KILIMANJARO FROM MAP OF GERMAN EAST AFRICA, 1:300,000, 1911. *Kilimandscharo* (sheet B5) published by Dietrich Reimer/Ernst Vohsen and prepared by Sprigade and Moisel. This excerpt shows the artistic nature of map production, especially the relief rendition designed by the Kolonialkartographisches Institut.
Size of the entire original: 62 × 85.4 cm; size of detail: 29.4 × 44 cm. Image courtesy of the Bayerische Staatsbibliothek, Munich.

maps at 1:1,000,000 and a variety of other scales for these three colonies.

German Southwest Africa was an exception to the system of German colonial cartography. Because the routes and vital water locations of this largely barren country were already well known at the beginning of the colonial period, topographic surveys were conducted very sporadically and sent on to Berlin. The Herero uprising in 1904 revealed a lack of accurate maps needed to fight the war and prompted the involvement in the colony's survey and mapping of the Preußische Landesaufnahme, which sent a military detachment to collect data. This detachment was responsible for: a primary triangulation that tied the central settlements to the colony's geodetic survey; precise leveling, especially along railway lines; and the production of topographic maps. Civilian surveying had also focused on triangulation since 1903 as the prerequisite for more detailed mapping. By 1914, Southwest Africa was second on the continent only to South Africa in the density of its triangulation network (fig. 1002).

After an unsuccessful attempt to use plane table surveying to conduct topographical surveys at scales comparable to those used in the German Reich, topographic data were recorded through route surveying, terrestrial photogrammetry, and croquis at a scale of 1:100,000. The resulting map coverage, at 1:400,000 in various editions, was suitable for military use. In addition, croquis at 1:100,000 covered large parts of the country. Furthermore, property maps produced by the civilian survey at 1:200,000 and 1:800,000 also featured topographic details. Because of communication problems and the different institutions participating, several coordinate systems existed in Southwest Africa (fig. 1003). The Gaussian coordinate system with meridian strips 3° wide, introduced experimentally by Heinrich Böhler, gained significance internationally when a revised version of its successful application was later introduced

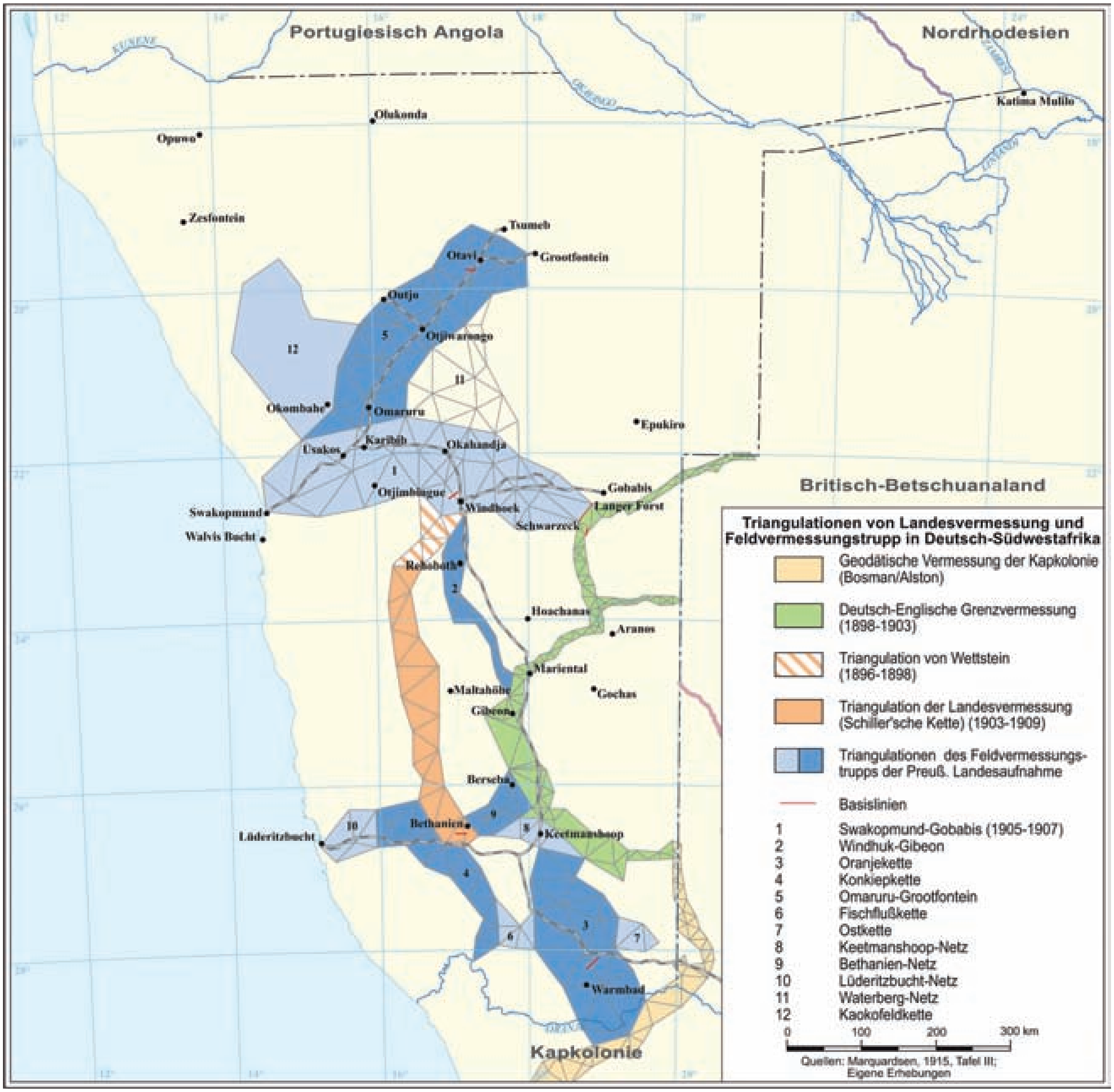


FIG. 1002. TRIANGULATION NETWORK OF GERMAN SOUTHWEST AFRICA BETWEEN 1898 AND 1909. Unlike most African colonies, whose borders were triangulated by the Boundary Commission, Southwest Africa, similar to South Africa, had a relatively dense triangle network, which covered the main settlement areas of the colonizers and served both military and civilian purposes.
From Moser 2007, appendix, figure A7. Image courtesy of Jana Moser.

worldwide as the Gauss-Krüger grid system (Demhardt 2000, 93–97).

In addition to the official maps, numerous maps of all German African colonies were available in diverse scales, based on expeditions or private surveys, which were published in magazines and books. The Germans produced few maps of areas beyond their colonial borders. One example is a 1933 map of Portuguese East Africa at 1:300,000, based on an expedition from Leipzig to Mozambique in 1931. Hydrographic maps of the German colonies were the responsibility of the German navy, which completed surveys and maps of the sea and coastal areas. Initially conducted only as needed, these surveys were later planned and refined with great care.

During World War II, the military produced maps of

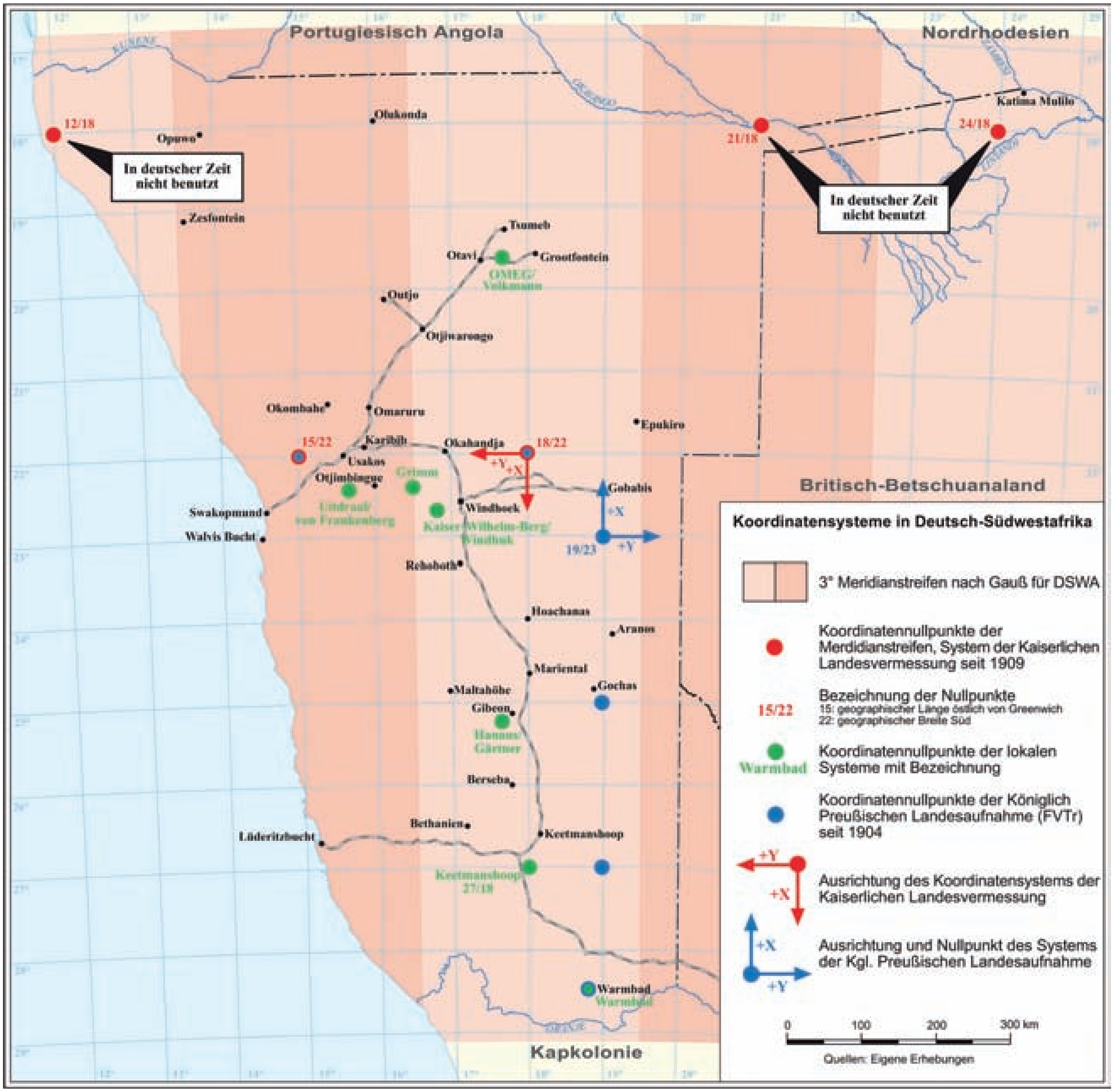


FIG. 1003. OVERVIEW OF THE COORDINATE SYSTEMS OF GERMAN SOUTHWEST AFRICA (BETWEEN 1900 AND 1918). This figure shows the different coordinate systems with their zero points and their orientation, as they were applied during the German colonial period in Southwest Africa. Notable are the numerous local systems for cadastral surveying (green) that were devised and oriented according to location, in line with the approach in South Africa. For the first time, civilian national surveying worldwide used a Gaussian median strip system 3° wide (alternating pink vertical bands). The overview shows, however, that the orientation was to the south and the zero points were in the field, not, as later commonly practiced, on the equator. Military surveying relied on the host country's own system (blue); the zero points lay mainly in the triangular chains that had been measured since 1905. Compare figure 1002.
From Moser 2007, appendix, figure A9. Image courtesy of Jana Moser.

Africa, particularly for the North African war theater, at scales between 1:5,000 and 1:2,000,000. Complied mainly from foreign source materials, these maps were rarely based on earlier German surveys. Reprints of some German maps of its former colonies were produced on a large scale, and occasionally these maps appeared in German magazines.

Little is known about topographic map production for Africa after 1945 by organizations or institutions of either West Germany or East Germany. The Gesellschaft für Technische Zusammenarbeit (GTZ) participated in the development of AFRICA-GIS and EIS-Africa since the 1990s. Already by the late 1980s GIS-development assistance for individual African states with limited support services could not be verified.

JANA MOSER

SEE ALSO: Military Mapping by Major Powers: Germany; Military Mapping of Geographic Areas: (1) North Africa, (2) Sub-Saharan Africa

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*Topographic Mapping by South Africa.* Although South Africa became independent on 31 May 1910, mapping of the country did not formally begin until 1 October 1920, when the position of Director of Secondary Triangulation in the Office of the Surveyor General of the Cape was changed to Director of Trigonometrical Survey. The incumbent, Willem Cornelis Van der Sterr, remained in office, and, due to his efforts, a Survey Commission was appointed in 1921 and a Land Survey Act promulgated in 1927. The latter provided for a national Trigonometrical Survey Office (TSO), responsible for national mapping, and a Survey Board, to establish and coordinate the required trigonometric network. In 1929 Van der Sterr established a topographical division in the TSO, which produced a few experimental maps of the Southwest Cape. With the primary and secondary survey of the country still incomplete, mapping on a national scale remained uncoordinated. In 1931 the surveyor general of the Transvaal attempted to improve this situation by establishing a separate Central Mapping Office (CMO) with the aim of mapping the entire country. In 1935 the CMO issued a 1:50,000 map of the Witwatersrand in three sheets (fig. 1004). In 1936, because of its limited personnel and equipment, the CMO was incorporated into the TSO (Watson 1962).

Cartographic history was made in South Africa during the first decades of the twentieth century when surveyor Henry Georges Fourcade developed a method, including requisite instruments, for efficiently making contour maps directly from photographs (Adams 1975; Storrar 1990). In 1934 the TSO published its pioneering map *Cape Peninsula*, based on Fourcade's work and produced on a 1:25,000 scale using terrestrial photographs (fig. 1005). This map was the first South African map compiled by photogrammetric methods (Thomas 1960).

By 1934 the lack of topographical maps proved a serious handicap to many government departments. A. D. Lewis, director of the Department of Irrigation, took the initiative, and from 1934 to 1937 surveyors from his department made history by using plane table methods to map South Africa on a 1:500,000 scale (fig. 1006) (Lewis 1938). For many years this ten-sheet so-called Irrigation Map was the only reliable map of large parts of the country.

By 1936 almost the entire country was covered by primary and secondary triangulation networks, with which accurate maps could be compiled using aerial photographs. Due to this development and the deteriorating political situation worldwide, the TSO was reorganized to proceed apace with the cartography of the country, using mapping scales of 1:50,000 for the whole of South Africa and 1:25,000 for the more populous areas (Liebenberg 1972, 336–37). During World War II, the director of the TSO also directed the Military Survey, and topographical mapping was considered part of an operational program run by the General Staff, Union Defense Force (UDF). All topographic maps published during the war were attributed to the UDF, not the TSO. In 1972 the TSO was renamed the Office of the Director-General of Surveys. In 1980 the official mapping agency of South Africa was renamed the Chief-Directorate of Surveys and Mapping (CDSM).

During World War II urban areas of the country were mapped at scales of 1:25,000 and 1:100,000, but these series had been discontinued by the 1960s. During the 1960s and 1970s the mapping of the entire country on a 1:50,000 scale (1,916 sheets) was vigorously pursued, and by 1976 the last sheet of this series was printed (Thomas 1982–84, 77). In 1991 the last 1:50,000 sheet was fully upgraded to metric specifications. During the 1980s digital technology replaced analog methods, and the first completely digital 1:50,000 edition was published early in 1998.

The size of the country and the dire need for maps also necessitated mapping at smaller scales. In 1936 a survey company of the South African Engineer Corps (SAEC) was commissioned to produce a 1:250,000-scale topographic-cadastral map of the country on the Gauss conformal projection, using the Irrigation Map as the base map (Liebenberg 1972). This series was eventually completed by 1947, but because of the need to control costs, only twenty-six of the forty-nine sheets were printed in color. This map series is important historically as the first full series compiled by the TSO/UDF


FIG. 1004. TOPOCADASTRAL MAP OF THE *WITWATERSRAND*, 1:50,000, 1935. The central sheet of the three-sheet map compiled by the CMO from existing records and published by the Survey Board.
Size of the original: 72.5 × 74.1 cm. Image courtesy of Elri Liebenberg. © National Geo-spatial Information. Permission courtesy of the Chief Directorate, National Geo-spatial Information (NGI) of the Department of Rural Development and Land Reform, Cape Town.

and the only South African map series ever published by the Survey Board. In 1961 a new 1:250,000 map series (seventy-two sheets on 1° × 2° sheetlines) superseded the 1:250,000 series of the Survey Board. The first all-digital 1:250,000 map was printed in 1999. Another new map series, compiled on the Lambert conformal conic projection at 1:500,000 and completed in 1951, replaced the Irrigation Map of the 1930s. Once full coverage was attained, efforts focused on revising and updating both the 1:250,000 and the 1:500,000 series. In 1969 the CDSM initiated an orthophoto map at 1:10,000 scale for metropolitan and suburban areas and other places with significant growth.

During the 1960s the South African CDSM carried out a complete resurvey of South-West Africa (SWA), called Namibia since 1990. This territory, which was first

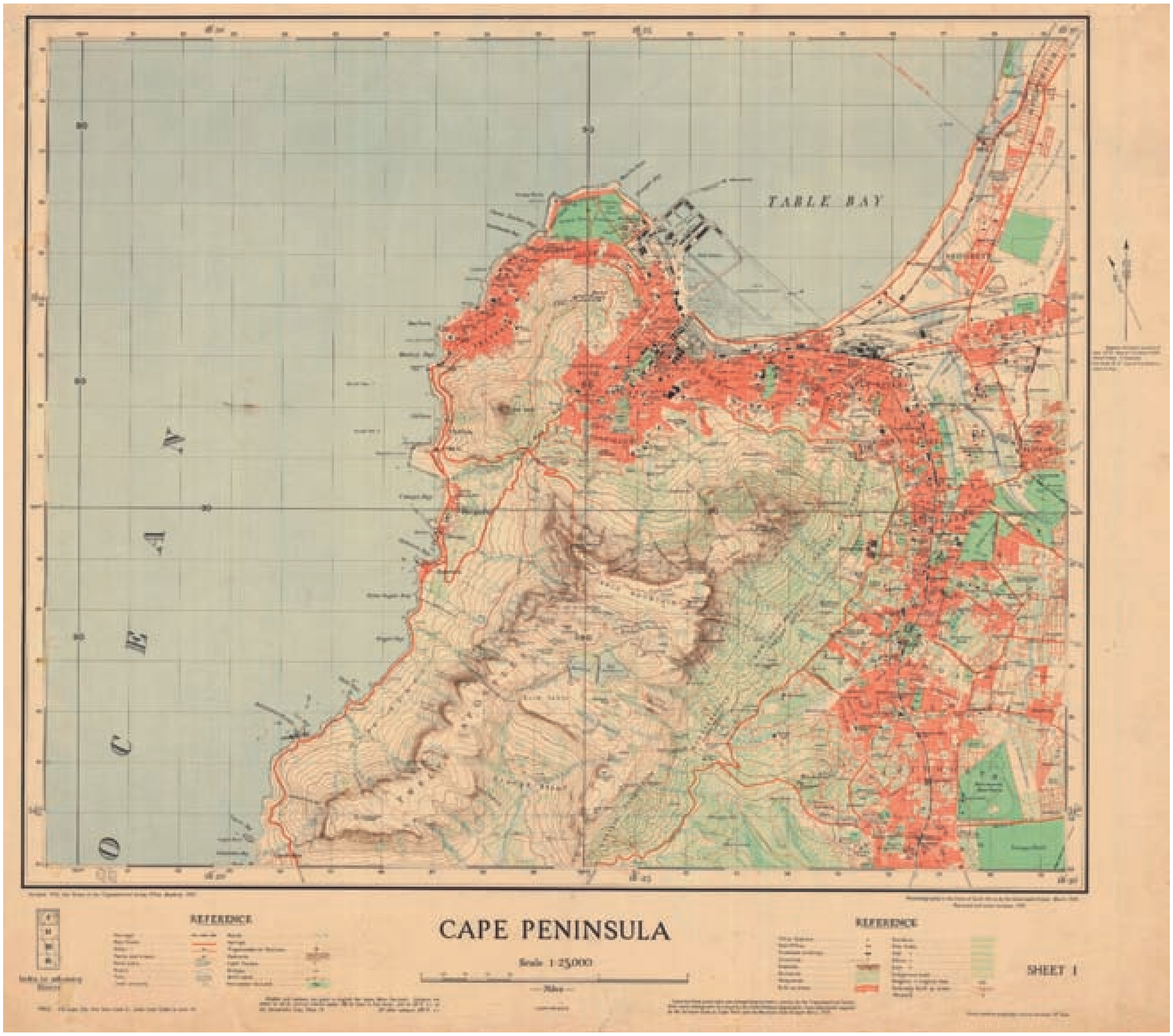


FIG. 1005. *CAPE PENINSULA*, 1:25,000 (SHEET I), 1934, REPRINTED WITH MINOR REVISIONS 1939. Compiled by the South African Trigonometrical Survey Office by plane table and stereophotogrammetric methods using terrestrial photos.

Size of the original: 72.3 × 81.9 cm. Image courtesy of Elri Liebenberg. © National Geo-spatial Information. Permission courtesy of the Chief Directorate, National Geo-spatial Information (NGI) of the Department of Rural Development and Land Reform, Cape Town.

mapped at 1:250,000, was remapped during the 1970s for a 1:50,000-scale series consisting of 1,218 sheets.

During the 1990s the CDSM mapped Swaziland on a 1:50,000 scale. This map series consists of thirty-one sheets, which follow the South African sheetlines and sheet numbering system.

ELRI LIEBENBERG

SEE ALSO: Military Mapping of Geographic Areas: Sub-Saharan Africa

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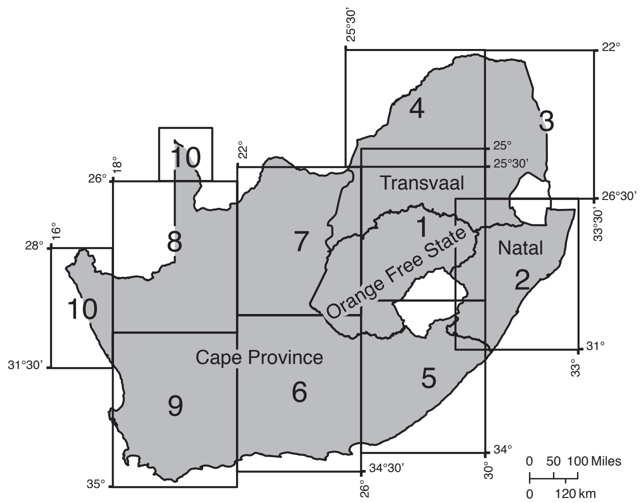


FIG. 1006. INDEX MAP OF THE 1:500,000 IRRIGATION MAP SERIES OF SOUTH AFRICA, 1934–37. The maps were compiled by plane table by the South African Department of Irrigation as an emergency measure to fill the dire need for topographic maps.

Watson, W. C. 1962. "Some Notes on the Central Mapping Office, 1934–1936." *South African Survey Journal* 9:45–48.

*Topographic Mapping in Western Europe.* By the beginning of the twentieth century each major nation-state had established its own national mapping organization and published high-quality topographic maps using distinctive "house" styles. Government and particularly military requirements had determined the scale, level of detail, and coverage of topographic mapping. Colonel Charles Frederick Close, a prominent British geographer and surveyor, claimed that "a good topographical map is such a vital military necessity, that the initiative in the matter of national surveys has, in nearly every country, been taken by the army" (Close 1905, 118). During the nineteenth century, Western European powers had mobilized surveying and cartographic resources in the wake of the impressive example set by the Cassini family and its publication of the *Carte géométrique de la France* during the late eighteenth century. National mapping organizations were invariably military concerns because they published map series at medium to small scales. Notable among them were the 1:100,000 *Carta corográfica de Portugal* published by the Instituto Geográfico e Cadastral from 1856–1907 and the 1:40,000 *Carte topographique de Belgique* published by the Institut géographique militaire between 1861–1951. The 1:100,000 *Karte des Deutschen Reiches* started in 1861 was the largest scale for which there was complete coverage of Germany. The Swiss 1:100,000 Dufour map provided complete coverage of the country with relief shown by hachures and elevation points and was based on a triangulation survey begun in 1832 (maps published 1845–65).

With topographic map production so dominated by military organizations it is understandable to assume that beauty and aesthetics played a minor role in map design. However, influential figures were aware of alternative designs. Close (1905, 119–20) provides a brief appraisal of topographic maps available at the beginning of the century, acknowledging the Swiss 1:25,000 and 1:50,000 series as "beautiful maps" and the German 1:25,000 *Positions-Karte* maps of Prussia, Baden, Saxony, and Württemberg as "good clear maps." However, his opinion was not always so positive, as he describes France's 1:80,000 carte d'État-Major, as "similar to, but inferior to, the black edition of the Ordnance Survey 1 inch."

Changing a design specification became increasingly difficult as time wore on. Once the surveying specifications and the subsequent generalizations for derived maps had been set, major change could take place only if a completely new survey was undertaken. The high level of inertia generated by this process combined with the constraints inherent to series mapping meant that wholesale changes to map specifications and design were rare. As cartographic house styles became embedded within topographic map design, a country's map series became another symbol of national sovereignty. The evolution of the Ordnance Survey's one-inch series of Great Britain demonstrated the gradual nature of this process, which involved the introduction of important developments in map reproduction techniques and surveying instruments (Hodgkiss 1981). The Ordnance Survey's renowned one-inch Old Series sheets were printed in black and white from engraved copperplates, the hachuring for relief portrayal being the distinctive and dominant feature of the series. By the end of the nineteenth century lithographic printing and photographic techniques, combined with an ever-growing amount of accurately surveyed data, enabled the series to evolve and in some peoples' eyes to culminate in the Fifth (Relief) Edition, begun in 1928 (fig. 1007). Delicate gray hachuring was combined with orange contour lines and layer tints to produce maps "of considerable aesthetic appeal" (Hodgkiss 1981, 171). In many respects the design was a radical shift from the Old Series but remained recognizably part of the same design stable. However, retrospective admiration for its beauty and overall design was not matched by contemporary popular opinion. Production of the series came to an end due to poor sales in 1937 (Seymour 1980, 253). Whereas some countries, most notably Switzerland, continued to extend the graphic sophistication of relief depiction using contours in three colors, detailed rock drawing, and hill shading, the Ordnance Survey yielded to pressure


FIG. 1007. *TRURO AND ST. AUSTELL*, OS FIFTH (RELIEF) EDITION, ONE INCH TO ONE MILE, 1934. Published by the Ordnance Survey of Great Britain (sheet 143). Though admired for its delicate treatment of relief, the series was withdrawn due to poor sales. (For a detail, see fig. 979.)

Size of the original: 70.3 × 95.3 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

for simplicity and reduced the graphic impact of relief to enable the enhanced depiction of other features. Subsequent one-inch series maps reflected the special emphasis placed on the depiction of the communications network in Britain.

Between the wars, national mapping organizations sought to employ photogrammetry in the production of their topographic maps. From 1922 to 1939, the Service géographique de l'armée (SGA) of France made extensive use of terrestrial photogrammetry in the mapping of the French Alps. From 1931, photogrammetry using aerial photography was introduced and became the standard method of survey from 1941 onward. Similar developments were witnessed elsewhere. For example, surveying for the 1:25,000 *Carta d'Italia* began in 1879 using plane table techniques, then moved to aerial photogrammetric techniques after 1935. The Dutch Topografische Dienst conducted a ground survey between 1904 and 1935 for the 1:25,000 Old Series. Sheets for a new series of the *Fotogrammetrische Kaart des Rijks* were begun in 1935 and compiled using photogrammetric methods with field-based revisions. Similar photogrammetric compilation was introduced to support the production of the 1:50,000-scale *Topographische en militaire kaart des Rijks* in 1935 (United States, Department of the Army 1956, 166–68, 236). The use of aerial photography enabled the detailed classification of land cover to include woods, brushwood, high and low pine forest, meadow with ditches, plant nurseries, orchards, arable land, heath, and sand that was already established. Though aerial photography offered the opportunity to expand and elaborate the land use or land cover classification, the level of detail shown on different map series remained a function of local differences in approach to the composition of the map. In most cases the introduction of aerial photography did not bring about a transformation in topographic map design prior to World War II. However, there were exceptions. The Swedish *Ekonomisk karta över Sverige* was one of the more radical innovations encouraged by technological advances and a growing concern for the management of natural resources. Production of the Swedish economic (land use) map began in 1937 and covered a third of the country with 7,000 sheets by 1962 (Geographical Survey Office of Sweden 1962, 35). Rectified air photographs at 1:30,000 were assembled to create 1:10,000 photomaps, with some less populated areas mapped at 1:20,000. Black-line detail, such as property boundaries, plan detail, hydrography, and lettering, together with brown detail (contours) and yellow-tinted arable land were added to the photomap to form a very effective hybrid topographic map to serve military, land use planning, and cadastral functions (fig. 1008).

Such progress was not necessarily seen elsewhere in

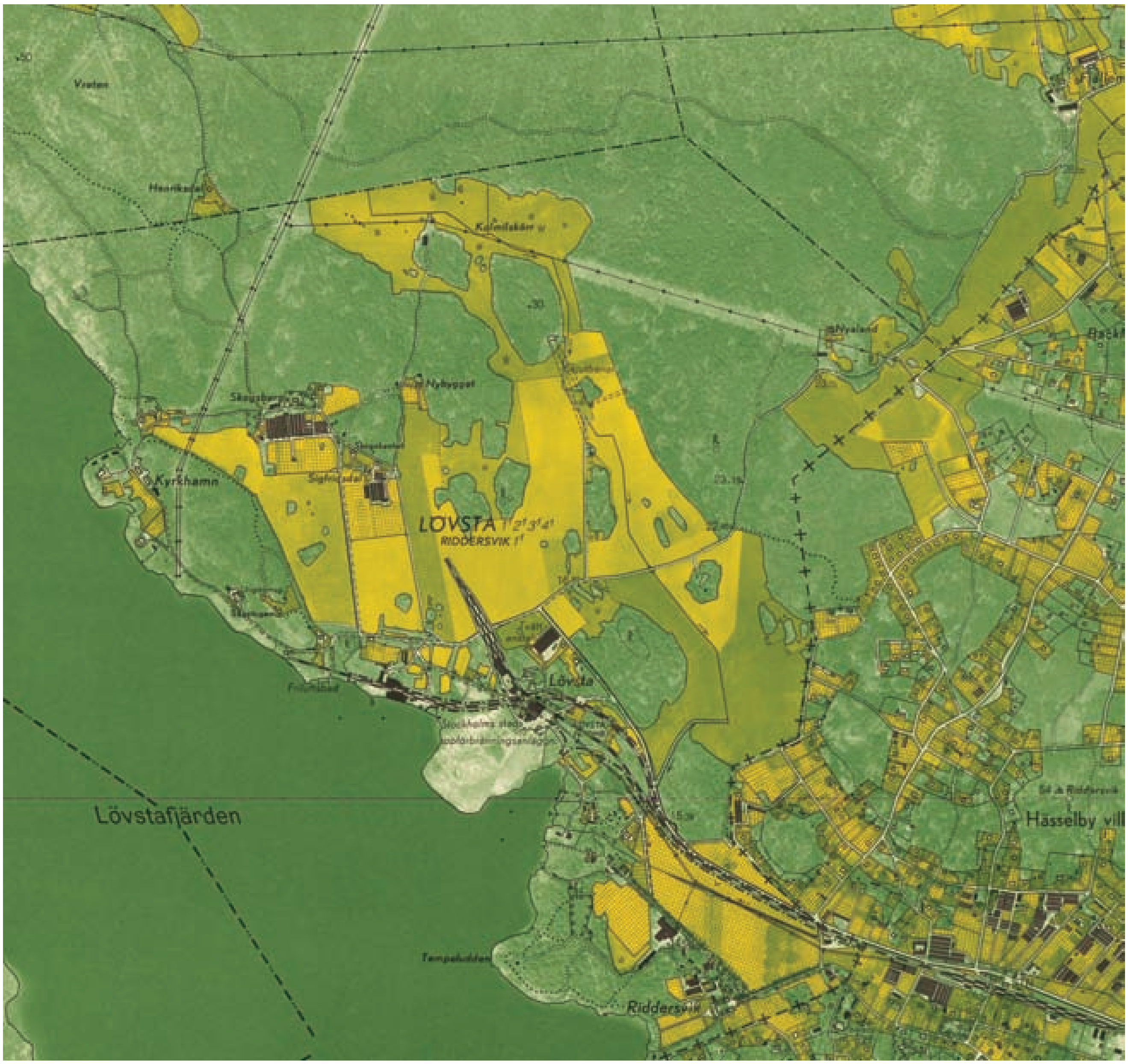


FIG. 1008. DETAIL FROM THE *EKONOMISK KARTA ÖVER SVERIGE*, 1:10,000, 1965. *Hässelby Villastad* (sheet 7C) published by the Rikets allmänna kartverk. Aerial photography offered new opportunities to innovate in the design and production of maps. The sheets of the *Ekonomisk karta över Sverige* were quick to utilize its benefits in the production of this innovative series.
Size of the detail: 27.7 × 29.4 cm. Image courtesy of Alastair W. Pearson. © Lantmäteriet Ref. no. R50325948_140001.

Western Europe. The nineteenth-century products underpinned topographic mapping in some areas well into the century. In Central Europe, large areas had been mapped using plane table methods at 1:25,000 from which the 1:75,000 *Spezialkarte* were produced. For example, up to World War II, most Austrian maps were based on the 1:75,000 *Spezialkarte*, which covered the whole of modern Austria, Hungary, Czech and Slovak Republics, and a large part of the Balkans. The *Provisorische Ausgabe der Österreichische Karte* 1:50,000, published between 1946 and the mid-1950s were enlargements of the 1:75,000 *Spezialkarte* published between 1877 and 1914 (fig. 1009). Though a few sheets covering Vienna, Salzburg, Graz, Mürzzuschlag, and areas along the Austrian-Italian border were contoured sheets based on the 1:25,000 maps, the vast majority continued to use hachures for relief representation after World War II. The initial costs of converting to photogrammetric data capture were high and a number of national mapping organizations struggled to maintain the high standards set by previous surveys. The SGA of France had commenced production of a 1:10,000 series for the whole of the country in 1840. By 1956 the series covered just 8 percent of France, mostly the Paris area.

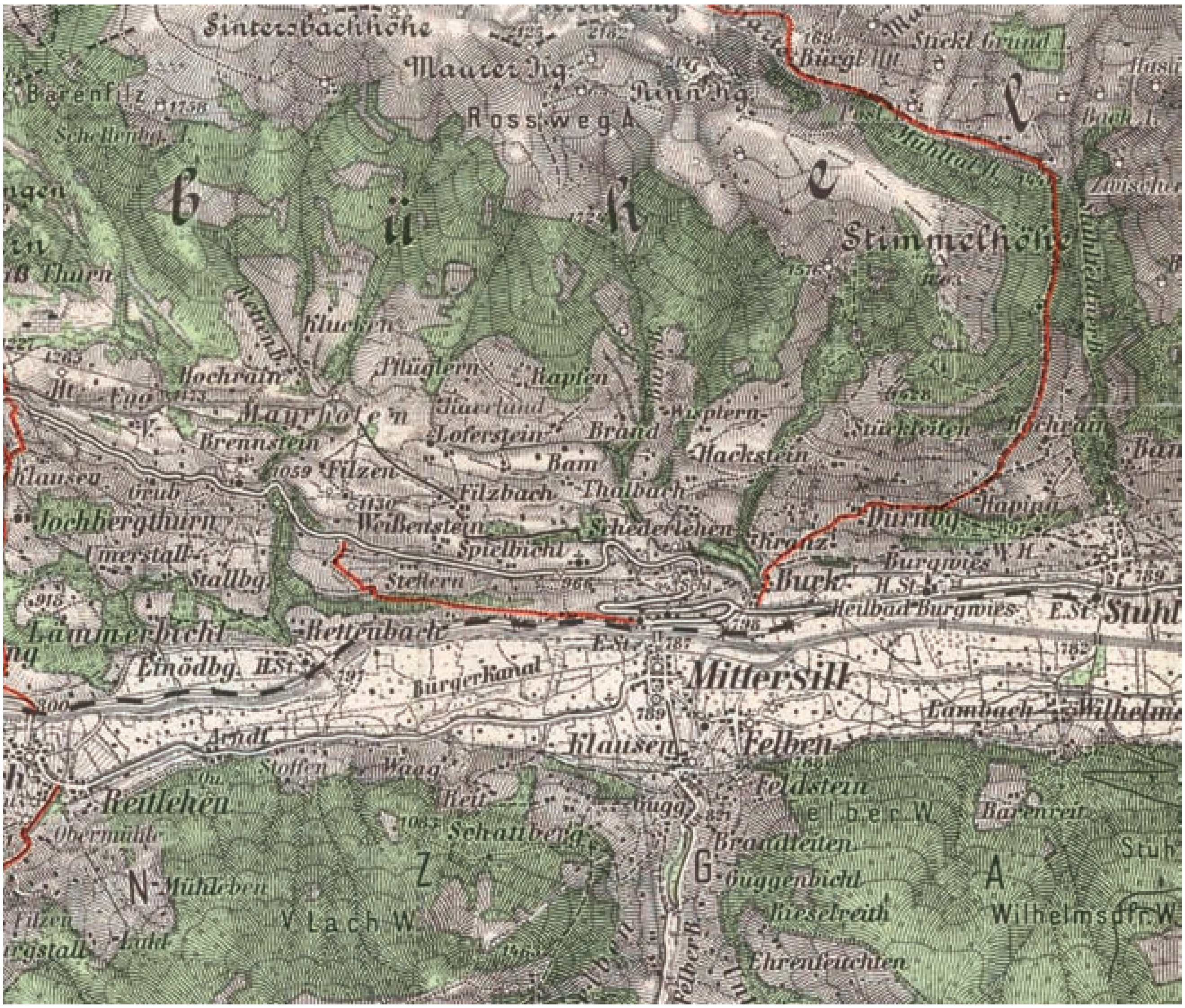


FIG. 1009. DETAIL FROM THE *PROVISORISCHE AUSGABE DER ÖSTERREICHISCHEN KARTE*, 1:50,000, 1953. *Kitzbühel* (sheet 122) published by the Bundesamt für Eich- und Vermessungswesen, Vienna. An example of an enlargement of the 1:75,000 *Spezialkarte*. The whole design was a relic of the nineteenth century and symptomatic of the chaos caused by disintegration of the Austro-Hungarian Empire after World War I.

Size of the detail: 15.2 × 17.9 cm. Image courtesy of Alastair W. Pearson.

By the same date the 1:20,000-scale series, which had commenced early in the century, covered only 25 percent of France and was mainly concentrated in the north and east of the country with scattered coverage near the Pyrenees. The slowness of production was in part due to the stringent accuracy requirements imposed on the series. With an average allowable horizontal graphical error of 0.2 millimeters and an average absolute vertical error of 0.30 meters, plane table surveys were only gradually replaced when new photogrammetric methods met these standards. The carte d'Etat-Major at 1:80,000, begun in 1818, covered the whole of France and was revised in areas not covered by the later 1:50,000 polychrome series (fig. 1010). The hachured relief depiction, however, betrayed its antiquity.

The turmoil that characterized the history of Europe during the century had a particularly profound impact on the topographic mapping of Germany. The official maps of Germany originated from the large-scale cadastral surveys carried out during the nineteenth century by the main states of Prussia, Würtemburg, Baden, Saxony, Hessen, and Bavaria. The Prussian surveys had resulted in the production of 3,700 plane table sheets (*Meßtischblätter*) at 1:25,000 scale covering the greater part of Germany. Other states published 1:25,000 maps derived from their larger-scale cadastral surveys. However, production was transferred to a civilian organization, the Reichsamt für Landesaufnahme, after the Treaty of Versailles, with the southern German states of Bavaria, Württemberg, Hessen, and Baden retaining varying degrees of independence. Uniformity of approach in such matters as symbolization and sheet size was therefore made difficult given the organizational structure of interwar German mapping. As a result, progress with the


FIG. 1010. DETAIL FROM THE *CARTE DU FRANCE*, 1:50,000, 1960. *Meyreuis* (sheet XXVI-40) published by the Institut géographique national. Delays due to World War II and a desire to produce maps to exacting standards resulted in the continued use of old series well beyond their intended duration of use.

Size of the detail: 19.7 × 26.9 cm. Image courtesy of Alastair W. Pearson.

1:5,000-scale *Deutsche Grundkarte*, which was to cover the whole of the country, varied between state mapping authorities as did the production of mapping at smaller scales. This situation persisted until the enforcement of a standardized style sheet through decree during the Nazi regime in 1937 (United States, Department of the Army 1956, 206–7). After World War II all mapping responsibility was vested in the respective Landesvermessungsamt, and from 1952 was overseen by the Institut für Angewandte Geodäsie. For decades after World War II topographic maps in West Germany continued to lack consistency in design despite concerted attempts to ensure uniformity through agreements between the various *Länder* (states). Furthermore, though the production of the multicolor 1:50,000 *Topographische Karte* represented a major achievement, by contemporary standards the design of topographic maps published by official agencies became outmoded. Any thoughts of innovation in map design were overwhelmed by the more urgent demand for large-scale surveys in support of postwar rebuilding and for more uniformity between the various *Länder*.

As a result of World War II central governments became much more aware of the diversity of mapping needs. Attempts to improve efficiency were sometimes made through major organizational restructuring. For example, in France the underresourced SGA had been exposed as inadequate in its support of the military requirements during the war and disbanded as a result. Its replacement, the Institut géographique national (IGN) was attached to the ministry of public works and absorbed the Service du nivellement général de la France and was completely reorganized so that "without augmenting the existing personnel, its output has increased by means of specialization, technical training and modernization of equipment and methods" (IGN 1952, 69).

Photogrammetric surveys began to replace ground surveys as the principal means of medium-scale topographic data capture, which, when combined with common methods of lithographic printing, scribing, and phototypesetting, encouraged convergence of cartographic style between countries. In many cases retriangulation and releveling programs had been followed by new surveys providing national mapping agencies (NMAs) with the opportunity to revise their production map specifications. For example, topographic mapping of the Republic of Ireland had stagnated since partition from the United Kingdom in 1922. Ireland adopted a new mapping policy in 1964, when 1:2,500 was established as the basic scale, underpinned by a recently completed first-order triangulation and leveling network. The Ordnance Survey of Ireland (OSI) entered into a joint program with the Ordnance Survey of Northern Ireland (OSNI) to complete a new 1:50,000 series of Ireland.


FIG. 1011. DETAIL FROM ORDNANCE SURVEY OF IRELAND DISCOVERY SERIES, 1:50,000, 1994. Overhauls of map series during the last quarter of the century offered opportunity to integrate photogrammetric and digital techniques into the production flow line as in this example, *Straith Eolais: Maigh Eo* (sheet 22) published by the OSI. Fine photogrammetric contouring combined with layer tinting made this an attractive topographic map series.
Size of the entire original: 113 × 80 cm; size of detail: 14.5 × 12.9 cm. Image courtesy of the Arthur H. Robinson Map Library, University of Wisconsin–Madison. © Ordnance Survey Ireland/Government of Ireland. Copyright Permit No. MP 000614.

OSI sheets were compiled from 1:30,000 aerial photography and, with its clean-cut photogrammetric and computer-assisted production, marked a major design shift away from its 1:63,360 predecessor (fig. 1011).

Rapid surveys were undertaken to assist in the postwar rebuilding of Europe. For example, *La Nouvelle carte de Belgique* at 1:50,000 scale (*Type Rapide*), published by the Institut géographique militaire from 1952 onward, demonstrated the emphasis on speedy production and the use of photogrammetric methods and a shift to a standard 1:50,000 scale as opposed to the previous nonstandard 1:40,000 scale. However, there were exceptions to the pervasive application of photogrammetry. For instance, photogrammetry was not in widespread use in official agencies in Germany due to the preference for classical methods of land survey, the existence of reasonably complete detailed surveys at large scales, and the restrictions placed on German use of aircraft and flying of air photography after the war (Rugg 1965). Apart from the conventions established through long usage, standardization of conventional signs was established through international agreement among North Atlantic Treaty Organization (NATO) member countries. The implementation of these agreements was controlled by technical instructions, though in view of the huge variety of symbols required to suit different scales of maps and types of terrain, such instructions were not necessarily followed to the letter. However, implementation of the standards was more straightforward where new series were produced in cooperation with the U.S. Army Map Service, as in the case of the 1:50,000-scale NATO Series M708 of Greece.

The modernization of topographic mapping in Norway typifies the general trend in NMA activity during the second half of the century in Western Europe. The old 100,000-scale series begun in 1867 (first published 1872) was based on plane table and aneroid surveys and drawn on either a Cassini or a polyhedric projection. Its replacement as a basic scale, the 1:50,000-scale Series M711, was begun in 1955 (fig. 1012) and published to NATO specifications with the assistance in northern Norway of the U.S. Defense Mapping Agency. The series was drawn on a Universal Transverse Mercator (UTM) projection using World Geodetic System (WGS84) datum and included a legend in both Norwegian and English. Place-names on the map were the official (standardized) names following the passing of a place-name law in Norway in 1991. Since the early 1980s digital mapping techniques had been introduced to the production process, and a digital terrain model was captured from the contouring with a 90-meter grid interval. Revision of the maps was carried out using a combination of photogrammetric methods and fieldwork. Though the overall design was unremarkable, Series M711 demonstrated the inevitable result of standardization and automation with digital techniques being successfully employed to produce a facsimile of a traditional, almost international topographic map.


FIG. 1012. DETAIL FROM THE *TOPOGRAFISK HOVEDKARTSERIE* M711, 1:50,000, 1990. *Gjøvik* (sheet 1816[I]) published by the Statens Kartverk, Landkartdivisjonen, Norway. The standardization of topographic maps to NATO specifications was a feature of postwar Western Europe. Though designed to conform to NATO standards, this series remains distinctive, especially in its treatment of cultivated land (orange).
Size of the detail: 10.4 × 11 cm. Image courtesy of Alastair W. Pearson.

Investment in digital technology by NMAs followed broadly similar lines throughout Western Europe. During the 1970s digital technology was brought in to improve the efficiency of paper map production, closely followed by more investment to cope with the increasing user demand for the digital data. However, the so-called digital revolution did not bring about any major changes to topographic map design. J. S. Keates (1996) argued that the inevitable preoccupation with technology had drawn attention away from map design. Trimming production costs was a far greater factor, he argued, in determining the appearance of many topographic maps. Ordnance Survey demonstrated this with the conversion of the 1:63,360 Seventh Series, originally designed in ten colors (later reduced to six), to production in six colors for the First Series of the 1:50,000-scale map. The employment of screens for linework initially drew criticism. Dot screens and annotations replaced hand-drawn symbols for such features as sand dunes, foreshore, and ornamental parks (Harley 1975, 107, 124–26, 129). The replacement of the 1:63,360 Seventh Series by the 1:50,000 Second Series acknowledged the need for standardization. Metric scales became standard in all other European countries and increased scale provided greater clarity. The European fashion to use blue for motorways was adopted and the Gill Sans typeface, used since the 1920s, was replaced with the sans serif font Univers. Revision of the Ordnance Survey's flagship topographic map specification not only acknowledged the need to reduce costs but also Ordnance Survey's increasing reliance on market research and awareness of European trends.

The increasing standardization in Western Europe was enhanced by the formation of the Comité Européen des Responsables de la Cartographie Officielle (CERCO) in 1980, which provided a forum for the exchange of information of common interest between the various NMAs. Most European countries were represented, normally by the heads of the NMAs. CERCO focused on developing a pan-European approach to geographic information by establishing the Multipurpose European Ground-Related Information Network (MEGRIN) in 1993. The primary intention was to provide European Union (EU) member states with cost-effective pan-European products and services. Tangible benefits included the Seamless Administrative Boundaries of Europe (SABE1). However, despite greater interaction between the NMAs, most topographic maps still reflected the survey organizations of the individual nation-states. Efforts to standardize concentrated mainly on standards for data quality and transfer, and as Robert B. Parry and C. R. Perkins (2000, 631) point out, "hard copy printed mapping continues to differ in style and specification from nation to nation, reflecting diverse and long histories of data collection and publication." The contrast of cartographic styles is no better illustrated than by Belgium, a country at the administrative heart of the EU. The marked differences between Belgian and Dutch topographic map designs is all too clear on Belgian sheets of border areas (fig. 1013).

During the century there were several important developments in topographic mapping. The most important of these was the change from the topographic map being designed for and created by the military to a market-oriented product fit for the consumer of the twenty-first century and created by profit conscious quasi-governmental agencies.

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FIG. 1013. DETAIL FROM BELGIAN 1:50,000 MAP, 2000. *Antwerpen* (sheet 15) published by the Institut géographique national, Brussels. Though at the administrative heart of the European Union, the sheet demonstrates the lack of standardization in West European topographic mapping. The Dutch specification of mapping is adopted in the top left corner for the area of the map that covers the Netherlands. Furthermore, users of the map are instructed to add two meters to all altitudes to adjust to the Belgian leveling, which uses the local Ostend datum.
Size of the detail: 13.6 × 17.1 cm. Image courtesy of Alastair W. Pearson.

SEE ALSO: Bundesamt für Kartographie und Geodäsie (Federal Office for Cartography and Geodesy; Germany); Bundesamt für Landestopographie (Federal Office of Topography; Switzerland); Cartographic Duplicity in the German Democratic Republic; Institut Géographique National (National Geographical Institute; France); Instituto Geográfico Nacional (National Geographical Institute; Spain); Ordnance Survey (U.K.); Preußische Landesaufnahme; Topografische Dienst (Netherlands)

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*Topographic Mapping in Eastern Europe.* Eastern Europe has been defined in different ways over the twentieth century, but here it will be taken to mean those countries that were formerly part of the Soviet Union or the Soviet Bloc, including the Baltic States, but excluding Belarus, Moldova, Ukraine, and Russia. It will also include East Germany between 1945 and 1990, when that country was part of the Soviet Bloc, and some adjoining areas where relevant.

Topographic mapping in Eastern Europe can conveniently be divided into four phases: (1) the period up to the end of World War I, when topographic mapping was largely the product of the three continental empires of Austria-Hungary, Germany, and Russia; (2) the interwar period, when independent national styles and methods started to emerge; (3) the Cold War, when the Soviet model was imposed throughout most of Eastern Europe; and (4) the post–Cold War period, which saw a reemergence of national styles and methods. For much of the twentieth century, topographic maps in Eastern Europe were secret documents not available to unauthorized users. The agencies producing them were usually branches of the national army. They were, therefore, almost indistinguishable from military maps. Indeed, prior to World War I there was little point in differentiating topographic and military maps.

At the start of the twentieth century the Austro-Hungarian, German, and Russian Empires were already mapped at medium scale by their respective mapping agencies. In Austria-Hungary and Russia these were large centralized bodies, the Militärgeographisches Institut and the General Strjelbitzki, respectively. In Germany the responsibility for mapping resided with local survey departments in the states that made up the empire. The whole of Austria-Hungary had been mapped at 1:25,000 between 1869 and 1887 using plane tables, and a new survey, the Präzisionsaufnahme, using tacheometry, had been under way since 1896 (Kretschmer 1991, 9, 11). But the most widely used topographic maps were the *Spezialkarte*, produced by reduction from the 1:25,000 plane table sheets and published at 1:75,000. In Germany the *Positions-Karte* had been produced at 1:25,000, together with a General Staff map at 1:100,000. The main mapping scale used in the Russian Empire was 1:126,000, for the so-called three-verst map. All three imperial powers were also busy producing topographic mapping of the Balkans using scales and styles of mapping similar to those used for their own territory (Bartholomew 1890).

The maps produced by the empires was broadly similar in appearance, usually printed in black and white with hachures to show relief. Color had been introduced on some printings of the German 1:100,000 General Staff map, with the use of blue for hydrology and brown for relief. However, black-and-white editions were still being issued through the end of World War II. The Austro-Hungarian 1:75,000 series also survived largely unchanged well into the century, in some cases merely being photographically enlarged to 1:50,000. Russian mapping of the Baltic States and Poland used hachures for relief depiction, but their mapping of the Balkans had brown contours. In part, this reflects the fact that the Balkan mapping was of a more recent vintage.

There were important cartographic differences among the three empires, which employed different projections, vertical datums, spheroids, and prime meridians. In addition, the triangulation schemes within the Russian Empire were not integrated. All of these differences created significant problems for successor states.

Some of the Balkan states had made a start on their own mapping, with Romania surveying and publishing at 1:10,000, with reductions to 1:200,000, and Serbia in the process of mapping at 1:75,000. Other countries, such as Bulgaria and Montenegro, had not established mapping programs, with all Bulgarian mapping still being derived from Russian surveys carried out in 1877–79 at 1:42,000 (United States, Department of the Army 1963, 203–6, 216–17).

Prior to World War I the Austro-Hungarian Militärgeographisches Institut had made considerable progress developing terrestrial photogrammetric techniques for Alpine mapping. The experience gained was to be a significant factor in the rapid adoption of photogrammetry in the successor states (Collier and Inkpen 2003).

Education in topographic mapping was largely carried out within the mapping organization for those staff involved directly in the production process. Staff members were usually trained in specific aspects of the process with little attempt to raise their awareness of the process as a whole. Military officers were usually responsible for management as well as aspects of the work requiring greater technical competence. These officers would normally have been trained in colleges of military engineering, which offered specialist courses in surveying to small numbers of officers selected for their academic ability.

Following World War I, Hungary, Czechoslovakia, Estonia, Lithuania, and Latvia were carved out of the former German, Austro-Hungarian, or Russian empires; Poland was created out of parts of all three former empires; and Yugoslavia was created from parts of the Austro-Hungarian Empire and the formerly independent states of Serbia and Montenegro. This meant that some countries could simply carry on with the mapping programs that were already in place (fig. 1014), often with many of the same staff. In the case of Poland, Wojskowy Instytut Geograficzny, the new national mapping agency, drew on the expertise of largely Austrian- and Russian-trained staff. In the west of the country the inherited mapping was at 1:25,000 and 1:100,000, and in the south it was at 1:75,000, while in most of the country it was at 1:126,000, with some areas also mapped at 1:84,000. While the German mapping was based on the Greenwich meridian, the Austro-Hungarian maps were based on Ferro and the Russian maps on Pulkovo. In all, the Wojskowy Instytut Geograficzny had to deal with mapping based on nine coordinate systems and four reference spheroids. The decision was made to standardize at 1:25,000 and 1:100,000, and the 1:25,000 coverage was completed just before the outbreak of World War II. Poland was one of the successor states that made rapid advances in the use of photogrammetric techniques. The rapid completion of the coverage at 1:25,000 was due, in part, to the early adoption of photogrammetric techniques. Even so, the series as a whole was produced as a secret military edition, with only selected sheets published in tourist editions.

Czechoslovakia also made considerable technical strides in the interwar period. A new 1:25,000 series, the *Topografickna Mapa*, was produced for border areas. The inherited 1:75,000 series continued in production as the *Speciálni Mapa*, recognizable still in the *Spezialkarte* style, but with overprints in green for woodland and red for some roads. New styles were being developed in the late 1930s, but few sheets had been published prior to the German invasion in March 1939. The mapping of Yugoslavia, formed by the union of the former independent states of Serbia and Montenegro and the former Austro-Hungarian territories of Croatia, Slovenia, and Bosnia-Herzegovina, was standardized at a scale of 1:100,000, although 1:75,000 and 1:25,000 mapping remained available for some areas (United States, Department of the Army 1963, 194–95). Yugoslavia was another country that benefited from early Austrian developments in photogrammetry.


FIG. 1014. DETAIL FROM HUNGARIAN 1:75,000 SHEET (*MÓR ÉS ZIRC*). Sheet 5060. Published in 1933 from surveys carried out in 1921 and 1923, this series still retained the appearance of pre–World War I Habsburg mapping.
Size of the entire original: 43.2 × 52.4 cm; size of detail: 14.9 × 10.4 cm. Image courtesy of Peter Collier.

While most of the new countries of Eastern Europe were starting their own survey departments, Albania was entirely dependent on the Italian Istituto Geografico Militare to meet its mapping needs. After World War II, Albania still lacked an independent mapping capability; the Soviet Union had assumed initial responsibility for providing maps, but China took over the mapping of Albania following the ideological split with the Soviet Union in the mid-1960s. An Albanian agency capable of meeting the country's need for basic topographic mapping was not established until 1975 (Parry and Perkins 2000, 642).

The appearance of maps started to change during the interwar period, when multicolor printing increased. This was linked with the general move from hachures to contours for relief depiction. However, the slow pace of revision meant that hachured editions were still widely available at the outbreak of World War II. Another significant change during the interwar period was the introduction of grids as an increasingly standard feature. In many cases this simply involved overprinting a grid on a previously nongridded sheet.

Following World War II, topographic maps were regarded as secret documents throughout the whole of the Soviet Bloc. This meant that the public had no access to accurate mapping or to any mapping at topographic scales. It also meant that accurate information on mapping programs was not available outside of the Soviet Bloc.

Immediately after World War II many of the countries of Eastern Europe continued with prewar mapping programs. However, by the early 1950s most programs had been brought into conformity with the Soviet 1942-System. This system was the standard adopted for all military mapping in the Warsaw Pact and used a sheet designation system and sheet lines based on the International Map of the World (IMW). The 1942-System had an importance beyond its military origins as its style and sheet designation system strongly influenced the development of civilian mapping in East Germany, Poland, and much of the Soviet Union. When the Baltic States were formally incorporated into the Soviet Union, they ceased to have any independent mapping programs, and Soviet authorities went to considerable lengths to obliterate any vestiges of the independent prewar programs by, for example, destroying prewar geodetic control networks (Collier et al. 1996, 133; Jagomägi and Mardiste 1994; Yashchenko 1990).

In East Germany, basic topographic maps were made in two versions by two organizations. The Ausgabe für die Volkswirtschaft (AV) were produced by the VEB (Volkseigener Betrieb) Kombinat Geodäsie und Kartographie for the interior ministry beginning in 1978 (initially only at 1:25,000 scale, although subsequently 1:10,000, 1:50,000, 1:100,000 and 1:200,000 were added) (fig. 1015). These AV versions were intended for administrative and economic purposes. The Ausgabe Staat (AS) versions were produced by the Militärtopographischer Dienst for the Ministerium für Nationale Verteidigung. Production began in 1954. Access to these sheets was highly restricted. Although the versions were superficially very similar, the AV version lacked geographical coordinates for the sheet corners and used a different grid and sheet numbering system. Additionally,


FIG. 1015. DETAIL FROM EAST GERMAN 1:50,000 SHEET (*SCHWERIN*, 2d ED.), 1978. Sheet 0504-2. In the Ausgabe für die Volkswirtschaft (AV) style. Note the lack of any geographical coordinates.
Size of the entire original: 45.5 × 34.7 cm; size of detail: 26.2 × 16.6 cm. Image courtesy of Peter Collier.

the AS edition was based on the Krasovskiy ellipsoid, and the AV edition was based on the Bessel ellipsoid, and this was to have implications for digital conversion after reunification (Collier et al. 1996, 134; Parry and Perkins 2000, 45).

Similar local variations existed in some satellite states such as Hungary and Czechoslovakia, although civilian maps from these satellite countries were visually very different from the 1942-System maps. Robert B. Parry and C. R. Perkins (1987, 402) state that Czech maps used a transverse conformal cylindrical Gauss projection with sheet lines based on subdivisions of the IMW system. This was true in the late twentieth century for topographic maps produced by the General Headquarters of the Czechoslovak People's Army (Generalni Stab, Československá lidová armádá), but there was also a series of so-called Basic Maps with sheet lines not based on established subdivisions of the IMW. Although different in appearance from the AV series in East Germany, these Basic Maps shared the same geometric characteristics (Collier et al. 1996, 135).

No graticule or grid was printed on Basic Maps at any scale, and graticule and grid ticks are not shown for scales smaller than 1:25,000. There is no key or reference box on any of the maps, and there is virtually no marginal information (e.g., no indication of magnetic north). This lack of marginal information (also a characteristic of the AV editions) seems to have been a common feature of East European mapping produced for nonmilitary users. Its origins are in the culture of secrecy that existed under Communism and in the desire that the maps should be of little value to unauthorized users (Collier et al. 1996, 135; Unverhau 2006).

Following the collapse of the Soviet system in Eastern Europe and the independence of the Baltic States, there were rapid moves to allow free access to previously secret topographic mapping. In some cases, this meant that existing 1942-System maps were made available to the general public, while in other instances the existing civil maps were made more widely available or new series were initiated (fig. 1016). In the case of the former East Germany, both the AV and AS sheets were made available prior to the reorganization of the whole mapping infrastructure to bring it in line with the *Länder*-based system in the former West Germany. It should be noted, however, that the existence in digital form of much of the former East German material enabled a very rapid conversion (Collier et al. 1996, 134–38).

PETER COLLIER

SEE ALSO: Cartographic Duplicity in the German Democratic Republic; Military Mapping by Major Powers: (1) Germany, (2) Russia and the Soviet Union; Preußische Landesaufnahme; Russia and the Soviet Union, Fragmentation of

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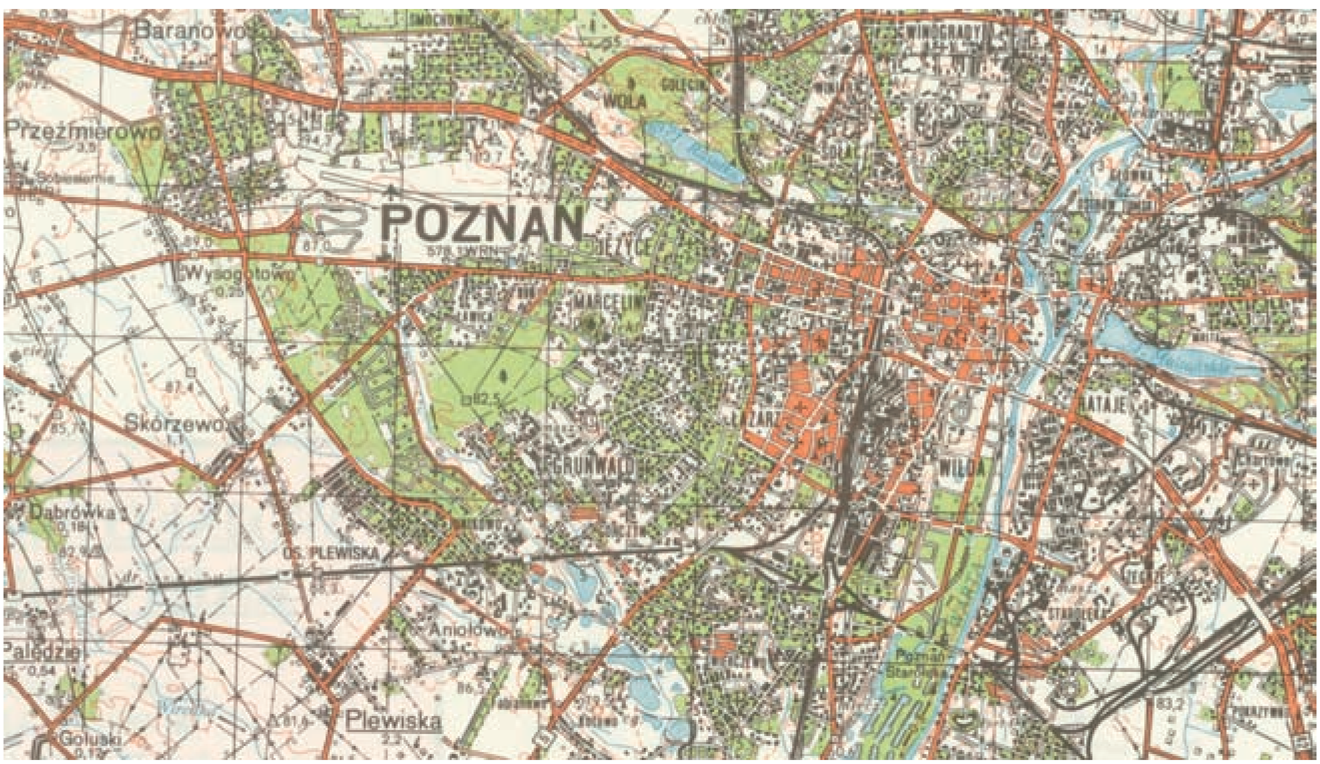


FIG. 1016. DETAIL FROM POLISH 1:100,000 SHEET (*POZNAŃ*) IN THE 1942-SYSTEM STYLE, 1992. Sheet N-33-130. Published after the end of communism for sale as an interim edition. Size of the entire original: 45.3 × 36.2 cm; size of detail: 9.9 × 17.3 cm. Image courtesy of Peter Collier.

Parry, Robert B., and C. R. Perkins. 1987. *World Mapping Today*. London: Butterworths. 2d ed., London: Bowker-Saur, 2000.

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*Topographic Mapping in Russia and the Soviet Union.* Historically, Russian cartography can be characterized by two practices: initial data collected in the field through direct local description and state organization and domination of cartographic activity. The greatest achievements of its early history are connected with the epoch of Peter I. It was under his decree that in 1720 regular national survey work began (the *senatskiye s"ëmki*, or senatorial surveys). This work provided material for the first maps and atlases of Russia. A second governmental project, the general surveying of lands, started in 1765 and resulted in even more data collection.

From 1822 to 1917 the military department (Voyennoye vedomsto) and its corps of military surveyors, Korpus voyennykh topografov (KVT), contributed significantly to the progress of topographic mapping. The KVT performed work on topographic surveying, development of triangulation, and leveling networks that resulted in the military half-verst (1:21,000), one-verst (1:42,000), and two-verst (1:84,000) topographic maps. The Akademiya nauk (with Pulkovo Observatory as the geodetic center) and the Russkoye geograficheskoye obshchestvo (RGO), cooperating with the KVT, also played leading roles in the development of surveying in Russia during this period. Geographer Alexey V. Postnikov (1996) provided a detailed history of Russian land mapping before the turn of the twentieth century.

Despite all efforts of the KVT and other departments tasked with conducting surveying and general topographic mapping during the nineteenth century, coverage of the country was not uniform by the beginning of the twentieth century. Most of the territory remained unexplored (fig. 1017), and existing maps exhibited frac-


FIG. 1017. TOPOGRAPHIC MAPPING OF RUSSIA BY 1917. Map showing the level of coverage of the territory of Russia by topographic surveys and maps by October 1917. The legend categories are: surveying and maps at a scale of 1:42,000 and larger, surveying and maps at a scale of 1:84,000, surveying and maps at a scale of 1:210,000, the eastern limit of the 1:126,000 map, the eastern limit of the 1:420,000 map, the frontier as of 1914.

Size of the original: 12 × 20.4 cm. From *Leninskiy dekret v deystvii: 60 let sovetskoy geodezii i kartografii* (Moscow: GUGK, 1979), pl. 6.

tional scales, heterogeneous mathematical bases, and a general lack of map editing.

To eliminate these limitations and consolidate efforts for the proper conduct of surveys, the Soviet government established the military topographic service, Voyenno-topograficheskaya sluzhba (VTS) on 2 May 1918 and signed the decree establishing the Vyssheye geodezicheskoye upravleniye (VGU) on 2 March 1919. Since then, surveying and geodetic work have been completed by joint efforts of military and civilian experts (Baranov and Kudryavtsev 1967).

From 1919 to 1930 the formation of Soviet cartography and the theoretical and practical foundations of mapping of the country were initiated. This was accomplished under the severe conditions of the Civil War (1918–21) and the restoration of the national economy. One of VGU's first activities was the transition to the metric system. The set of topographic map scales (1:10,000, 1:25,000, 1:50,000, 1:100,000, 1:200,000, 1:300,000, 1:500,000, and 1:1,000,000) was adopted in 1923. A uniform map sheet division and nomenclature based on a 1:1,000,000 map (still in use at century's end) was introduced. The decision was made to move to a system of rectangular coordinates on the Gauss-Krüger projection. In 1928, based on the ideas of Feodosiy Nikolayevich Krasovskiy, a design was completed for the establishment of a national triangulation network to unite all surveys and topographic work and provide them with control points. These ideas were written into the instructions for first-order (1928) and second-order (1930) triangulation and for first- and second-order astronomical measurements (1928).

The VGU began its first geodetic and surveying activities in 1919. Experts from the Moscow Mezhevoy institut (land surveying institute), and topographic and technical schools founded in 1919–21, were involved in the surveys. A few VGU branches were organized in outlying regions. There was a priority on the manufacture of geodetic instruments, which resulted in enough devices for triangulation, astronomical measurements, and leveling by 1925.

Despite several restructurings and renamings of the VGU (see table 18), the geodetic service continued to increase its work, which was of national importance. In 1929, the Tsentral'nyy nauchno-issledovatel'skiy institut geodezii, aero"yëmki i kartografii (TsNIIGAiK) was founded. All airphoto surveying enterprises reported to the geodetic division (Baranov and Kudryavtsev 1967).

In 1930, the geodetic faculty of the Mezhevoy institut established the Moskovskiy geodezicheskiy institut. This geodetic institute started training specialists in many fields. Cartographic specialties were begun in the Geography Departments of Moscow and Leningrad universities in 1929–31. New approaches to surveys that considered the physiographic features of the territory and the economic significance of regions were adopted on Krasovskiy's initiative. The first obligatory instructions were drafted. At first the surveys were conducted in the European part of the Soviet Union, then extended to Central Asia, western Siberia, Transbaikalia, and the Far East.

Because of the increasing importance of official topographic surveys and the publishing of basic topographic maps, surveying was radically restructured during 1930–40. All efforts focused on the 1:100,000 survey to complete the mapping of the country. Larger scales were used only in special cases. Photogrammetric instruments, for photomaps and contour maps from aerial photography, became available by 1930. This period was characterized by wide application of these capabilities. New techniques for geographic editing of topographic maps were established and widely applied to mapping of less explored and remote areas of the northern and eastern Soviet Union (fig. 1018).

In 1938 the VGU became an independent body, the Glavnoye upravleniye geodezii i kartografii (GUGK). Unification of basic instructions was completed between 1938 and 1940. Basic provisions for establishing the national geodetic control network of the Soviet Union (*Osnovnyye polozheniya o postroyenii gosudarstvennoy opornoy geodezicheskoy seti SSSR*, 1939); new instructions (obligatory for all Soviet organizations) for 1:10,000 to 1:100,000 topographic surveys (1940); and uniform conventional signs for 1:25,000 to 1:100,000 topographic maps (1940) were approved. Preparation work for publishing a new 1:1,000,000-scale map was finished. In 1940 a manual on designing and preparing the 1:1,000,000 official map of the Soviet Union for publication was issued. This manual (*Nastavleniye po sostavleniyu i podgotovke k izdaniyu Gosudarstvennoy karty SSSR masshtabe 1:1 000 000*) detailed the experience and achievements of Soviet cartography in designing multisheet maps.

From 1941 until 1945, during World War II (called the Great Patriotic War in the Soviet Union), GUGK and the VTS provided the country's armed forces with topographic maps, geodetic data, and airphoto materials. While working at the front they continued performing geodetic and topographic surveys across the country (fig. 1019). Progress was made creating uniform geodetic and leveling networks. On 6 April 1946, the Soviet Union's Council of Ministers introduced a new uniform system of geodetic coordinates labeled 1942 Pulkovo that was coupled with a Baltic system of heights measured from a zero datum at the tide gauge in Kronstadt. During this time the size of the terrestrial ellipsoid derived by Krasovskiy was used in all geodetic work.

Military map use resulted in a number of specific requirements for topographic maps that were incorporated in the 1946 tables of conventional signs, and their


FIG. 1018. TOPOGRAPHIC MAPPING OF THE SOVIET UNION BY 1941. The work of devoted professional topographers and surveyors allowed geodetic and topographic surveying to be started in the farthest regions of the country—areas that had not previously been covered cartographically. The two categories in the legend are: topographic investigation of the country by 1 January 1932 and topographic investigation of the country by 1 January 1941.
Size of the original: 13.2 × 21.2 cm. From *Leninskiy dekret v deystvii* 1979, pl. 14.


FIG. 1019. TOPOGRAPHIC MAPPING OF THE SOVIET UNION BY 1946. The legend categories are: topographic investigation by 1 January 1941 and topographic surveys performed from 1941 to 1945. The text to the right lists achievements by the VTS and the GUGK during the Great Patriotic War: they made surveys and did reconnaissance in an area of about 5 million square kilometers, published 880.5 million copies of topographic maps, designed and prepared for issue 19.6 thousand topographic map originals, and compiled and published 575 catalogs and lists with 333 thousand geodetic points.
Size of the original: 13.5 × 27.8 cm. From *Leninskiy dekret v deystvii* 1979, pl. 20.

subsequent editions, and also in the first issues of map design manuals (1943, 1945). Despite the wartime difficulties it took only a short time (1941–45) to complete a new 1:1,000,000 official map. It was the largest scale map of all Soviet territory. In 1947 the map was awarded the Big Gold Medal of the RGO, and an important stage in the development of the system of Soviet topographic maps of nationwide importance came to an end.

In the postwar years (1946–56) it was necessary to update and sometimes fully replace topographic maps due to local changes caused by the war. The restoration of triangulation and leveling points that had been destroyed and the renewal of precision geodetic and photogrammetric instrumentmaking were critical needs. The extent and pace of surveys grew rapidly again.

The goal of finishing 1:100,000 mapping of the entire Soviet Union was established. From 1948 simultaneous work on the 1:100,000 surveys and the surveys at 1:25,000 and 1:10,000 began. Late in 1954 mapping at the official base scale (1:100,000) was completed and 1:25,000 was approved as the scale for a new base map of the country (fig. 1020).

The basic provisions for establishing the national geodetic network of the Soviet Union were updated in 1954 and supplemented in 1961. This was of tremendous importance for the geodetic service, as it formed a new standard for its development and accuracy. The provisions for designing topographic maps at various scales (*Osnovnyye polozheniya po sozdaniyu topograficheskikh kart masshtabov 1:10,000, 1:25 000, 1:50,000 and 1:100,000 masshtaba)* were adopted in 1956. These provisions defined the contemporary purpose, accuracy, and contents of maps at each scale as well as their projection, coordinate systems, heights, map sheet division, nomenclature, requirements for air surveying, and methods of map design. This document replaced the obliga-


FIG. 1020. TOPOGRAPHIC MAPPING BY THE SOVIET UNION BY 1956. The legend categories are: topographic investigation by 1 January 1946, topographic surveys performed from 1946 to 1950, and topographic surveys performed from 1951 to 1955. Creation of topographic maps is a prerequisite to development of the country's productive forces and defensive capacity. Creation of maps to a scale of 1:100,000 for a territory as vast as the Soviet Union was unprecedented in the history of the world's cartography.
Size of the original: 15.1 × 22.2 cm. From *Leninskiy dekret v deystvii* 1979, pl. 25.

tory instructions for topographic surveys valid since 1940 (Vereshchaka 2002).

During 1956–66 intensive development of the 1:25,000 and 1:10,000 surveys took place including mapping of important industrial and agricultural areas and surveys in the northern and eastern territories, where extensive development of natural resources was planned. This in turn resulted in establishing and developing triangulation, traverse, and leveling networks.

In the 1950s and 1960s the second edition of the 1:1,000,000-scale map, using the new 1951 specifications, was finished. Completion of later 1:100,000 surveys, in the 1960s and 1970s, led to the third edition. Significant progress was made on the 1:25,000 and 1:10,000 surveys due to the introduction of new techniques and technologies. Up until this time surveyors used highly accurate light and radio range finders. In 1958, they started successfully adjusting geodetic networks with the help of electronic computers. New aerial cameras and other devices to improve the quality of aerial pictures were developed. Work on building highly accurate universal photogrammetric instruments, e.g., the stereoprojector designed by G. V. Romanovskiy, F. V. Drobyshev's stereograph, and the later stereograph STs-1, and the use of methods for spatial phototriangulation were introduced. These instruments enabled new ways of implementing horizontal and vertical control of surveys at any scale (from 1962). Simultaneously they began to apply a more accurate analytical method for photogrammetric densification of horizontal and vertical networks.

The period from 1966 to 1978 is characterized by an increase in the rate and extent of large-scale surveys (1:10,000 to 1:1,000) to fully meet the requirements of various branches of the national economy, regular increases in available funds for topographic maps, and the surveying of the northern and eastern regions of the country. In 1967 GUGK again became directly subordinated to the Soviet Council of Ministers. Its regional facilities, geodetic support, structure, and management were improved, which led to increased research, particularly the establishment of the research institute of applied geodesy, Nauchno-issledovatel'skiy institut prikladnoy geodezii (NIIPG 1969); Priroda (Nature), the state research and production center (1973); and a number of regional engineering and surveying institutes. Topographic surveys at 1:10,000 became widely implemented for the purposes of agricultural land improvement, and from 1972, 1:5,000 and 1:2,000 surveys were used in cities and large urban communities. Economic programs in northern and eastern regions of the country were also supported.

New standards for conventional symbols on 1:10,000 maps were published (GUGK 1977). As a result, various branches of the national economy, e.g., land reclamation, agriculture, geological exploration, industry, hydropower, line construction, urban layout and development, were studying their requirements for large-scale topographic maps. Large-scale topographic surveys in major areas were assigned to the national service in order to restrict departmental survey involvement.

Topographic plans became divided into basic and specialized branches. Basic standards for designing topographic plans at 1:5,000, 1:2,000, 1:1,000, and 1:500 scales (1970) were devised. These standards formed the basis for modernizing instructions and conventional symbols (GUGK 1973). The tables of conventional symbols for 1:10,000, 1:5,000, and 1:500 maps contained symbols for both broadly useful topographic objects and those specifically required by separate departments.

Old and new geodetic networks in cities were developed along with surveys. Investigations of new instruments, methods, and technologies for airphoto surveying were encouraged. Various aspects of topographic map design and updating technology were considered (Vereshchaka and Podobedov 1986). Research on topographic photomaps was performed and a tremendous number of surveys of underground communications lines in cities and urban-type communities were completed.

The use of space imagery in geodesy and cartography began in the 1960s and 1970s. Priroda was responsible for collecting, processing (including research), storing, and distributing these materials. In the 1980s Priroda established branches in other cities. To increase the expediency of the supply of space imagery to its customers, Priroda developed an automated information retrieval system, FOTOKOM Space Information National Fund.

In 1970, GUGK initiated regular work in Antarctica and experimented with remote sensing materials from space. This made it possible to produce photomaps and topographic maps for areas where surveying to necessary accuracy by conventional methods was impossible. In 1984, work began on radar sensing of glaciers and on the mapping at 1:500,000 and 1:1,000,000 of the subglacial bedrock relief. These techniques were then applied where useful within the Soviet Union.

In 1974 GUGK began developing new instruments for surveying the sea shelf, such as small sonic depth finders, sea meters to register the speed of sound in water, and topographic side-scanning sonar devices. Surveying of large lake, river, and reservoir beds proved useful for other ministries and departments. Applying the experience and scientific achievements of the country's hydrographic service, GUNiO (Glavnoye upravleniye navigatsii i okeanografii Ministerstva oborony SSSR), scientists and experts solved the problems of geodetic bases, scales needed, content of maps, and map design for these new map types. Provisional technical requirements written jointly by GUGK and GUNiO in 1975 were used for future instructions and guides (*Instruktsiya* 1985).

During the late 1970s and the 1980s, basic surveying continued until 1:25,000 mapping of the Soviet Union was completed. A new stage in topographic support began—updating the official topographic maps at each map scale. Large-scale surveys continued and became pressing as a basis for cadastral work and thematic large-scale maps. Not only cities, but also similar urban communities and villages were included in large-scale surveys (1:500 to 1:5,000).

During these years, past experiences resulted in revised and supplemental standards and technical documentation, basic provisions, instructions, and manuals. Still in effect, the *Osnovnyye polozheniya po sozdaniyu i obnovleniyu topograficheskikh kart masshtabov 1:10 000, 1:25 000, 1:50 000, 1:100 000, 1:200 000, 1:500 000, 1:1 000 000* (GUGK 1984) recorded industrial, scientific, and technical achievements and defined requirements for each type of map at all scales in conformity with the goals of the topographic and geodetic service. Thus, topographic mapping in the Soviet Union underwent a long and complex path of development. At different stages, the level of its investigation, its techniques, and its methods for creating maps varied, as did the accuracy and contents of those maps. As a result, a whole system of nationwide topographic maps at a broad range of scales, contents, and up-to-dateness was generated. GUGK was transformed into the Komitet geodezii i kartografii (Glavkartografiya) by decree on 20 April 1991 (and underwent numerous changes since then) (Borodko 2004; Drazhnyuk 1999).

Throughout the last decade of the twentieth century, the activities of the state cartographic service were complicated by reforms and structural transformations. The disintegration of the Soviet Union and the formation of independent states in the territories of the former union republics halted the work of Glavkartografiya in 1992, and it was replaced by Roskartografiya and cartographic and geodetic services in the new republics. In 1995, the federal law on geodesy and cartography (O geodezii i kartografii) was adopted, with subsequent supplements and changes in 2003.

Roskartografiya faced new problems caused by the changed political and economic climate. Substantial geodetic, topographic, and cartographic effort was needed to delimit, demarcate, and verify the changed Russian frontier and borders. This created a need for revised topographical surveys of Russian frontier areas, which have been conducted across an area of more than 15,000 square kilometers (Borodko 2004).

Economically, it is necessary to have expeditious information to solve problems of management, planning, ecological safety, land reforms, registration, and control of natural resources. Digital and electronic maps keep the public informed, and work on digital mapping was begun in 1992. Federal and regional information centers were established in different cities across Russia. Introduction of automated technologies was accompanied by the formation of cartographic databases and geographical information systems, including three-dimensional models. The entire territory of Russia was covered by 1:1,000,000 and 1:200,000 digital topographical maps. A concept for creating and developing an infrastructure of spatial data was being devised. More digital maps of larger scales were planned as well as the updating of maps of all scales on the basis of new information using remote sensing imagery, photogrammetric methods, and computer techniques (Drazhnyuk 1999). Corresponding standards and documents for making and updating digital maps, including *Osnovnyye polozheniya po sozdaniyu i obnovleniyu tsifrovykh kart* (1996) were drafted.

Since 1989, the Voyenno-topograficheskaya upravleniye and Roskartografiya published a series of commercial and governmental maps based on modern topographic maps and plans. These are general topographic, regional, and city maps. According to the federal law on naming geographical objects (O naimenovaniyakh geograficheskikh ob"ektov), Roskartografiya also maintains the state place-name catalog.

In the mid-1990s joint adjustment of the three geodetic networks was completed with the establishment of a space geodetic network (SGN), a Doppler geodetic network (DGN), and an astronomic-geodetic network (AGN). This resulted in a more accurate reference system (called SK-95). It came into use for geodetic and cartographic work on 1 July 2002 by a governmental order dated 28 July 2000. Since 1999 the national system of geodetic coverage has used space geodesy and GLONASS (Global'naya Navigatsionnaya Sputnikovaya Sistema) and GPS (Global Position System) satellite navigation systems. A program for the modernization of the first- and second-order leveling networks was implemented.

By the beginning of the twenty-first century, topographic and geodetic work unprecedented in world history had been performed by several generations of experts. During the twentieth century, a national astronomic-geodetic network, a high-accuracy vertical control network for the whole territory of the Soviet Union, and a system of national topographic maps and plans had been established (table 52).

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SEE ALSO: Antarctica; Glavnoye upravleniye geodezii i kartografii (Chief Administration of Geodesy and Cartography; Russia); Mili-

TABLE 52. Map types in the Russian Federation's system of topographic maps and plans. A total of 517, 202 named topographic map sheets at scales of 1:10,000 to 1:000,000 were completed (Borodko 2004).

| Map type | Scale | Area |
|---|---|---|
| Topographic maps | 1:25,000<br>1:50,000<br>1:100,000<br>1:200,000<br>1:500,000<br>1:1,000,000 | Entire Soviet Union |
| Industrial and agricultural maps | 1:10,000 | All industrial and agricultural areas, an area of 4.5 million km$^2$ |
| Plans | 1:1,000<br>1:5,000 | Cities, urban communities, industrial zones |
| Custom topographic maps for internal water bodies and continental shelf | 1:10,000<br>1:25,000 | Area of 350,000 km$^2$ |
| Digital maps | 1:200,000<br>1:1,000,000 | All of Russia |
| Topographic maps of Antarctica | 1:200,000 | Area of 300,000 km$^2$ |

tary Mapping by Major Powers: Russia and the Soviet Union; Russia and the Soviet Union, Fragmentation of; Tsentral'nyy nauchno-issledovatel'skiy institut geodezii, aeros"yëmki i kartografii (Central Research Institute of Geodesy, Air Survey, and Cartography; Russia)

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*Topographic Mapping in the Middle East.* In 1900 the only two organizations in the Middle East capable of carrying out topographic mapping were a military mapping section of the General Staff in the Ottoman Empire and the Survey Department in Egypt (later renamed the Survey of Egypt). Following World War I survey organizations were established in Palestine, Iraq, and Syria, but these tended to act, either directly or indirectly, as agents of colonial powers. Truly independent national surveys were established in most countries of the region only after World War II, and in some countries, such as Qatar, only toward the end of the twentieth century. This means that much of the topographic mapping in the Middle East has been carried out either by external government agencies, such as Ordnance Survey International's mapping of Yemen in the 1980s, or by civil contractors, such as the mapping of Bahrain in 1977 by Fairey Surveys (Parry and Perkins 2000, 434, 582).

At the beginning of the century the existing topographic mapping of the Middle East had little to distinguish it from the military mapping of the area. Topographic mapping was, in any case, available only for very small areas of the Middle East in 1900. British Army surveyors had mapped western Palestine at 1 inch to 1 mile (1:63,360) on behalf of the Palestine Exploration Fund (PEF) in the 1870s. Under British direction, Egypt had started to produce the best-quality mapping in the region, but the survey department was mainly involved in cadastral mapping, and topographic mapping had a much lower priority than cadastral surveys (Murray 1950).

Within the Ottoman Empire a start had been made on high-quality mapping by the end of the nineteenth century, but this was limited to the empire's European territory and had not been extended to the areas under their control in the Middle East. Following the seizure of power by the Young Turks in 1908, a start was made on reconnaissance mapping at 1:200,000 (completed in 1929) and topographic mapping at 1:50,000. The topographic scale was later changed to 1:100,000 except for some military garrison areas, which were mapped at 1:25,000. After a few 1:25,000 sheets had been published, the decision was made to extend coverage at that scale to the whole country. Progress was very slow, however, and few sheets were available at the outbreak of World War I.

In the period leading up to World War I the British became concerned about possible threats to the Suez Canal from a potentially hostile Ottoman Empire. This led to the survey of northern Sinai, carried out at 1:125,000. A survey of the Wilderness of Zin (the Negev), ostensibly for archaeological purposes, was carried out under the command of Stewart Francis Newcombe in 1913–14. In addition, the Egyptian Survey Department had mapped the areas either side of the Suez Canal at 1:50,000; a strip on the eastern side, 10,000 yards wide, was also mapped at 1:15,000. All of this survey work used conventional plane table techniques (Collier 1994).

Some areas had also been mapped to the east of the River Jordan, both by the PEF and by the Deutschen Verein zur Erforschung Palästinas, although some of the German sheets were not published until after World War I. The only other maps available were the 1:250,000 sheets of eastern Turkey in Asia compiled by Francis Richard Maunsell for the Intelligence Department War Office as IDWO 1522 (Collier, Fontana, and Pearson 1997). While some of these sheets were of good quality, those of Mesopotamia were described as "inconsistent in quality and amount of detail shown" (Tandy 1925, 7).

During World War I the British carried out significant amounts of topographic mapping for military purposes in Sinai, Palestine, southern Lebanon, and southern Syria, and indirectly through the Survey of India in Mesopotamia (after 1920, Iraq) (Collier and Inkpen 2001). The Survey of India also carried out some mapping in Persia (after 1935, Iran) (Tandy 1925). Parts of the hinterland of Aden and areas around some of the Red Sea ports of Arabia were also mapped, but there was little consistency in this work. The military mapping of both Palestine and Mesopotamia laid the foundations for subsequent topographic surveys of those areas.

At the end of World War I, the League of Nations awarded Britain mandates for Palestine (subsequently divided into Palestine and Transjordan) and Iraq. One of Britain's first steps was to establish survey departments in Palestine and Iraq designed to meet all local mapping needs. By contrast, France, which had mandates for Syria and Lebanon, set about mapping the recently acquired territory using personnel from the Bureau topographique des troupes françaises du Levant (BTTFL) to meet immediate needs and personnel from the Service géographique de l'armée (SGA) to carry out systematic accurate surveys. The earliest sheets produced by the BTTFL were Ottoman 1:200,000 sheets with romanized names and sometimes enlarged to 1:100,000 (United States, Department of the Army 1963, 84–85). The scales and styles of maps produced by the SGA were largely based on the maps already being produced for France's North African colonies of Algeria and Tunisia. Plane table surveys were the main technique used for detailed survey. In the French tradition, the topographer responsible was identified on the individual sheets.

The Survey of Palestine was able to build on the work carried out during the war and even adopted the scale of 1:20,000 for its Topocadastral Series covering areas north of 31°15′N (Gavish 2005) (fig. 1021). However, the triangulation network established during the British advance in 1917–18 was far from robust and needed to be remeasured before detailed mapping work could commence. The decision to produce the 1:20,000 series was dictated, in part, by the geopolitical situation: a significant increase in Jewish immigration into Palestine following the Balfour Declaration and the granting of the British mandate. Increasing conflict over land between the new Jewish immigrants and the existing, largely Arab, population meant that much of the effort of the Survey of Palestine was focused on cadastral mapping. The largest scale covering the whole country was a three-sheet edition at 1:250,000, but the settled lands of central and northern Palestine were also covered at 1:100,000. Despite attempts to initiate air surveys in Palestine, nearly all the detail survey work was carried out using plane table methods.

Iran was the only other country in the Middle East with anything approaching systematic topographic coverage. The Survey of India mapped the entire country at quarter-inch scale (1:253,440) and part of the country at half-inch scale (1:126,720) using conventional plane table techniques.

In Iraq the newly established survey department carried on with the mapping of settled areas begun during the war. There was no attempt at mapping the desert areas, and modern mapping coverage for the whole country was not initiated until the 1960s. Mapping in Transjordan followed a similar course, with little real progress during the interwar period. Australian and South African military survey parties mapped some

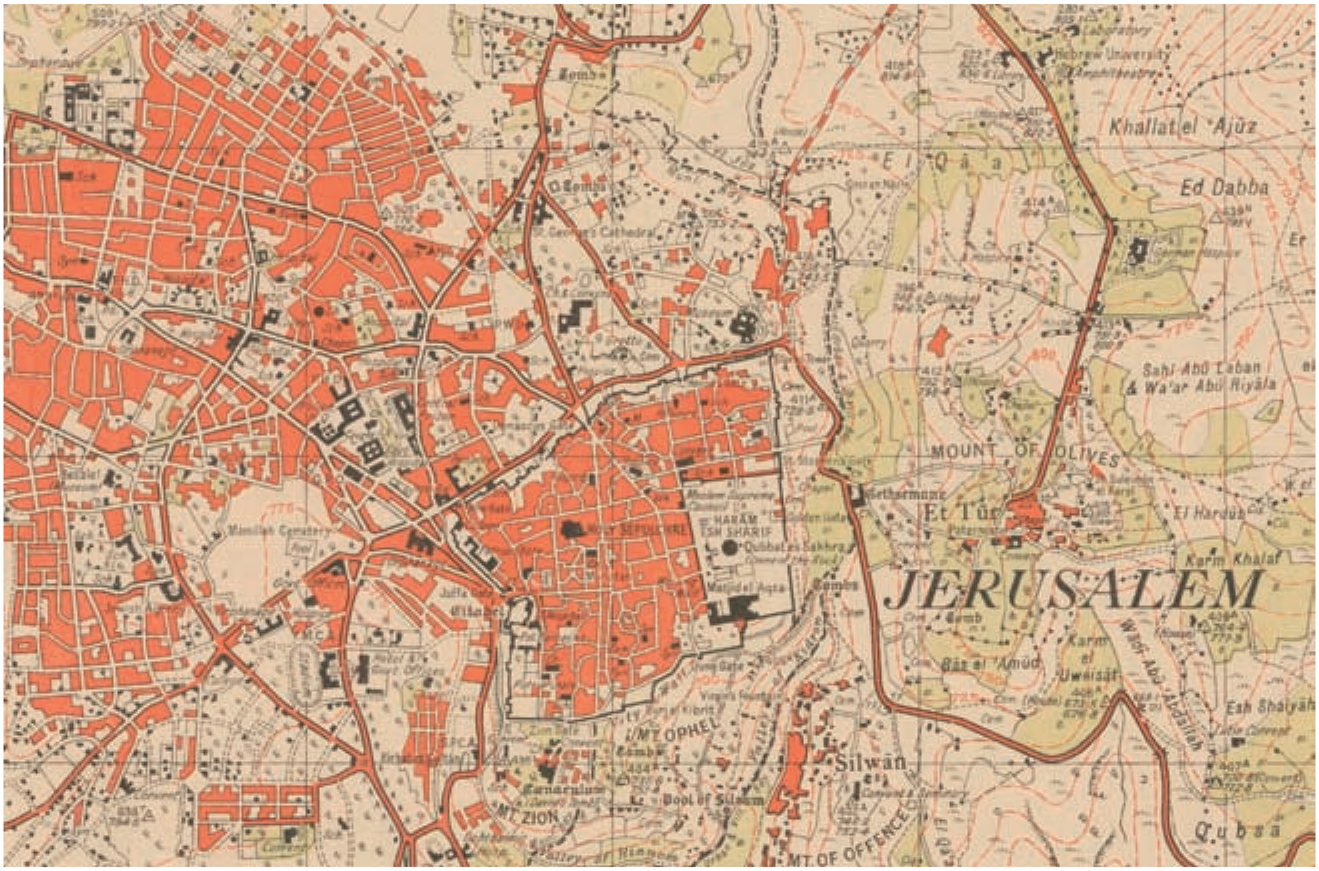


FIG. 1021. DETAIL OF 1:20,000 TOPOCADASTRAL SHEET, *JERUSALEM*, 1943. Sheet 17–13, compiled, drawn, and printed by the Survey of Palestine.
Size of the entire original: 65 × 55 cm; size of detail: 14.1 × 21.4 cm. Image courtesy of Peter Collier.

parts of western Transjordan during World War II using photogrammetric and field survey methods, but the work was not intended to provide systematic coverage.

Throughout the rest of the Middle East there was little or no attempt to provide topographic mapping. Whatever mapping was produced usually supported the exploitation of mineral resources or the development of communications related to those mineral resources, such as the oil pipeline between the Iraqi oilfields and the terminus on the Mediterranean in Haifa. When Raye R. Platt carried out his world review of topographic mapping at scales of 1:253,440 or larger, he found that mapping was absent for the whole of the Arabian Peninsula (except for the hinterland of Aden), all of southern Iraq, and all of Iran (Platt 1945). In Egypt only the Nile Valley, the Red Sea and Mediterranean coasts, northern Sinai, and some areas of the Western Desert were covered. Palestine west of the Jordan River, Syria, and Lebanon (fig. 1022) were the only territories completely covered. While Platt seems to have been ignorant of the Survey of India's mapping in Iran and the mapping already noted in Iraq, the picture he presented was close to the truth.

The strategic position of the Middle East, and its oil reserves, ensured that during the Cold War both the Western powers and the Soviet Bloc would want access to good topographic maps of the region. However, much of this mapping was the product of covert mapping programs and not available for general use. Although largely in the form of conventional topographic mapping, it must therefore be considered military mapping.

During the first decades after World War II there was little new mapping produced outside of the countries that already had established mapping programs. In the early 1950s, 1:100,000 mapping was compiled from a variety of source material for the western part of Jordan in a strip running down to the Gulf of Aqaba and including the West Bank and eastern Israel. The maps did not show the ceasefire line (or Green Line) agreed by the Armistice Commission, nor did they show any of the new Israeli settlements on the Israeli side of the

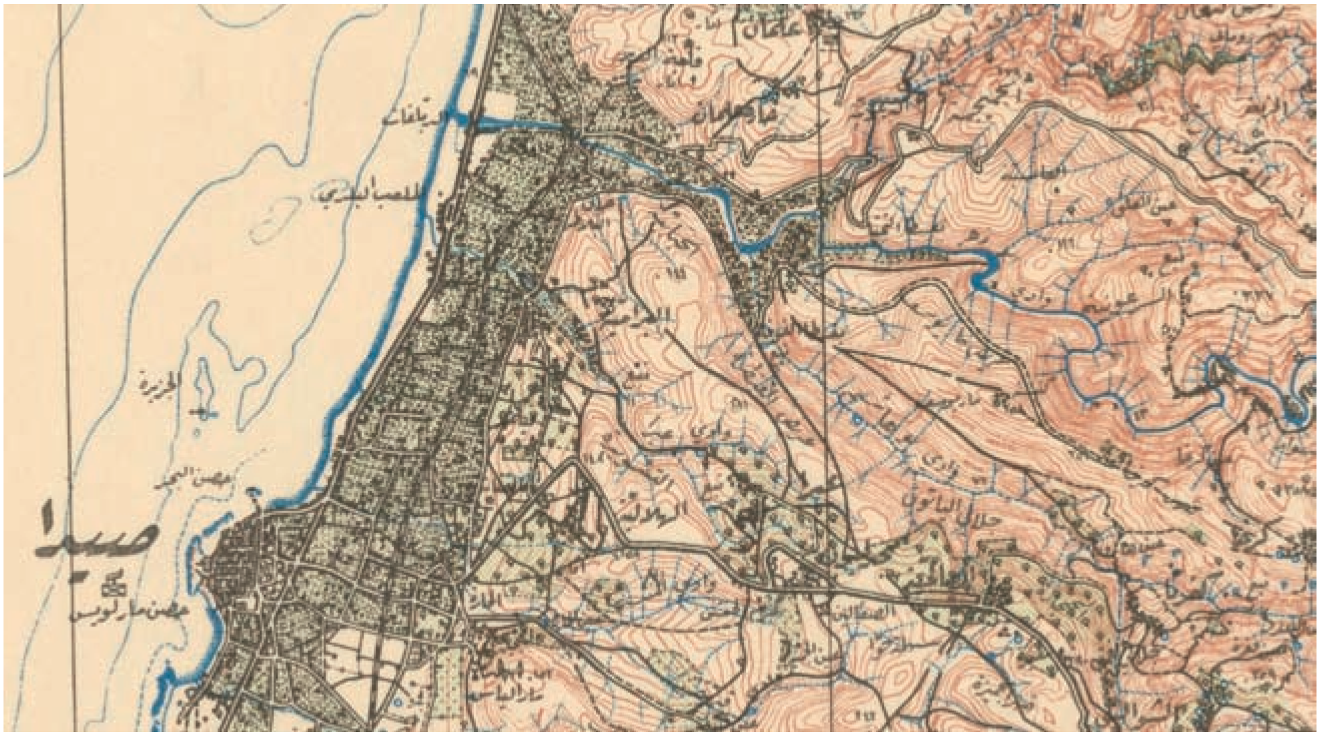


FIG. 1022. DETAIL OF 1:50,000 TOPOGRAPHIC MAP, SAÏDA (SIDON), 1953. Sheet NY-36-XII-3B, Geographical Service, Lebanese Army. Size of the entire original: 66.7 × 54.0 cm; size of detail: 9.6 × 17.3 cm. Image courtesy of Peter Collier.

Green Line (fig. 1023). Apart from the substitution of Arabic lettering, these first Jordanian topographic maps were virtually identical to the maps at the same scale produced by the Survey of Palestine and the first maps produced by the Survey of Israel (fig. 1024). Because the Jordanian Department of Lands and Surveys lacked printing facilities, the maps had to be printed in a British military survey depot.

In 1953 Iran established its own civil mapping agency, the National Cartographic Centre, with assistance from the United Nations. The initial focus of the organization was on large-scale mapping of urban areas with some topographic mapping at 1:10,000 and 1:20,000. Medium-scale topographic mapping remained the responsibility of the National Geographical Organization of the Iranian Army. The two organizations were merged in 1968 but separated again following the Islamic Revolution. The entire country of Iran was mapped at 1:50,000, but this was a restricted military series. Systematic civil mapping of the whole country at 1:25,000 was not initiated until 1990 after the Iran-Iraq war (Parry and Perkins 2000, 472).

Following independence from France, Syria established a national mapping agency, the Service géographique de l'armée, in 1955. In 1962 a start was made on mapping the country at 1:25,000. Initially coverage was limited to western Syria, but with Soviet assistance it was extended into eastern Syria in the 1970s. The mapping in this area conformed to the Soviet 1942-System specification (Jagomägi and Mardiste 1994, 86–87), which used a sheet designation system and sheet lines based on the International Map of the World (IMW). Mapping at 1:50,000 was also produced from the original 1:25,000 coverage. Lebanon established the Directorate of Geographic Affairs and produced national coverage between 1964 and 1974 at 1:20,000, but because of the unsettled political situation the maps have not been revised (Parry and Perkins 2000, 512).

Kuwait was the first of the states on the Persian Gulf to develop a mapping capability with the establishment of the Public Works Department in 1951. Bahrain followed in the 1970s, Oman and the United Arab Emirates in the 1980s, and Qatar only in 1990. Although both Saudi Arabia and Yemen have some mapping capability, both have been highly dependent on external agencies to meet their mapping needs. In the case of Saudi Arabia, this included the production of orthophotomaps, while Yemen had 1:100,000 topographic mapping produced for it by Ordnance Survey International from SPOT (Système Probatoire d'Observation de la Terre) satellite data.

After the move to digital techniques in topographic mapping the Survey of Israel found that its existing map

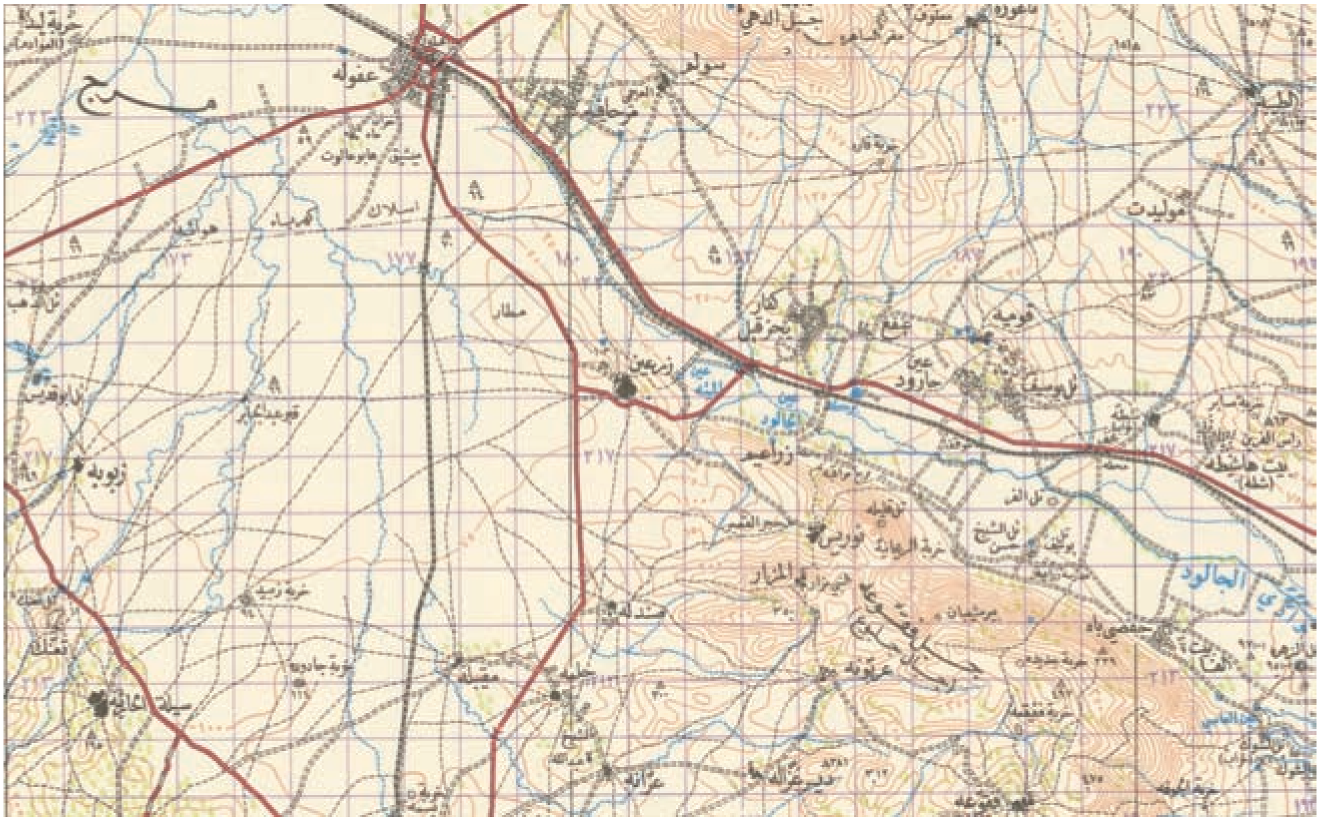

FIG. 1023. DETAIL OF 1:100,000 TOPOGRAPHIC MAP, JENIN, 1950. Sheet 3, compiled and drawn by the Lands and Surveys Department of the Jordan. This map does not show the Green Line or any new Israeli settlements. Size of the entire original: 56 × 60 cm; size of detail: 14.4 × 23.2 cm. Image courtesy of Peter Collier.

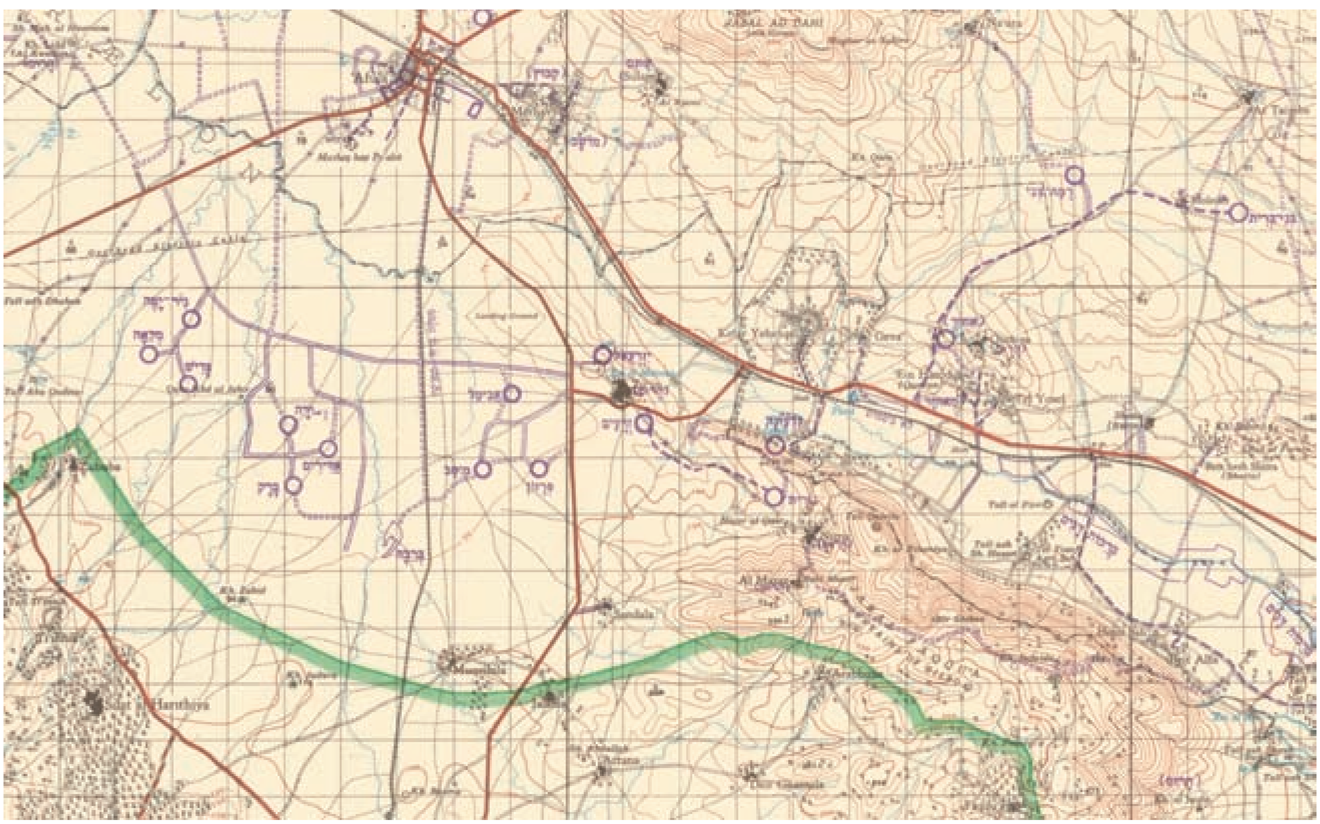

FIG. 1024. DETAIL OF 1:100,000 TOPOGRAPHIC MAP, *NAZARETH*, 2d ED., 1958. Palestine, sheet 5, Survey of Israel. Map showing the Green Line and new Israeli settlements as a purple overprint. Size of the entire original: 46 × 57 cm; size of detail: 14.4 × 23.2 cm. Image courtesy of Peter Collier. Permission courtesy of the Survey of Israel, Tel Aviv.

data were highly inconsistent. This led to a decision to remap the country using the latest techniques, ensuring the consistency of its digital database.

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SEE ALSO: Military Mapping by Major Powers: (1) Great Britain, (2) Ottoman Empire, (3) Israel; Military Mapping of Geographic Areas: Middle East; Paris Peace Conference (1919)

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*Topographic Mapping in China*. China has a long indigenous cartographic tradition going back at least 2,000 years. However, modern-style topographic surveys and mapping only started in the early years of the century with the establishment of the Jingshi lujun cehui xuetang京师陆军测绘学堂 (Military Survey Institute) in 1902. A map series at 1:1,000,000 was planned by the institute, and surveys were started covering 60 percent of the country. There was little progress with the surveys under the imperial government, and it was not until after the Revolution of 1911 that topographic survey and mapping started to be pursued with some urgency. However, the political and military situation in China at the time meant that there was little coordination of the work carried out in different provinces. Each province adopted its own style of mapping and its own datum, meaning that maps of adjacent provinces were not compatible (Williams 1974, 7–8).

Centralized control of mapping started with the establishment of the Zhongyang guotu cehui ju 中央国土测绘局 (Central Bureau of Land Survey; CBLS) in 1928, which was under the Zong canmoubu 总参谋部 (Army General Staff), to plan and carry out major topographic surveys and to coordinate the work of other government agencies, including those at provincial level. First-order triangulation was started in 1929 in Zhejiang province, and this was followed by triangulation work in other provinces starting in 1931. As the need for mapping was urgent, individual provinces could not wait for the completion of the national geodetic network. This meant that topographic work was still being carried out based on local control and creating additional problems of discrepancies between adjacent sheets. Based on these surveys, maps were published at 1:25,000, 1:50,000, 1:100,000, and 1:300,000 scales (Williams 1974, 8–9).

Photogrammetry was introduced into China in 1931, but was not much used until 1934 (Williams 1974), when imported airborne cameras and photogrammetric equipment helped produce topographic maps at 1:50,000. The CBLS was able to deploy nine airplanes on photographic work until 1937, when the outbreak of the war due to Japanese invasion curtailed much of the survey work. China's Nationalist government ceased aerial photography in 1940 (Williams 1974, 9).

Attempts were made by the Nationalist government to resume mapping work as part of postwar reconstruction, but the civil war that followed meant that little progress was achieved. The organization of mapping was overhauled following the withdrawal of the Nationalist government from the mainland to the island of Taiwan in 1949 and the establishment of the People's Republic of China. Rapid economic development after 1949 stimulated intensive technological development and large-scale projects for topographic mapping. Multiscale topographic maps were produced at national, provincial, and municipal levels using traditional and advanced technology. The Guojia cehui ju 国家测绘局 (State Bureau of Surveying and Mapping; SBSM) was established under the Guowu yuan 国务院 (State Council) in 1956. Its responsibilities included coordinating the plans for all mapping operations, developing unified instructions and standard symbols for use in topographic, geodetic, and cartographic work, carrying out surveys of importance to the state, collecting and archiving survey and cartographic data, publishing textbooks, training personnel, and organizing scientific research in geodesy and cartography (Li, Chen, and Baltsavias 2008; Williams 1974, 12–16).

China defined its basic topographic map series with map scales of 1:1,000,000, 1:250,000, 1:100,000, and 1:50,000 (for the whole country, produced by the central government); 1:10,000 (for individual provinces, produced by provincial authorities); and 1:5,000, 1:2,000, 1:1,000, and 1:500 (for cities, produced by municipalities). Photogrammetry has served as the mainstream technology for multiscale topographic mapping in China, and has evolved from analog through analytical to digital methods. Analog photogrammetry, repre-

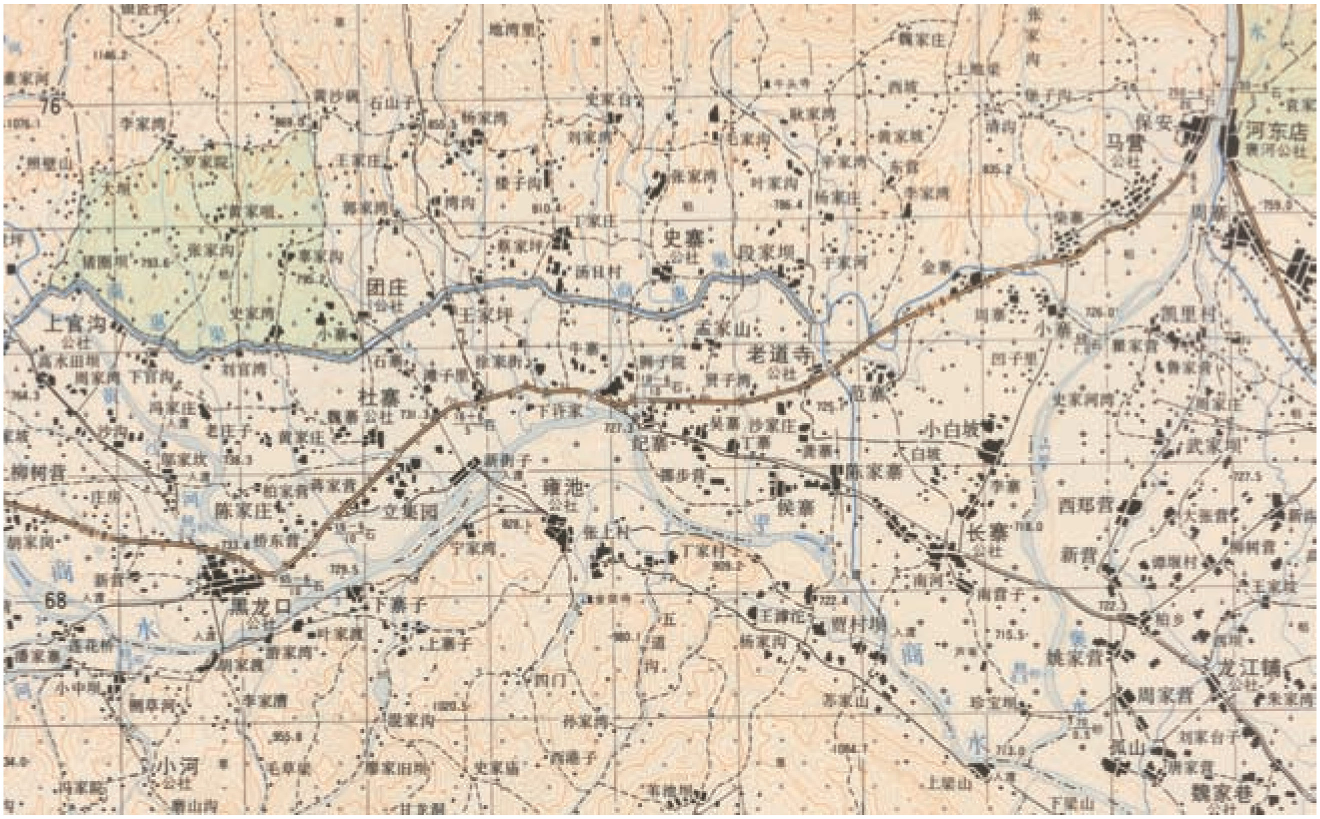


FIG. 1025. DETAIL FROM *SHANXI SHENG HEILONGKOU 1:100,000 DIXINGTU* 陕西省黑龙口 1:100,000 地形图 编号 I-49-64 (1:100,000 TOPOGRAPHIC MAP OF HEILONGKOU, SHAANXI PROVINCE, NO. I-49-64), 1979. About one hundred kilometers southeast of Xi'an in central China, this area in Shaanxi Province shows its rural nature and interconnected small communities through the many roads (solid lines) and paths (dashed lines) and one large road (solid brown line). Waterways are labeled using blue characters. Elevations are given in forty-meter contour intervals and indicate a flowing general terrain supportive of agriculture.

Size of the entire original: 44.4 × 52.2 cm; size of detail: 13 × 21.1 cm. Image courtesy of the Guojia jichu dilixinxi zhongxin 国家基础地理信息中心 (National Geomatics Center of China), Beijing.

sented by optical-mechanical analog plotters, was widely used for national topographic mapping from the 1950s. Large numbers of 1:100,000 and 1:50,000 topographic maps were produced between the 1950s and the 1970s (fig. 1025). Due to the very labor-intensive and time-consuming nature of manual processing of stereo aerial imagery with optical-mechanical plotters, the change from analog to analytical photogrammetry was studied with the advent of computers. In the early 1960s, Wang Zhizhuo 王之卓 developed a computer-based analytical control densification and strip adjustment. Programs for block adjustment were developed on the basis of the independent model method and became the main software system for photogrammetric control densification between the 1970s and the 1990s. All the imported analog plotters (such as the Wild B8S and the Zeiss Jena Topocart models) were converted into analytical plotters. Chinese analytical plotters, such as the JX3, were also developed and were installed in mapping agencies across the country.

In order to improve the efficiency and automation of topographic mapping, in 1978 Wang Zhizhuo proposed to develop the "theory and methods for fully digital and automatic photogrammetric mapping" (Wang 1998). This stimulated research and development into digital photogrammetry in China. After nearly twenty years of research and development, breakthroughs were made in digital image correlation leading in 1994 to the development of a fully digital photogrammetry workstation called VirtuoZo. Another microcomputer-based digital photogrammetry workstation, the JX4, was subsequently developed. These digital photogrammetric workstations provided a complete set of functions for photogrammetric data collection and processing and were widely used in topographic mapping projects at national, provincial, and municipal levels.

Table 53. Completed topographic maps at small and medium scale in China as of 2000.

| Map scale | Whole map sheets | Completed map sheets | Mapping technology |
|---|---|---|---|
| 1:1,000,000 | 77 | 77 | compilation |
| 1:250,000 | 819 | 819 | compilation |
| 1:100,000 | 7,176 | 7,176 | aerial photogrammetry |
| 1:50,000 | 24,218 | 19,186 | aerial photogrammetry |
| 1:10,000 | | 179,454 | aerial photogrammetry |

Table 53 lists the smaller- and medium-scale topographic maps produced in China. The 1:1,000,000, 1:250,000, and 1:100,000 topographic maps were completed for the whole country in the 1970s. By the year 2000 about 19,000 map sheets at 1:50,000 scale were produced covering about 80 percent of the country. There were about 5,000 map sheets of 1:50,000 scale remaining to be completed (covering about two million square kilometers in western China), due to difficult natural environments and technological constraints, such as inaccessible desert and high mountainous areas.

From the early 1970s, topographic mapping at 1:10,000 was done by provincial surveying and mapping authorities. About 180,000 such maps were produced, covering about 43.2 percent of the country (fig. 1026). Because 1:50,000-scale mapping is considered sufficient for areas such as deserts and high mountains, full coverage of topographic maps at 1:10,000 scale was not planned.

Municipalities were responsible for producing topographic maps at larger scales. For instance, Shanghai municipality produced 7,511 map sheets at 1:2,000 to cover its administrative territory. There were 5,060 map sheets at 1:1,000 for its urban fringe area and 7,758 sheets at 1:500 for the downtown area.

From the late of 1980s, resources and efforts were devoted to the development of digital geospatial databases at national, provincial, and city levels. National geospatial databases at scales of 1:1,000,000 and 1:250,000 were established in 1994 and 1998, respectively, and the completion at 1:50,000 was expected early in the new century.

Some technical specifications of these three national geospatial data sets are given in table 54. The 1:250,000 database was composed of 816 map sheets with fourteen theme layers such as drainage, transportation network, administrative boundaries, residential areas, topography, and vegetation. The digital elevation model (DEM) database was composed of two grids at 100 × 100 meters and 3 × 3 seconds. The geographical name database included over 807,000 entries. The 1:50,000 database consisted of digital line graphs (DLG), DEM, digital orthophoto model (DOM), geographical names (GN), as well as digital raster graph (DRG), land cover (LC), control points (CP) and metadata (MD). The resolution of the DEM was 25 × 25 meters. The geographical name database contained 5.2 million entries.

In order to support the geospatial database development, a digital surveying and mapping system was developed by integrating a variety of data processing and information management packages, such as raster-to-vector conversion, laser scanners, digital photogrammetric workstations, geographic information systems (GISs), and other digital surveying and mapping systems.

Several techniques and tools were also developed for the continuous updating of these national geospatial databases. One method was to update the existing topographic data using new orthophotos. Another approach was to update small-scale data sets by generalizing newly produced large-scale data. These methods were used to update the 1:1,000,000, 1:250,000, and 1:50,000 databases.

Since 1990 several individual provinces started to develop their own geospatial databases at 1:10,000. By the end of 2000 about twenty large- and medium-sized cities had completed their 1:500- to 1:2,000-scale databases.

Used in China since 1950, two geodetic coordinate systems have served as the horizontal datum for topographic mapping. The first is the 1954 Beijing zuobiaoxi (1954 年北京坐标系; Beijing geodetic coordinate system 1954). A nongeocentric and local coordinate system that used the Krasovskiy ellipsoid as its reference, the Beijing geodetic coordinate system 1954 was established after the adjustment of the first-order triangulation chains in northeast China. The second-order triangulation networks were then adjusted under the control of the first-order chains. The cluster adjustment was completed in the late 1960s. Established in 1982 after the adjustment of first-order and second-order astro-geodetic networks, the 1980 Xi'an zuobiaoxi (1980 年西安坐标系; Xi'an geodetic coordinate system 1980) was the second used in China since 1950. It was still a nongeocentric local coordinate system, and IUGG 1975 ellipsoid parameters were used instead of the old ones. The semiminor axis

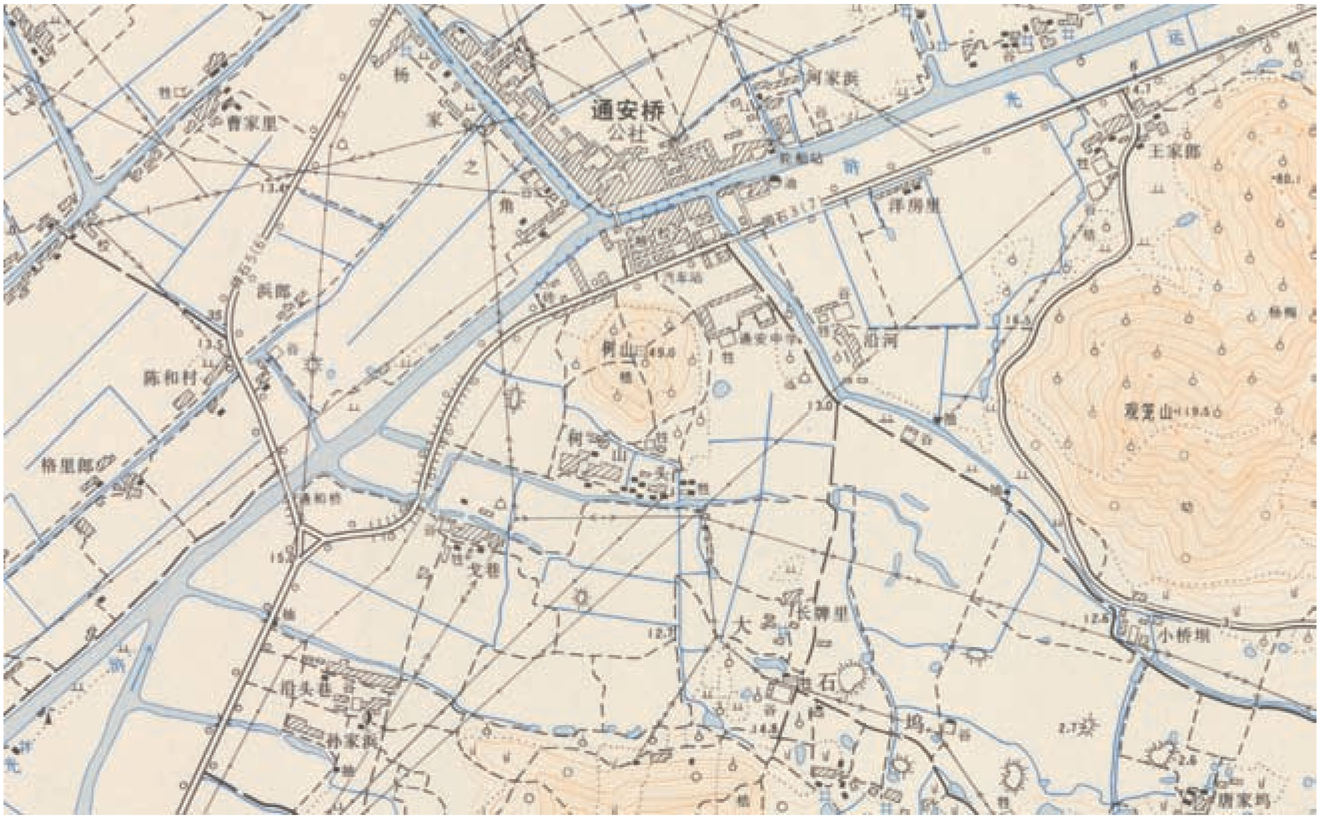


FIG. 1026. *JIANGSU SHENG SUZHOU DIQU WUXIAN TONGANQIAO 1:10,000 DIXINGTU* 江苏省苏州地区吴县通安桥 1:10,000 地形图 编号 H-51-13-(63) (1:10,000 TOPOGRAPHIC MAP OF TONGANQIAO, WUXIAN, SUZHOU, JIANGSU PROVINCE, NO. H-51-13-[63]), 1974. Situated on a branch off the old Chinese Grand Canal near Suzhou, this map conveys the essential features about a community in Jiangsu Province—its schools, bus station, hills planted with trees (especially on the right) and fields further south (not shown) assumed to be planted in rice.
Size of the entire original: 51.8 × 62.2 cm; size of detail: 13 × 21.1 cm. Image courtesy of the Guojia jichu dilixinxi zhongxin 国家基础地理信息中心 (National Geomatics Center of China), Beijing.

TABLE 54. Specifications for national geospatial databases

| Scale | Digital line graphs | Digital elevation model (meters/seconds) | Digital orthophoto model (resolution in meters) | Geographical names (number) |
|---|---|---|---|---|
| 1:1,000,000 | 16 data layers | About 800 × 600/28.125 × 18.75 | no | 80,000 |
| 1:250,000 | 14 data layers | 100 × 100/3 × 3 | no | 807,000 |
| 1:50,000 | 23 data layers | 25 × 25 | 1 meter air photo digital orthophoto model or 10 meter satellite digital orthophoto model | 5,285,000 |

was defined parallel to the direction from the center of the earth to the pole JYD1968.0. The reference ellipsoid was oriented to minimize the sum of the squares of the height anomalies of astro-geodetic points. Its origin is located at Yongle, a small town sixty kilometers north of Xi'an. There were about 50,000 first- and second-order triangulation points with a mean baseline length of twenty-two kilometers. Different kinds of observations were used to establish the network, such as triangulation, electromagnetic distance measurements (EDM), and astronomical observations. The accuracy of the side is 1 part in 260,000, and that of direction being ±0.9″ (Cheng et al. 2009).

The National Height Datum was established to provide height control for topographic mapping and engineering applications. Several different regional height datums were in use before 1950. The 1956 Huanghai gaochengxi (1956 年黄海高程系; Yellow Sea height system 1956), based on tide gauge data, was established with its origin in Qingdao. The Guojia gaocheng xi (国家高程系; National Height System) was constructed by setting up a first-class leveling network consisting of 100 leveling traverses and circles, with a combined length of 93,000 kilometers, between 1951 and 1981. The national second-class leveling network, which consists of 793 second-class traverses and circles with a combined length of 137,000 kilometers, was established between 1982 and 1998. The 1985 National Height System was established after readjusting the first- and second-class leveling networks with a total length of 220,000 kilometers. Third- and fourth-order leveling networks were established and surveyed by the provinces with a combined length of more than 1 million kilometers using the 1985 datum control. The first-class leveling was remeasured to update the height system and deduced a vertical deformation map.

The development of a new national geodetic reference system was started in 1997 and was called the 2000 Zhongguo dadi zuobiaoxi (2000 年中国大地坐标系; China Geodetic Coordinate System 2000; CGCS2000). It is a geocentric coordinate system associated with an earth ellipsoid defined slightly different from the Geodetic Reference System 1980 (GRS80) and the World Geodetic System 1984 (WGS84). CGCS2000 is referred to the International Terrestrial Reference Frame 1997 (ITRF97) at the epoch of 2000.0. As of the end of the twentieth century, the reference frame of CGCS2000 consisted of the national Global Positioning System (GPS) control network 2000 and the national astro-geodetic network after combined adjustment with the GPS network.

Multiscale topographic maps and geospatial databases have played a significant role in China's national economic and social development by providing governments at all levels and professional institutions with unified geospatial information platforms for their spatially referenced systems used for planning and administration or systems in support of decision making.

JUN CHEN

SEE ALSO: Military Mapping by Major Powers: China

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*Topographic Mapping in Japan.* The Japanese Imperial Land Survey (JILS; Dai Nippon teikoku rikuchi sokuryōbu 大日本帝国陸地測量部) was established in 1888, during the Meiji period, as part of the effort to modernize the country using Western technologies. Like most of the European survey departments of the time, it was a military organization under the General Staff, and remained so until the demilitarization of Japan in 1945. In addition to mapping, the JILS was responsible for all fundamental survey work, including the establishment of datums. The Tokyo Datum was first established in 1892 and referenced to the Bessel 1841 ellipsoid, using the Azabu observatory as its origin (Mugnier 2002). A refined determination of the longitude of Azabu resulted in the introduction of the Tokyo Datum of 1918. Between 1892 and 1921 the JILS used the Gauss-Schreiber Transverse Mercator Projection, with the country divided into four zones—the East, West, North, and Formosa Belts (Formosa, now known as Taiwan, was then under Japanese control; the Formosa Belt covered southern Japan as well as Formosa) (Mugnier 2002).

First-order triangulation had started in 1875, and a scheme to cover the whole empire was initiated in 1877 (Wheeler 1885, 453) and completed in 1909 (Mizuno 2010). Production of the 1:50,000 topographic series was started in 1888 and completed for the Japanese home islands by 1925 (fig. 1027). The first sheets were based on the monochrome General Staff maps being produced in Europe, but their basic scale was larger than 1:100,000, the scale used for most European maps at the time. In addition, the maps showed relief using contours and spot heights in meters, not hachures, which were still in use on much European mapping (fig. 1028). In common with other contemporary topographic maps, the Japanese sheets lacked grid lines, which were not introduced on civilian mapping until after World War II.

In 1915 the JILS began work on a series of 1:25,000 topographic maps, designed to cover only those areas

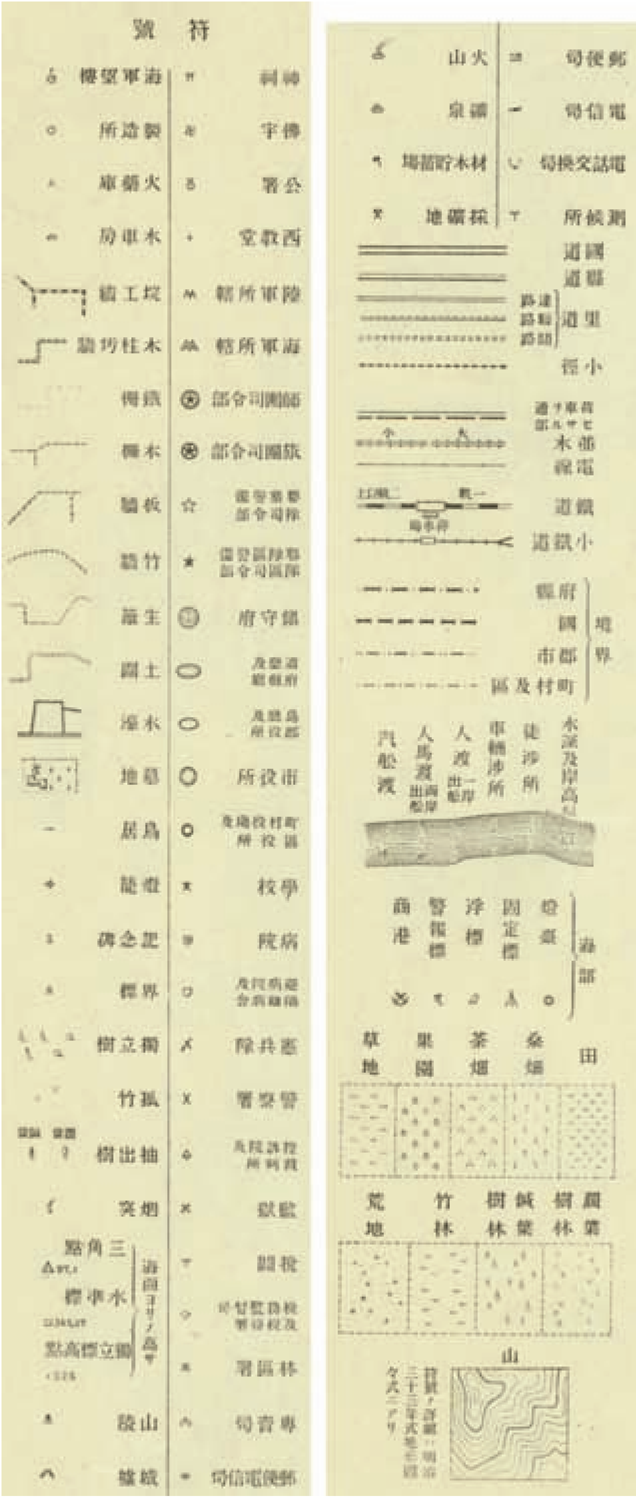

FIG. 1027. KEY TO JAPANESE 1:50,000 TOPOGRAPHIC MAP, SENDAI 川内 SHEET, 1921. The Japanese maps used more symbols than any monochrome map of the same scale. A large and comprehensive key was needed to enable users to interpret the map.
Size of the entire original: 43.3 × 54.6 cm; size of the detail: 42.2 × 4.5 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

FIG. 1028. DETAIL OF A MONOCHROME 1:50,000 MAP, FUKUOKA 福岡 SHEET, 1940. This demonstrates the nature of the map and the difficulty of map reading.
Size of the entire original: 42.6 × 53.9 cm; size of the detail: 12.6 × 8.4 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

considered strategically important. When completed in 1942, the series encompassed only about 25 percent of the home islands (United States, Department of the Army 1963, 120). As with the 1:50,000 series, this was a monochrome map with contours and spot heights in meters. The JILS also mapped major metropolitan areas at 1:10,000.

The JILS was also heavily involved in mapping both Formosa (Taiwan) and Korea. Mapping started in Taiwan in 1895, and in Korea in 1910, with both endeavors continuing until the end of World War II (United States, Department of the Army 1963, 122, 131). In both cases the mapping was virtually identical in appearance to that of the home islands and at the same scales. Some use was made of aerial photography for map revision in Taiwan toward the end of World War II (United States, Department of the Army 1963, 131), but photogrammetry played no significant role in Japanese topographic mapping until after the war.

Following the end of World War II all mapping outside of the home islands ceased and the JILS was reorganized more than once until it became the Kokudo chiriin 国土地理院 (Geographical Survey Institute [GSI]), a civilian mapping agency under the Kensetsushō 建設省 (Ministry of Construction) in a demilitarized Japan. Destruction of all major Japanese cities by aerial bombing in the last year of the war created an urgent need to revise existing mapping. In 1946 the Sensai Fukkōin 戦災復興院 (War Rehabilitation Commission) initiated an extensive program of city mapping, which was subsequently decentralized to city or prefecture offices.

Despite these changes in the agencies responsible for topographic mapping in Japan, there were no immediate changes in the maps themselves. The 1:50,000 series remained a monochrome map until the late 1950s, when the first two- and three-color sheets were issued. A large-scale topographic program started by the GSI in 1960 was regulated by the National Base Map Program, established in 1964 to provide systematic updating of aerial photography (Parry and Perkins 2000, 483). Photography acquired every three years for urban areas and every five years for other lowland areas was used to produce or revise mapping at 1:2,500 for urban and 1:5,000 for rural areas. The urban mapping was compiled by local authorities in cooperation with the GSI, which provided aerial triangulation data and map specifications. By the end of the century most of the 1:5,000 mapping was being published as photomaps. From 1988 most large-scale maps were produced to GSI's digital standard.

A program to provide 1:25,000 mapping for the whole country was started in 1964 and completed in 1983. Over 90 percent of these maps were produced by private companies. The series was maintained using a continuous revision process, whereby a revision was triggered when the number of units of change reached a set threshold. In practice, this meant that mountainous areas were revised at a ten-year interval, while urban areas were revised every three years and intermediate areas every five years (Parry and Perkins 2000, 483). Complete recompilation would take place after three or four revisions. In 1993 the GSI adopted raster-based revision methods for this series, and by 1997 all new editions were produced entirely by digital methods.

The last new series initiated by the GSI was 1:10,000 mapping of all urban areas. The first sheets were published in 1984. Designed to provide a basic topographic framework for all major urban areas, this series was unusual in that it showed building heights in addition to normal topographic information. Available in digital form, this map series was described as the "most frequently used Japanese digital map data" (Parry and Perkins 2000, 483).

At the beginning of the century Japan was already the best-mapped country in East Asia, but it still lagged behind India and much of Western Europe. By the end of the century the range, currency, and quality of topographic mapping available in Japan compared favorably with that available for any country in the world.

PETER COLLIER

SEE ALSO: Military Mapping by Major Powers: Japan; World War II

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*Topographic Mapping in Indonesia.* By 1900 the Netherlands East Indies—the territory of present-day Indonesia—was mapped in a detail matched by few tropical countries. The central mapping agency, Topografische Dienst van Nederlands Indië, located in Batavia (present-day Jakarta) became operational in 1864 as a part of the Koninklijk Nederlandsch Indisch Leger (KNIL) directly under the Dutch General Staff. The Topografische Dienst was responsible for topographical mapping and beginning in 1906 also for coordinating all sizeable government mapping activities, which in addition to topographic mapping consisted of cadastral mapping (department of finance), geological and vulcanological mapping (department of mining), and soil, forestry and irrigation mapping (department of agriculture). The Topografische Dienst was also charged with the reproduction of all maps produced by other government departments, so that its reproduction facilities became the largest in Southeast Asia. In 1938 over 17.5 million maps were printed. To better account for its civil functions, the Topografische Dienst, as an independent army unit, was moved in 1907 from the General Staff to the war ministry, Departement van Oorlog, as section IX.

At its peak in the 1920s the Topografische Dienst employed about 600 persons, divided among its central office in Batavia, six topographic brigades employed in outer parts of the archipelago (one was a triangulation brigade), and three revision brigades based on Java. One of the topographic brigades became a training brigade, and after an initial itinerant existence established itself in Malang in eastern Java in 1924. The schooling for an officer of the topographic survey took 3½ years, including one year in the triangulation brigade. Indigenous staff were also recruited for the three-year training program for topographers and the two-year training program for cartographers. In 1920 more than half the topographers were indigenous; in 1935 their share had risen to 75 percent. At that time it was unusual for an army establishment like a topographical survey to employ scientists other than geodesists. However, in 1921 geographer Samuel van Valkenburg became chief of the cartographic section (Kartografische Afdeling) of the survey in Batavia, which was responsible for derived mapping at smaller scales (fig. 1029). In 1926 Van Valkenburg left for the Unites States, where he assumed a professorship at Princeton University. In 1935 A. J. Pannekoek was appointed chief of the cartographic section. His cartographic research in Batavia provided some important new insights into cartographic generalization, and his publications were widely cited.

The Kartografische Afdeling was established for the standardized production of small-scale topographic overview maps like the sheets of the 1:250,000 and 1:750,000 series. It started with the *Overzichtskaart van Java en Madoera* at the scale 1:250,000 in 10 sheets (1924–29), after which an *Overzichtskaart van Sumatra* at the same scale in 28 sheets was begun. These overview sheets were derived in a consistent way by the Kartografische Afdeling from large-scale topographic


FIG. 1029. DETAIL OF OVERVIEW MAP OF *BALI* 1:200,000 (1935). Map has a combination of layer tints, hill shading, and land use representation. Batavia: Reproductiebedrijf Topografische Dienst.

Size of the entire original: 61 × 83 cm; size of the detail: 14.6 × 18.3 cm. Image courtesy of Ferjan Ormeling.

maps. Their contents consisted of hypsometric tints, settlements, administrative boundaries, hydrography, roads, railways, and toponymy. Between 1927 and 1939 an *Overzichtskaart van Sumatra* at the scale 1:750,000 in 10 sheets was produced. The Kartografische Afdeling became an independent unit of the Topografische Dienst in 1936 and was transformed after 1945 into the Geografisch Instituut.

Java was first mapped systematically based on triangulation between 1853 and 1886 at the scale 1:100,000. This led to the *residentiekaart*, a map series of Java based on its subdivision into twenty-three administrative areas. The series included extensive land use detail. The first revision of the topographic map series of Java started in 1886 and was completed in 1924 at the scale 1:50,000. The next revision cycle, started in 1924, profited from the uniform neatline and numbering system introduced for the entire country in 1922 on the basis of the meridian of Batavia. A 1:25,000 map series of Java was started in 1899 but only completed for central Java.

The Netherlands East Indies also participated independently in international mapping projects such as the International Map of the World (IMW) at 1:1,000,000 and its derived aeronautical edition. In view of the war threat, work on the latter aeronautical series was pushed forward, so that by 1939 all sheets of this series were available, in a provisional version. Most sheets of the IMW were well under way by that time as well. It was a special year as the Topografische Dienst had its seventy-fifth anniversary, and in its jubilee publication the expectation was voiced that the detailed mapping of the sparsely populated outer islands could be accomplished within thirty years with the use of aerial photogrammetry (*75 jaren* 1939, 79).

By 1936 no regular topographic maps existed for one-third of Borneo and large parts of central Celebes and New Guinea. For those areas a systematic sketch map concept was developed that entailed the compilation according to uniform rules of all available information on a base map derived from hydrographic charts with their reliable coastlines. The data could be derived from scientific expeditions, military patrols, and sketch maps by missionaries using observations with minor instruments like compasses. In the broad alluvial plains of Sumatra and Borneo triangulation was based on astronomical observations.

After photogrammetric surveys of the islands of Bangka and Tarakan in the 1930s, a photogrammetric brigade was established in 1937. In 1939 the personnel of this brigade were trained to process aerial photographs, flown by the Koninklijke Nederlandsch-Indische Luchtvaart Maatschappij (KNILM; the Netherlands East Indies branch of KLM) and the Nederlandsche Nieuw-Guinee Petroleum Maatschappij in the years 1935–37, into topographic maps of New Guinea at the scale 1:100,000 (fig. 1030). World War II intervened, and dur-

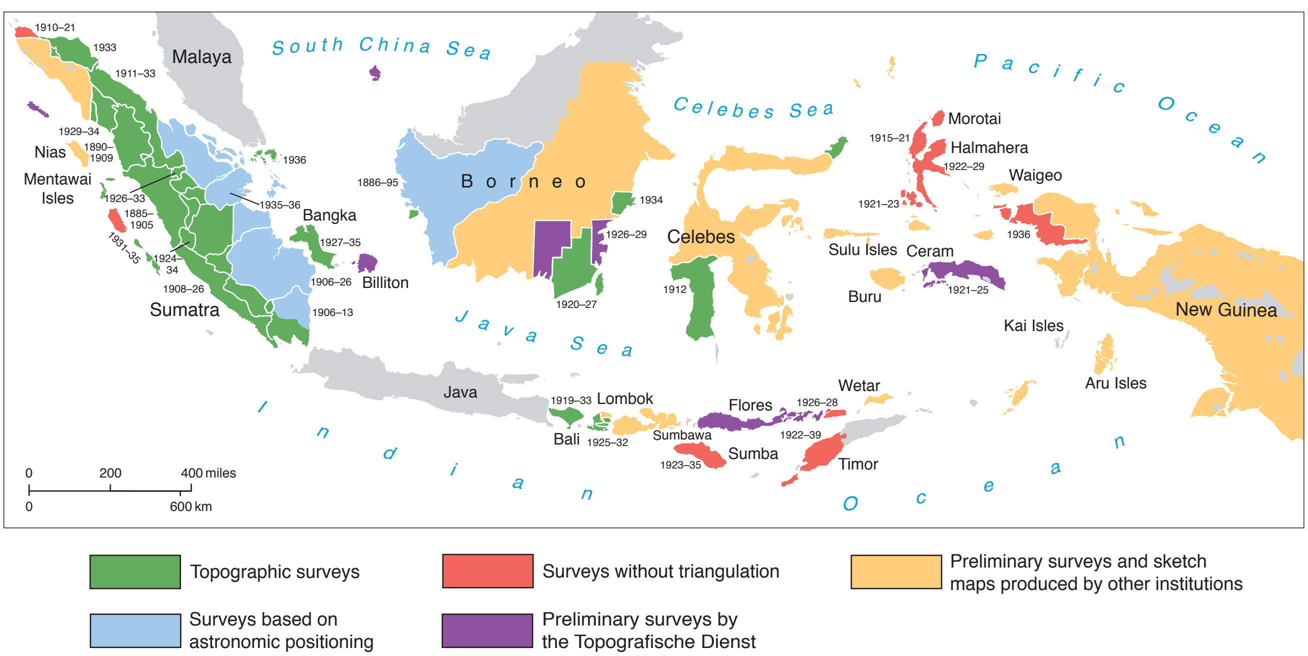


FIG. 1030. STATUS OF TOPOGRAPHIC MAPPING OF THE NETHERLANDS EAST INDIES OUTSIDE JAVA IN 1939. Based on the *Jaarverslag van den Topografischen Dienst in Nederlandisch-Indië*, 1939. The island of Java had first been mapped at 1:100,000 between 1853 and 1886, at 1:50,000 from 1886 to 1924, and mapping at 1:25,000 started in 1899.

ing the war, both the United States and Britain produced army maps of the area at different scales based upon map materials produced by the Topografische Dienst.

The national atlas of the country, *Atlas van Tropisch Nederland*, an initiative of the Koninklijk Nederlands Aardrijkskundig Genootschap, was realized by the sponsorship of the Topografische Dienst in Batavia, and most of its maps were drawn there. The entire atlas was printed there just in time for it to be presented at the International Geographical Congress held in Amsterdam in July 1938.

After the Japanese occupation (1942–45), Dutch authority over Batavia and Bandoeng was restored in 1946, and the Topografische Dienst resumed its activities. The indigenous personnel were supplemented by Dutch officers. Its Kartografische Afdeling was renamed Geografisch Instituut and headed by Pannekoek's successor Ferdinand J. Ormeling in 1947. A new simplified legend for the existing mapping series was designed and a training program established. The ideas developed in this Geografisch Instituut for a training program in the mapping sciences were first presented to former Dutch prime minister Willem Schermerhorn when he visited in 1949. In 1950 such a training institute, ITC (International Training Centre for Aerial Survey), was established in Delft, with Schermerhorn as its first director.

Until late 1949 there remained a war situation in most parts of Java and Sumatra. Therefore surveying activities were planned for Borneo first, and the American wish to extend the World Aeronautical Chart over unmapped parts of Asia led to cooperation with the U.S. Army Map Service. The result was the TOPAM project for mapping the Netherlands East Indies (Ormeling 2007). Starting in 1948, American planes from Clark Air Base in the Philippines took aerial photographs of Borneo that were processed at the Geodetisch Instituut of the Topografische Dienst in Bandoeng. This project halted in 1949 when the Dutch government transferred its sovereignty over the Netherlands East Indies to the Republic of Indonesia. The transfer happened on 27 December 1949 but did not include Netherlands New Guinea. Sovereignty over that territory was transferred to the United Nations (UN) in 1961 and by the UN to Indonesia in 1963. Between 1948 and 1961 the Dutch took responsibility for mapping the western half of this island and continued to chart its waters to produce sheets of the General Bathymetric Chart of the Oceans (GEBCO) for this area. The topographic mapping operations consisted of the production of a map at a scale of 1:100,000, which was half finished by the Topografische Dienst in Delft in 1961; the other half remained in manuscript.

The Republic of Indonesia was proclaimed 17 August 1945, but it was 1950 before the topographic survey was transferred to the Indonesian army, as Djawatan Topografi (JATOP) under its first director, Colonel Soerjo Soemarno, a graduate of Delft University. The topographers and cartographers employed by the Topografische Dienst were indigenous personnel, but staff positions were held by Dutch officers. Upon the departure of those officers few qualified Indonesian geodesists were available to take their place, and it took time before the mapping operations were resumed. D. H. G. van Bergen van der Grijp, the last director of the Topografische Dienst, left for the Army Map Service in Washington in 1949. Ormeling and Herman Th. Verstappen of the Geografisch Instituut remained until 1957, when all Dutch persons were declared persona non grata under Sukarno's policy of confrontation and left for Europe, where they continued to have an important influence on the development of cartography and geomorphology.

In Jakarta, due to political and economic problems, mapping activities were at first restricted. In 1958 some map sheets of the 1:25,000, 1:50,000, and 1:100,000 series were published. In the early 1960s, a ten-year plan was approved that called for basic topographic maps at scales 1:50,000 and 100,000 (*peta topografi dasar*), a general map at the scale 1:250,000 (*peta topografi ichtisar*), and the Indonesian sheets for the IMW to be produced for the whole country. In 1963 the western part of New Guinea, called Irian Jaya, which had remained under Dutch sovereignty, was incorporated into Indonesia. The political unrest that followed the failed coup d'état in 1965 as well as the economic situation prevented JATOP from realizing the ten-year plan.

In 1969 the Indonesian government launched its first five-year development plan (*pelita*), and under this plan a new mapping organization was established by presidential decree (17 September 1969). It was responsible for geodetic work and for the production of topographic map series. Badan Koordinasi Survei dan Pemetaan Nasional (BAKOSURTANAL), the national coordination agency for surveys and mapping, replaced the Komando Survei dan Pemetaan Nasional established in 1965, an earlier (military) organization for mapping coordination. BAKOSURTANAL was initially located in Jakarta, but in 1978 under director Major General Ir. Pranoto Asmoro, it moved its headquarters to Cibinong, between Jakarta and Bogor. The military topographical survey, JATOP, remained in Jakarta.

BAKOSURTANAL initiated a national base mapping program in 1969 consisting of a map series at 1:25,000 of Java and the Lesser Sunda Isles; a series 1:50,000 of Sumatra, Borneo, Sulawesi, and Maluku; and a series 1:100,000 of western New Guinea but destined to cover the whole country (in 380 sheets). The last started in 1976 and was expected to be completed by 1993. New specifications were elaborated for these series. Australia and the United Kingdom assisted BAKOSURTANAL during the first *pelita* and second *pelita* (1969–79) in the production of the maps for Sumatra and parts of Borneo at 1:50,000, and also with mapping parts of New Guinea and the Moluccas at 1:100,000. In 1976 East Timor, a former Portuguese territory, was incorporated into Indonesia and quickly mapped at 1:50,000. During the third *pelita* (1979–84), with assistance from Canada and the World Bank, aerial photographs of Sumatra, Java, and the Lesser Sunda Islands were produced. In the national base map program, Indonesia was assisted by Canada in the aerotriangulation of Sumatra and western Borneo.

To accelerate mapping activities and to help Indonesia's *transmigrasi* (transmigration) project (resettlement of farmers from overpopulated Java to the outer islands), the TRANS-V mapping project was started in 1986 with a loan from the World Bank. Foreign contractors and a technical advisory team (from the Netherlands, Germany, and Indonesia) assisted Indonesian private mapping companies (Rais and Polderman 1993).

BAKOSURTANAL produced map series on the scales 1:250,000 (140 sheets), 1:500,000 (85 sheets), and 1:1,000,000 (30 sheets, revised in 1983). All of the maps were available in digital form, and by 1986, with an enormous effort, all the production goals had been reached (table 55). BAKOSURTANAL was active in the 1990s in resource mapping, the production of digital files, atlas production, and in the promotion of geographic education and tourism.

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SEE ALSO: Military Mapping of Geographic Areas: Southeast Asia; Topografische Dienst (Netherlands)

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TABLE 55: Status of topographic mapping in Indonesia in 2003 (from Matindas et al. 2003, 2)

| Scale | Area covered | Paper map | Digital |
|---|---|---|---|
| 1:250,000 | whole of Indonesia | x | x |
| 1:100,000 | small part of Papua | x | — |
| 1:50,000* | Sumatra, Borneo, Celebes | x | x |
| 1:25,000 | Java, Bali, Lesser Sunda Islands | x | x |
| 1:10,000 | Surabaya, Yogyakarta, Bogor | x | x |

* not yet complete for the whole area.

*Topographic Mapping in Australia.* Australia's topographic mapping program did not effectively begin until after World War II. In 1901, when the former British colonies were federated into a single nation, less than 1 percent of the country had been mapped. Responsibility for land was not centralized, which hindered a national approach to topographic mapping. State cadastral surveys continued as a priority for land settlement throughout the first half of the twentieth century, but with no national geodetic framework, little overall mapping was possible. In 1912 the Department of Defence established a small mapping survey unit, but with a country of more than 7 million square kilometers—5 percent of the world's land area—little could be achieved using plane table surveys.

World War II brought a heightened appreciation of the value of mapping. To deal with the threat of military action on Australian soil, government mapmakers produced approximately 360 interim large-scale map sheets. Nonetheless, by 1945 less than 6 percent of the country had been mapped, even at marginal standards (fig. 1031).

Immediately after World War II a National Mapping Council created by state and federal bodies began the national coordination of mapping. Vertical aerial photography at a nominal scale of 1:50,000, deemed suitable for use as reconnaissance mapping, was commenced in 1946 using wartime Mosquito aircraft. With restricted funding, mapping proceeded slowly on a 1:253,440 (four-miles-to-the-inch) series until 1956, when the federal government established the Division of National Mapping. The immediate task was a preliminary R502 map series of 544 map sheets without contours covering the continent at 1:250,000. Each stan-


FIG. 1031. AUSTRALIA'S 1:100,000 AND LARGER-SCALE MAPPING AS OF 31 DECEMBER 1945.
Size of the original: ca. 7 × 8.7 cm. From Lines 1992, 162 (fig. 8.3).

dard sheet covered an area of 1.5 degrees of longitude by 1 degree of latitude, and compilation relied heavily on reconnaissance photography flown by the Royal Australian Air Force. Astrofixes (positioning based on astronomical observations) provided the ground control, and features were transferred to paper from air photos using slotted-template techniques rather than stereo photogrammetry. Publication of the R502 series was completed in 1968 (Hocking 1985, 1998). In 1965 the Australian government initiated the National Topographic Mapping Series (NTMS) program of 3,062 standard map sheets at 1:100,000, with a twenty-meter contour interval, to replace the preliminary map series. In 1988 the series was completed to standard specifications using advanced methods of geodetic survey, photogrammetry, and cartography. This was a cooperative program with the Australian Army Survey Corps and state authorities (Coulthard-Clark 2000). Ultimately, only half the map sheets were printed, with 1,460 inland sheets made available only as line compilations. In 1991 the companion full-cover series of 1:250,000 printed maps, with fifty-meter contours, was completed (Lines 1992, 296). Most of the maps were field-checked for detail before publication, and some were field-checked for positional accuracy (Manning 1983). Map historian Dorothy F. Prescott's 2003 *Bibliography of the History of Australia's National Topographic Mapping Agencies* is a key source of information on the mapping activities of this era.

After completion of the NTMS in the early 1990s, the Intergovernmental Committee for Surveying and Mapping, successor to National Mapping Council, provided national coordination. The federal government was generally responsibility for nationwide coverage at scales of 1:100,000 (fig. 1032) and 1:250,000 as well as for smaller scales, such as 1:1,000,000, whereas state authorities were responsible for mapping at larger scales, such as 1:25,000 and 1:50,000, and for mapping the western region of New South Wales at 1:100,000 (O'Donnell 2006). In addition, the Department of Defence produced maps and data sets at a range of scales, principally for homeland security. State governments retained responsibility for cadastral surveys, while local governments were responsible for mapping local infrastructure.

A growing need to coordinate not just topographic mapping but also the sharing of spatial data among organizations led to the creation in 1986 of the Australia Land Information Council (which became the Australia New Zealand Land Information Council [ANZLIC] in 1991) and the related concept of the Australian Spatial Data Infrastructure (ASDI). The ASDI fostered online access to cadastral land information for integration into the national topographic framework, with links to related land infrastructure databases (Williamson, Rajabifard, and Feeney 2003, 132–33). At the national level, the 1:250,000 national map series had been fully revised using space imagery and made available in digital form, with no map more than ten years old (fig. 1033).

Technology had a massive impact on topographic mapping in Australia in the second half of the twentieth century, when aerial photography provided an efficient means of mapping a vast area quickly and reliably. The first seven decades of the century saw only gradual advances in technology in nonautomated cartography, as film replaced linen, and scribing instruments replaced pen and pencil. With the introduction of digital technologies in the early 1980s, cartographic technology underwent a revolution. Although the digital transition initially focused on replacing scribing with digitizing and automated drafting, developments in geographic information systems (GIS) required more digital data. In response to this demand, the national 1:250,000 topographic data were digitized and released in 1994 as the topologically structured GEODATA TOPO 250K Series 1. An updated Series 2, with individual map sheets available online, followed in 1998. The availability of high-capacity computers heralded a significant change in map revision, a concept that took a major step forward in 2003 with GEODATA Series 3, which organized geographic information as themes within a seamless database, rather than as individual map sheets. Fuller use was encouraged by a significant shift in federal policy: instead of requiring users to pay for data, the government made the data available online free of charge.

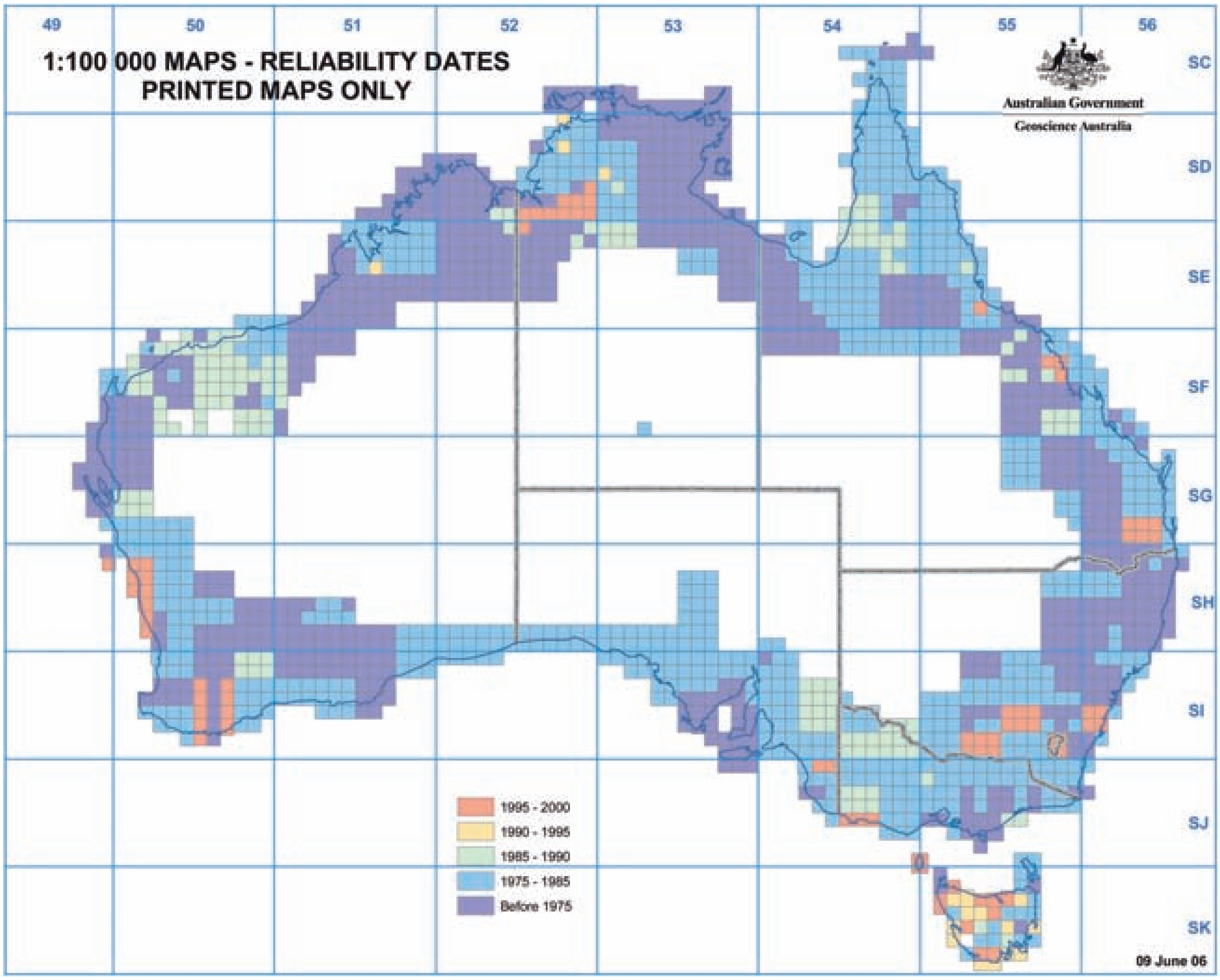


FIG. 1032. PUBLISHED COVERAGE OF AUSTRALIA'S 1:100,000 MAPS BY 2000.



In summary, the twentieth century witnessed a massive change in the topographic mapping of Australia. In 1900, provisional topographic paper maps covered less than 1 percent of the country. By contrast, in 2000 nationwide coverage was complete, and digital topographic data were easily superimposed on high-precision satellite imagery, conveniently integrated with a variety of spatial data sets, and readily available online from anywhere in the world.

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SEE ALSO: Indigenous Peoples and Western Cartography; Military Mapping of Geographic Areas: Australia

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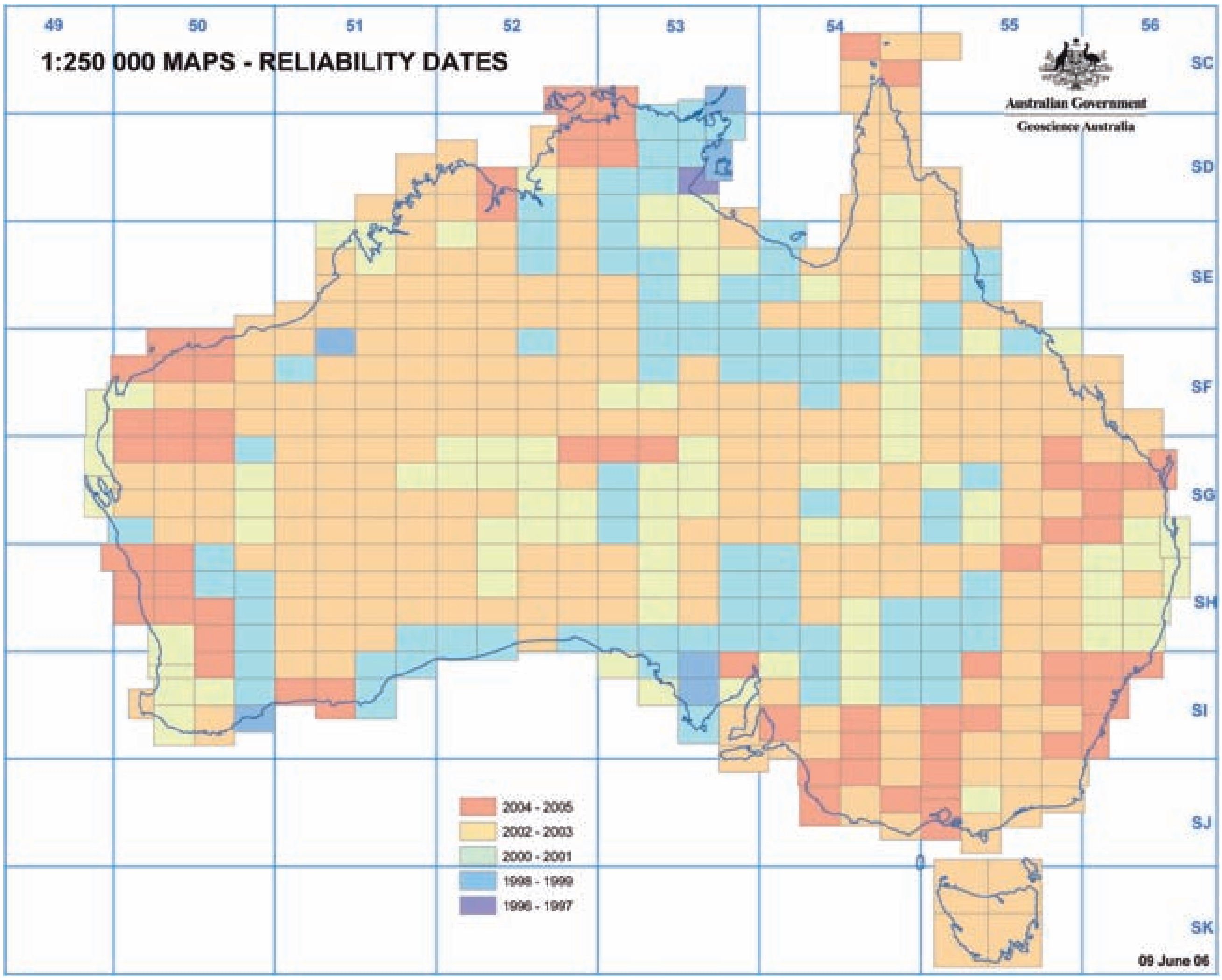



FIG. 1033. THE 250,000 NATIONAL MAP COVERAGE OF AUSTRALIA IN 2005.


Williamson, I. P., Abbas Rajabifard, and Mary-Ellen F. Feeney, eds. 2003. *Developing Spatial Data Infrastructures: From Concept to Reality*. London: Taylor & Francis.

***Touring Club Italiano*** ***(Italian Touring Club).*** As Italy's principal tourist organization throughout the twentieth century, the Touring Club Italiano (TCI) published numerous travel guides and maps, which are highly regarded for their accuracy and aesthetic quality. Founded in Milan as Touring Club Ciclistico Italiano on 8 November 1894, the organization changed its name to Touring Club Italiano in 1900. (For a short period between the two world wars, the organization was known as the Consociazione Turistica Italiana.) From an initial roster of fifty-seven cycling enthusiasts, membership increased to 784 by the end of 1895, passed 21,000 in 1900, and totaled about 400,000 in 1926. This substantial growth allowed numerous initiatives promoting tourism, geography, and travel.

These initiatives reflect the leadership of Luigi Vittorio Bertarelli, a founding member of the club and a key backer of its cartography division, established in 1914. Bertarelli succeeded Federico Johnson, the first director of the TCI, and played an important role in nurturing an informed exploitation of the country's historical, artistic, and natural resources. The TCI's cartographic endeavors brought together private and public institutions by involving not only local scholars and tourist offices but also the ministries of public works and agriculture as well as key national mapmaking organizations such as the Istituto Geografico Militare (IGM) and the Istituto Geografico De Agostini.

The first major product of this partnership was the *Carta d'Italia* at a scale of 1:250,000. The first edition was published between 1907 and 1914 in collaboration with the Istituto Geografico De Agostini, which was responsible for cartographic drafting as well as printing the map in seven colors (fig. 1034). The map consisted of fifty-nine individual sheets (each 44.3 × 33.2 cm) and could be assembled as a mosaic covering more than 16 square meters. Each sheet was compiled from six of the IGM's 1:100,000 maps and updated with thousands of pieces of new information provided by the members of the TCI. The short intervals between new editions and revisions of the map—on average, there was a new edition every seven years up to 1962—makes the TCI's *Carta d'Italia* a highly reliable source of information for historians: at a territorial level, it reflects significant changes in the country's transportation system and other public infrastructure, changes in the boundaries of administrative areas, the more obvious transformations of the landscape, and expansion of the built-up area around Italian cities (Marcarini 1982).

With the completion of the first edition in 1914, the TCI opened its own cartographic office, Ufficio cartografico. Initially headed by Pietro Corbellini, this division immediately provided support for the organization's most important project, the *Guida d'Italia* series, which Bertarelli had eagerly promoted. The first edition was issued between 1914 and 1928, and several additional books were published in 1929 to cover possessions and colonies (*Possedimenti e colonie*). The original project divided Italy into seven main geographical areas: (1) Piedmont, Lombardy, and the Canton Ticino; (2) Liguria, Tuscany (north of the Arno), and Emilia; (3) Sardinia; (4) Sicily; (5) Veneto, Friuli, and Venezia Giulia; (6) Central Italy; and (7) southern Italy. The guides contained three different types of maps: a section of the 1:250,000 *Carta d'Italia*; a general depiction of the territory at a scale of 1:65,000 (fig. 1035); and maps of the main urban centers, usually at a scale of 1:15,000 (or larger for specific sites; fig. 1036) (Bertarelli 1925). Many people informally referred to the books as the "red guides," after the color of their cover, which occasionally led to confusion with the better-known Michelin *Guide rouge*. Because of high-quality lithographic printing, accurate cartographic content, and typography and symbols that were visually attractive and easy to use, the series enjoyed phenomenal success: by 1929 more than four million copies had been distributed (Iuliano 2007, 101). The Centro di Documentazione, Milan, houses various rough drafts of maps. There are very often corrections upon existing maps for a new edition of the guide, on loose (nonfolded) sheets with the corrections in pen (Iuliano 2010, 94–97).

The logic guiding construction of the maps is illustrated by the reflections on the process by Bertarelli, who often used the club's official publications—initially the *Rivista Mensile del Touring Club Italiano*, later *Le Vie d'Italia*—to update members on the progress of the work. In 1913 he described the final choices of maps for the guides:

> Everyone acknowledges that maps are a factor of prime importance in a guide. . . . In a general, nondetailed guidebook—that is, one such as a Baedeker or a TCI guide—the maps are of great value, but as a synthesis of information; the guide is a synthesis of information, and the maps should be so too. . . . Summarizing, therefore, on the basis of the experience of the best writers in this field, the main requirements are: general maps to very small scale, and small maps and city plans. . . .
>
> Along with many other things, a good city map must meet two main requirements. One is well-chosen schematization. Certain alleyways and dead-ends, plus all courtyards, are details that are to be omitted because they clutter up the whole. The main roads and arteries should, on the other hand, be slightly enlarged in comparison to other streets, so that they stand out more. . . . The second stratagem is to engrave the names of the streets on a different plate from that which bears the planimetry of the buildings, printing the latter in a relatively light-color ink (perhaps a pale bistre or a reddish-brown), and the former in sharp, clear black. (Bertarelli 1913, 409–13)

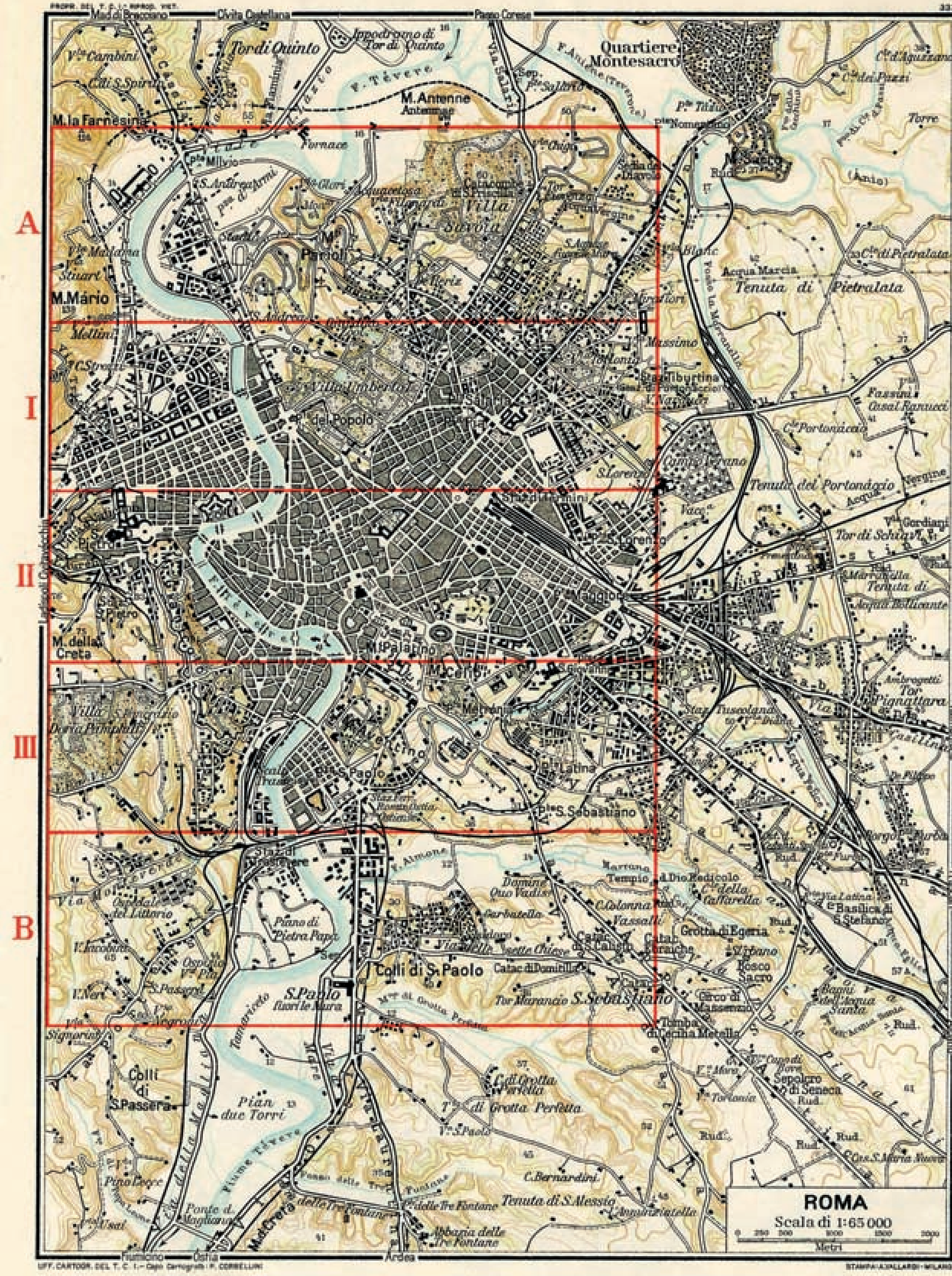
The extraordinary success of the guides led to translated editions, the first of which was the French version of the *Guida d'Italia per stranieri*, published in 1922. As exemplified by *Italy: A Complete Guide to 1,000 Towns and Cities and Their Landmarks, with 80 Regional Tours* (1999), versions available at the end of the twentieth century were carefully adapted for non-Italian readers.

Having opened an office in Tripoli in 1914, the club also produced important works in the realm of colonial

(*Facing page*)

FIG. 1034. *CARTA D'ITALIA*, SHEET 35, *NÁPOLI*, 1907. Scale, 1:250,000.
Size of the original: 58.1 × 39.1 cm. Image courtesy of the Labor Archives/Historical Collection and the Donald W. Hamer Maps Library, Pennsylvania State University, State College.


CARTA D'ITALIA DEL TOURING CLUB ITALIANO
Pubblicazione diretta da L.V. BERTARELLI
Foglio 35
Nàpoli
GOLFO DI GAETA
GAETA
I. d'Ischia
GOLFO DI NÀPOLI
NÀPOLI
I. di Capri
Scala di 1:250.000


PROPR. DEL T.C.I. - RIPROD. VIET.
ROMA
Scala di 1:65 000
Metri
A
I
II
III
B
Civita Castellana
Passo Corese
Quartiere Montesacro
Tor di Quinto
Ippodromo di Tor di Quinto
F. Tevere
M. Antenne
M. la Farnesina
Fornace
P.te Milvio
S. Andrea
Acquacetosa
Villa Savoia
Parioli
M. Mario
Tenuta di Pietralata
Acqua Marcia
Massimo
Staz. Tiburtina
C.le Portonaccio
Fassini
Casal Ranucci
Tenuta del Portonaccio
Campo Verano
S. Lorenzo
P.za del Popolo
S. Pietro
M. della Creta
M. Palatino
M. Celio
Tor di Schiavi
Tenuta di Acqua Bollicante
Tor Pignattara
Villa Doria Pamphili
Staz. Tuscolana
P.ta Latina
P.ta S. Sebastiano
P.ta S. Paolo
Staz. di Trastevere
Ospedale del Littorio
Piano di Pietra Papa
Garbatella
Colli di S. Paolo
S. Paolo fuori le Mura
Domine Quo Vadis
Vassalli
Grotta di Egeria
Catac. di Domitilla
Tor Marancio
S. Sebastiano
Circo di Massenzio
Tomba di Cecilia Metella
Sepolcro di Seneca
Colli di S. Passera
Pian due Torri
Fiume Tevere
C. Bernardini
Tenuta di S. Alessio
Ponte d. Magliana
Abbazia delle Tre Fontane
Fiumicino
Ostia
Ardea
UFF. CARTOGR. DEL T.C.I. - Capo Cartografo: P. CORBELLINI
STAMPA: A. VALLARDI - MILANO

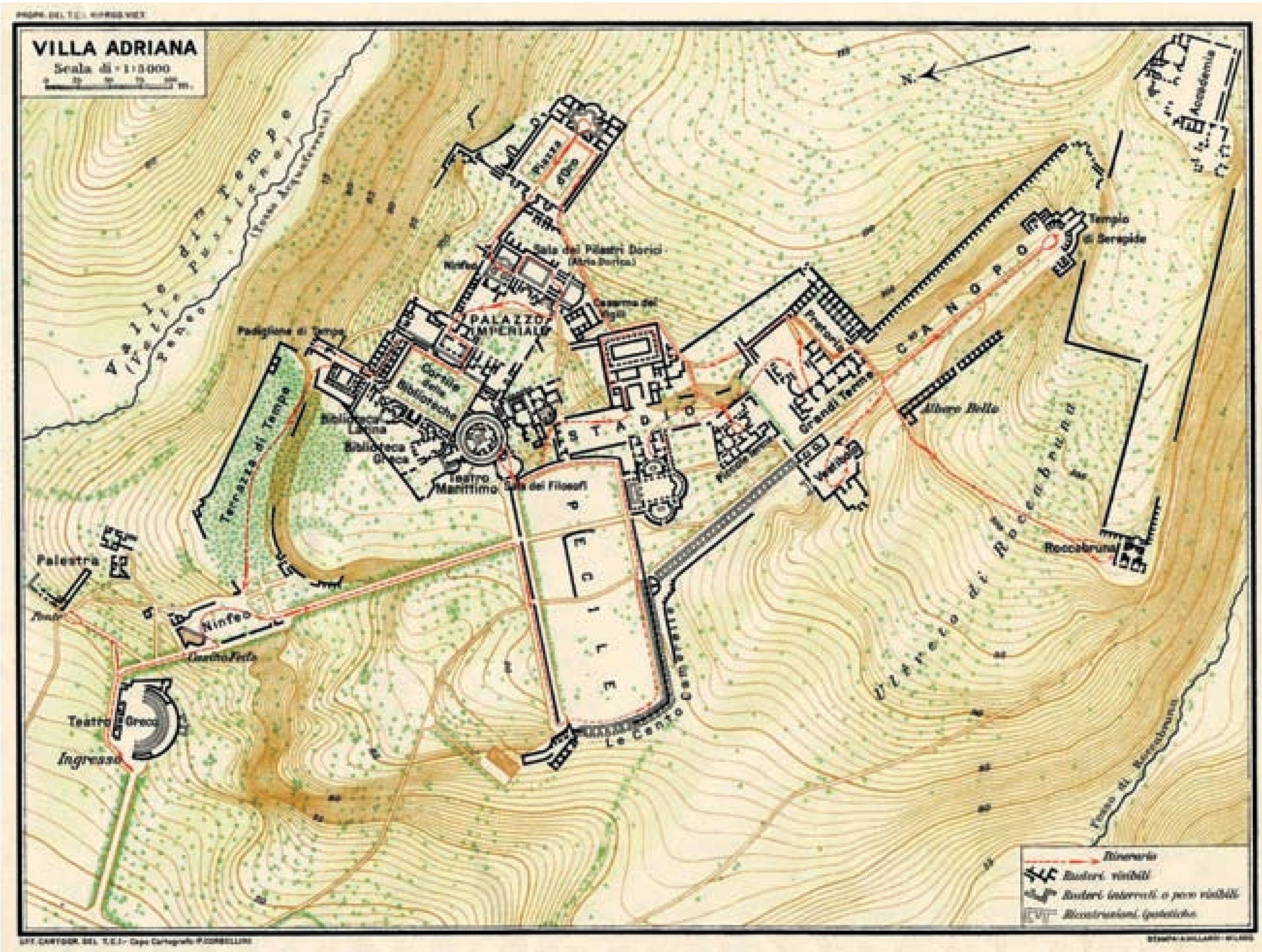



FIG. 1036. *VILLA ADRIANA*, 1925. Scale, 1:5,000; draft print from the archives.
Size of the original: ca. 14.9 × 19.8 cm. Image courtesy of Marco Iuliano. Cartography Touring Editore. Authorization February 2014. © 2014 Touring Editore Srl.

cartography, most notably the *Atlante internazionale del Touring Club Italiano*, which Bertarelli developed in collaboration with Corbellini and the well-known geographer Olinto Marinelli. The first edition of the atlas, consisting of 169 sheets at different scales, was published in 1927. Its 200,000 place and feature names were based on the official language of the country portrayed, and terrain was depicted using relief drawing without contour lines. The quality of the series was confirmed in 1928, when the second edition of the *Atlante internazionale* received the highest of awards at the twelfth International Geographical Congress, held at Cambridge, England (fig. 1037). The eighth (and last) updated edition was published in 1968.

The TCI's uniquely informative and accurate maps led other Italian organizations and publications to use its cartography. Between 1929 and 1937, for instance, the club created cartographic plates to supplement the *Enciclopedia Italiana*, which had been founded by Giovanni Treccani. The TCI also produced other high-quality customized cartography, including maps of tourist areas, alpine refuges, spa resorts, and various road maps. A complete catalog of works published through the early 1950s was issued to celebrate the sixtieth anni-

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FIG. 1035. *ROMA*, 1925. Scale, 1:65,000; draft print from the archives.
Size of the original: ca. 20 × 15 cm. Image courtesy of Marco Iuliano. Cartography Touring Editore. Authorization February 2014. © 2014 Touring Editore Srl.

FIG. 1037. DETAIL FROM *SPAGNA E PORTOGALLO (ESPAÑA Y PORTUGAL) FOGLIO OVEST*, 1:500,000, 1928. Size of the entire original: 55.2 × 43.3 cm; size of detail: 7.6 × 9.3 cm. From *Atlante internazionale del Touring Club Italiano*, 2d ed. (Milan: Touring Club Italiano, 1928), 39–40. Permission courtesy of Touring Club Italiano, Milan.

versary of the founding of the TCI (Vota 1954). Because of the TCI's efficient Ufficio cartografico, a large part of its publications were still in print at the end of the century in updated versions produced using the latest technology.

MARCO IULIANO

SEE ALSO: Marketing of Maps, Mass; Road Mapping: Europe

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***Travel, Tourism, and Place Marketing.*** The relationship between travel and mapping is an ancient one. Sea charts and road maps, of course, were already well-established genres by the nineteenth century, when a great variety of new mapping forms emerged to support travel via Industrial Age transportation technologies, such as railroads, steamships, and bicycles. That century also saw the emergence of modern tourism—that is, of leisure travel undertaken as a form of recreation. The origin of modern tourism is usually traced to the Grand Tour, an extended excursion through the European continent made as a rite of passage primarily by young Britons of wealth and privilege to familiarize themselves with the monuments of continental art and culture. The general social expansion of tourism from the later decades of the nineteenth century, embracing the middle and working classes in Europe and North America, established tourism as a major economic, commercial, and social force (Koshar 2002b; Baranowski and Furlough 2001). By the early decades of the twentieth century the tourism industry was a major producer and consumer of maps.

The range of maps published for the use of travelers during the twentieth century defies simple classification and summary. This brief survey considers some major genres and formats but makes no pretense of geographical exhaustiveness and offers no working typology or chronology. Statistically, guidebooks may account for the largest proportion of all maps published for travelers, particularly in the early decades of the century. Though an ancient textual form, guidebooks published before the nineteenth century were mostly individualistic ventures offered by single authors. During the mid-nineteenth century publishers such Karl Baedeker and John Murray III developed the modern guidebook, oriented to leisure travelers and issued in a series of volumes, uniform in design, and devoted to different geographic subjects. The cartographic component of these series varied from publisher to publisher but was often (as in the case of Baedeker) both extensive and fine. Regular series of reference and topographic maps designed for travelers and issued by commercial publishers and state agencies also appeared during this period, most of which, like John Bartholomew & Son and the Ordnance Survey in the United Kingdom, appealed to specific national markets.

By the early twentieth century myriad ephemeral publications, promotional brochures, pamphlets, and handbills incorporating maps were issued by or for businesses and other interests that stood to benefit from tourism. Initially these interests were mostly commercial, including railroads and steamship lines and companies devoted to the organization of tourism, most famously Thomas

Cook & Son, the archetype of the modern touring company (Brendon 1991). These were joined in the twentieth century by airlines, automobile and tire manufacturers, and petroleum companies (Akerman 2002; Harp 2001). Industrial and consumer associations, notably automobile clubs and hotel associations, were major publishers of maps and guidebooks for tourists during the twentieth century. Local authorities, mindful of the value of tourism to economic development, also became major publishers of mostly ephemeral materials, including maps, promoting cities, historic sites, and other attractions within their purview. And, as the twentieth century progressed, national states emerged as major sponsors of tourist publications and cartography, valued for their role in promoting economic development and national identity.

Twentieth-century travel maps addressed two fundamental and intertwined needs: wayfinding and promotion. While the relationship between maps and wayfinding might seem to need no explanation, most wayfinding tasks do not require a map because they involve navigation through familiar spaces along a pathway long since internalized. Maps are mostly required for movement through complex spaces or navigating an unfamiliar route to a new place. As long as the pace of travel was that of a human or a horse, local informants or verbal itineraries sufficed for most travelers before the eighteenth century. But as the pace, volume, and range of travelers increased, so did the need for maps (Delano-Smith 2006; Akerman 2006b). The increasing reliance of twentieth-century travelers on maps to reach and navigate unfamiliar places also made them susceptible to suggestion. A map useful to general navigation might also steer them to a specific destination or service (fig. 1038). More subtly, and perhaps more powerfully, twentieth-century tourism maps offered interpretations of the meaning of the journey and its component destinations. They achieved this through a variety of iconographic and textual devices, such as pictorial vignettes, cover art, and captions. But subtle uses of conventional map symbols also interpreted the landscape and its value as an object of the tourists' admiration. *Across Canada . . . West Bound*, published by the Canadian Pacific Railway in 1921, for example, includes a series of maps depicting sections of the route. Most of these make no reference to local topography, except for rivers and lakes. A single map covers the entire 832 miles of the journey across the Great Plains from Winnipeg to Calgary presented on the smallest scale of any map in the book, as if to say there is little of interest here. When the route reaches the Rocky Mountains and Pacific coastal region, the scale of the maps dramatically increases, and mountains are added to the representations, urging passengers to pay attention to what lies before them out the train's windows (fig. 1039).

These techniques were not new in the twentieth century. What sets travel and tourism mapping of the latter part of the nineteenth and the twentieth century apart is the extent to which wayfinding and the evocation of meaning to journeys and destinations are mutually invested. To a considerable extent this is because the manner in which travelers found their way was complicated by the unprecedented variety of conveyances at their disposal. But it also reflected the degree to which private and state institutions had become involved in the encouragement of tourism as a means of recovering investment and promoting economic development. The sponsors and publishers of twentieth-century travel cartography found that if, in the course of aiding navigation and giving people reasons to travel, it was possible to direct them to sites and services that would bring profit or development, so much the better.

## The Journey: Planes, Trains, Boats, and Automobiles

The twentieth century dawned in the midst of a flurry of globally significant transportation improvements. North Americans had recently completed five major transcontinental rail routes, and construction of the Trans-Siberian Railway was well under way. Colossal steamships vied for transatlantic speed records while moving thousands of migrants and tourists between Europe and North America. The opening of the Suez Canal in 1869 dramatically simplified and shortened travel between the North Atlantic and the Indian Oceans, as the opening of the Panama Canal in 1914 revolutionized movement between the Atlantic and the Pacific. Promotional maps commemorating these improvements expressed the general confidence of the age in the ability of new transportation technologies to reduce travel times and promote development and the common good. One 1912 map of the Panama Canal employed the raised relief technique to emphasize the difficulty of "the world's greatest engineering feat" (fig. 1040). Statistics appended to the map underscore the colossal scale of the project and the reductions in travel distances it would make possible. In addition to commemoration, such publications reflected a new dynamic between transportation and promotion: Industrial Age transportation technology was expensive; investors in this technology required a return on their investment, and this required promotion.

North American railroads established the value of maps as promotional tools during the last decades of the nineteenth century using carefully manipulated maps to put particular routes in a favorable light vis-à-vis their competitors (Musich 2006). Such manipulations, still common in the early twentieth century, show the subtle

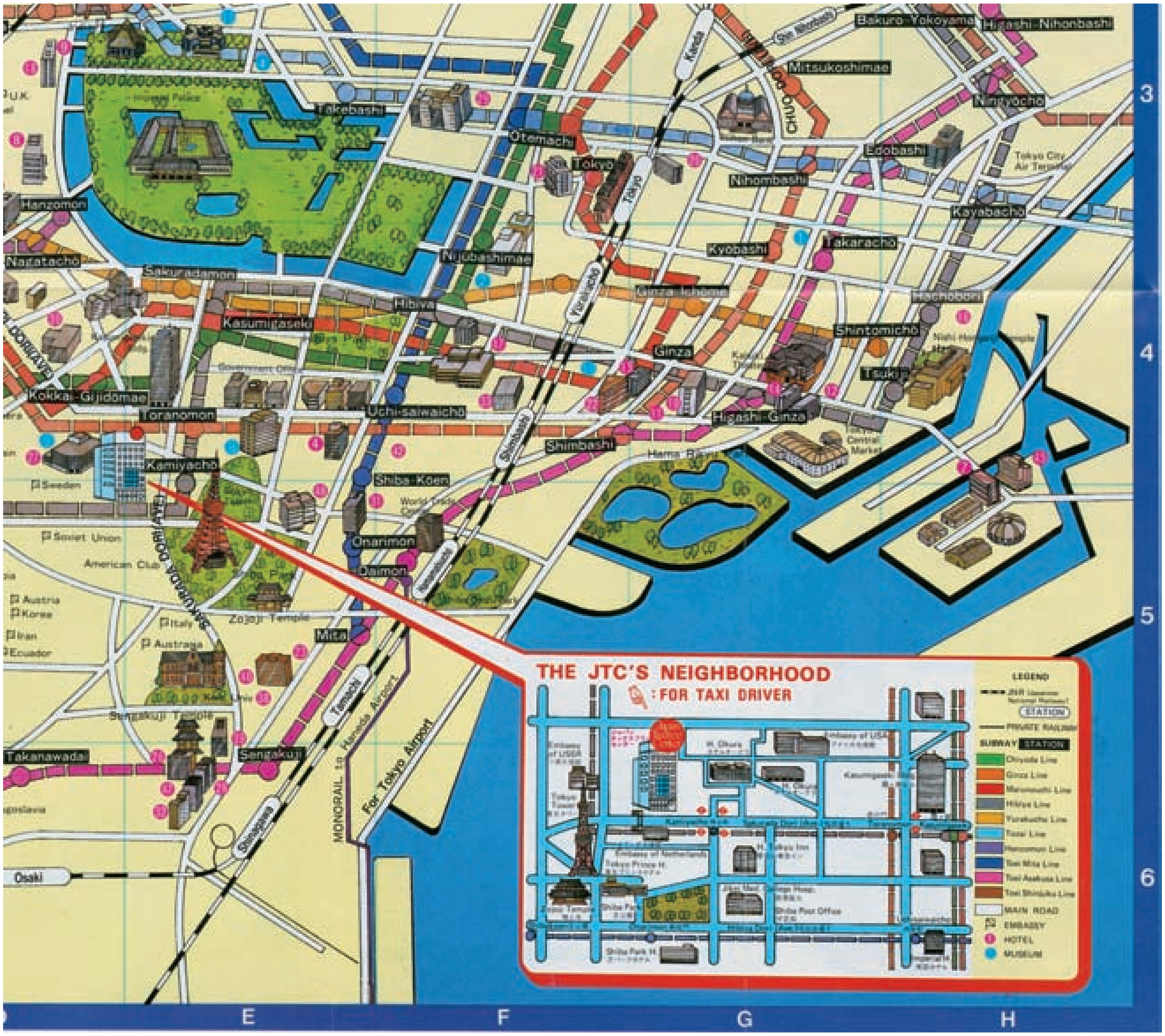


FIG. 1038. DETAIL FROM *PANORAMIC VIEW OF CENTRAL TOKYO.* Inset map of *The JTC's* [Japan Taxfree Center] *Neighborhood: For Taxi Driver*, 1980s.

Size of the entire original: 42 × 59 cm; size of detail: 24.6 × 27.7 cm. From *Guide Map, Tokyo* (Tokyo: Amita, 198–. Image courtesy of the Newberry Library, Chicago.

power of maps to influence a potential passenger's perception of a railroad's geographical location relative to competing lines and desirable destinations, such as the national parks of the American West. These schematic maps were still navigationally useful because railroad passengers played no role in piloting their trains. Once on board, they needed only to know the order and timing of potential stops to plan their exit. The passenger's most important decision was whether to make the journey in the first place. For this reason railroad companies, both in North America and in Europe, reserved more detailed and colorful maps for the description of the tourist destinations they served.

Under comparable circumstances the maps in cruise guidebooks tended to offer only schematic maps of the general path of the cruise or cruises offered by a given line while offering more detailed maps of destinations. *The Cunard Line Handbook* (1905), a small glossy keepsake for Anglo-American travelers to the Mediterranean and the European continent, includes several fine folded plans of common ports-of-call and railway maps of Italy, Switzerland, and the Low Countries but

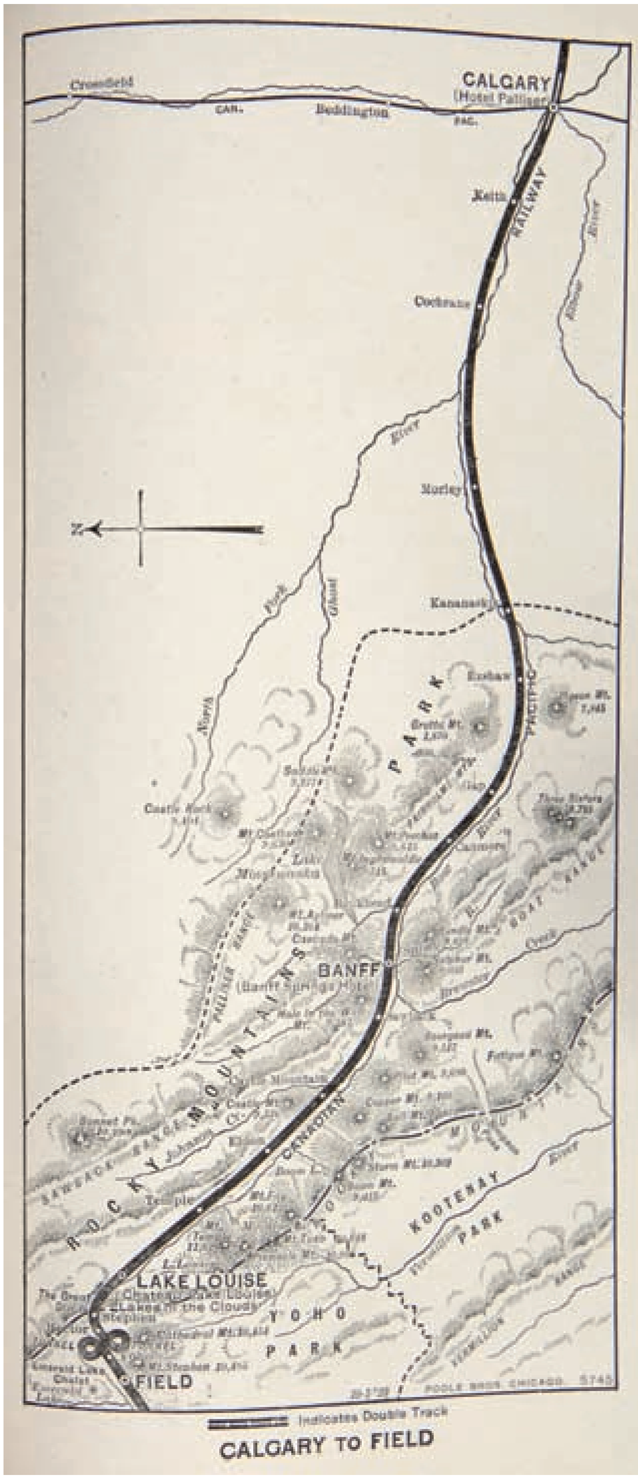


FIG. 1039. CALGARY TO FIELD SECTION OF CANADIAN GUIDEBOOK, 1921.
Size of the original: ca. 23.5 × 10.2 cm. From *Across Canada: Annotated Guide via Canadian Pacific, the World's Greatest Transportation System, West Bound* (Montreal: Canadian Pacific Railway, 1921), 93. Image courtesy of James R. Akerman.

no overarching map of cruise routes. *The Mediterranean Cruise*, by Rolland Jenkins (1927), similarly looks landward with nine detailed maps of Mediterranean ports, the Riviera, Palestine, and Egypt, supplemented only by a simple outline map of the Mediterranean printed inside the front and back covers. While cruising, there was simply little for passengers to see and gain from a map, except information about the next destination. Among the more detailed maps provided to cruise passengers were plans of the ships themselves and their decks; these large and often complex spaces that passengers spent most of their time navigating over the course of the cruise (fig. 1041). Such plans also served to highlight the ship's amenities. Exceptions to this general pattern were most notably when the cruise was designed to enable viewing of spectacular adjacent landscapes, as in the cases of the Inland Passage of British Columbia and Alaska and Rhine cruises (see fig. 879).

Cruise lines and railroad promotional brochures were mindful that for some travelers a long-distance journey of several days or even weeks by rail or ship also meant inactivity and boredom. In compensation for the long duration and ennui of the journey, steamships and trains offered travelers a geographical range not achievable by other modes of transportation before development of the full potential of the automobile and airplane. Glossy promotional maps continued to make this argument well into the twentieth century. A 1937 Canadian Pacific Railway world map portrays the company's rail and steamship lines as a nearly seamless service spanning the world, binding East Asia and Western Europe within reach of the North American interior (fig. 1042). The map is unequivocally North American in orientation, but it is more importantly a global view, extolling the ability of modern transportation technology to bring the world together.

The Canadian Pacific might also have been mindful in 1937 of the global pretensions of the emerging air industry. Early air navigation was an intensely map-oriented activity almost by definition (Ehrenberg 2006), and much the same could be said of the industry's early cartographic approach to passengers. As with travel by ship or train, air passengers do not pilot their vehicles, and their interaction with the passing landscape is momentary at best. In the early stages of air travel, passenger interaction with the ground was nevertheless greater than at century's end. Commercial flights flew at lower altitudes, and aircraft cabins were narrower, putting views of the ground within the sightlines of proportionally more passengers. The range of passenger aircraft was also shorter, only a few hundred miles per leg, necessitating many more stops on longer journeys. The maps supplied to air travelers before the jet age consequently were often highly elaborate and detailed.

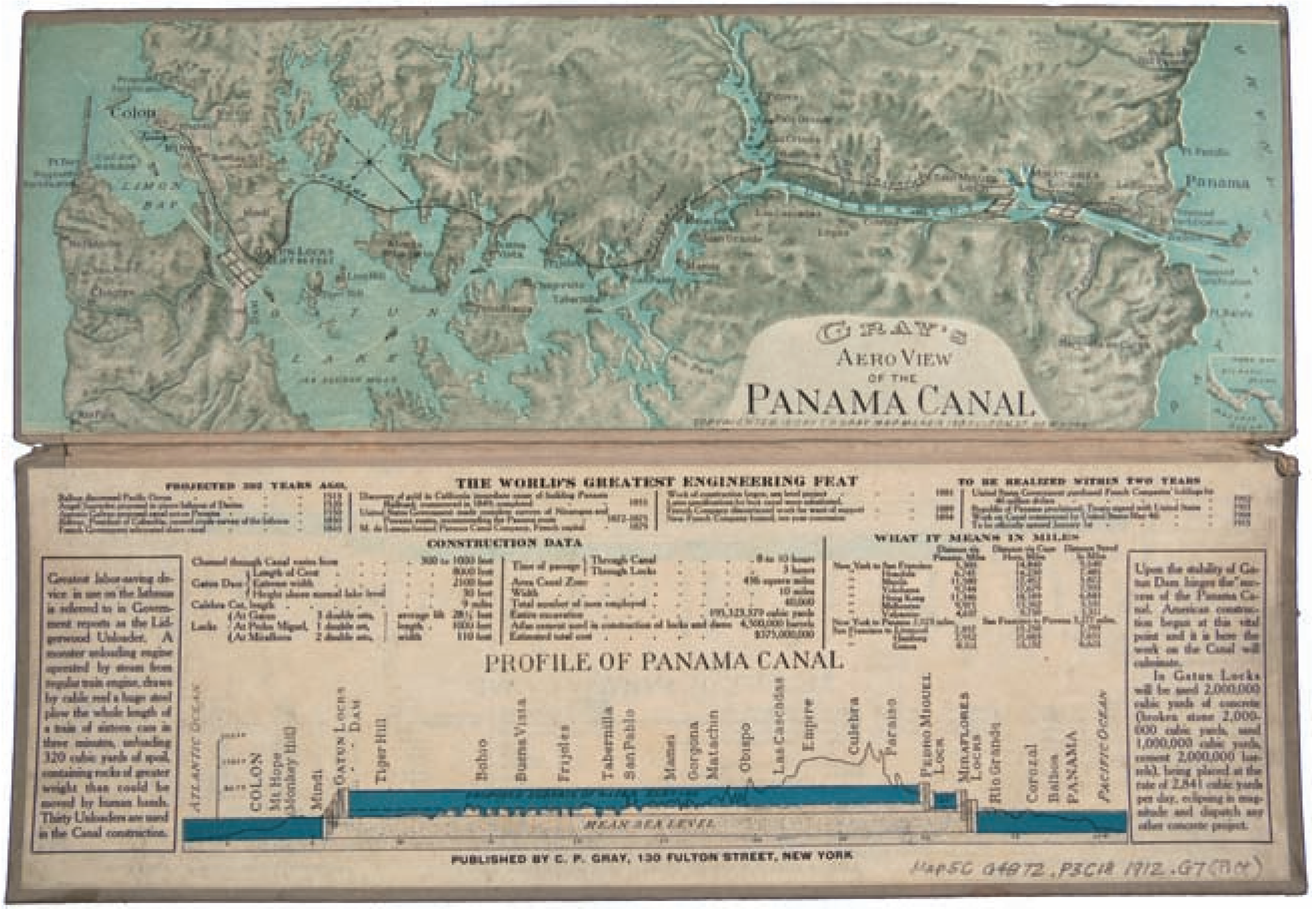


FIG. 1040. *GRAY'S AERO VIEW OF THE PANAMA CANAL* (NEW YORK: C. P. GRAY, 1912). Published for distribution by the Hamburg-American Steamship Line. Size of the original: 24 × 34 cm. Image courtesy of the Newberry Library, Chicago.

Usually presented in strip format at medium scales, they provided far more information about the ground below than was common later, including the locations of intermediate airports, beacons, and landing fields, and sometimes even guidebook-style descriptions of landscapes, cities, and landmarks visible below. The novelty of flight was still such that many souvenir maps provided space for passengers to keep a log of their journey.

In the jet age, airlines operated more complex networks linking many cities with nonstop flights. Larger aircraft placed more passengers some distance from the windows, and higher flight altitudes put the landscape below farther out of sight and out of mind. Mapping air routes for passengers in detail consistent with past practices would have been costly and pointless. The maps offered to passengers during the 1950s to 1970s made a rhetorical shift to the strategic presentation of the airline within a continental or global context, usually against the backdrop of an attractive, if less detailed, shaded relief base map. An airline passenger map published by Air India about 1970 for consumption by a global Anglophone audience illustrates the widening horizons of jet age passengers, in this instance made all the more poignant because this enhanced mobility was offered by and to citizens of a country newly independent from colonial rule (fig. 1043). Toward the end of the century, as air travel became still more routine, airlines phased out these maps, replacing them with diagrammatic maps of routes buried in the back of their in-flight magazines. More detailed maps were provided of airline terminals, complex spaces that (like the decks of cruise ships) passengers had to navigate for themselves.

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FIG. 1041. *CUNARD LINE S.S. CARINTHIA CRUISE PLAN*, APRIL 1932 (NEW YORK: CUNARD STEAMSHIP COMPANY, 1932). Size of the original: 84.5 × 101.5 cm. Image courtesy of the Newberry Library, Chicago.

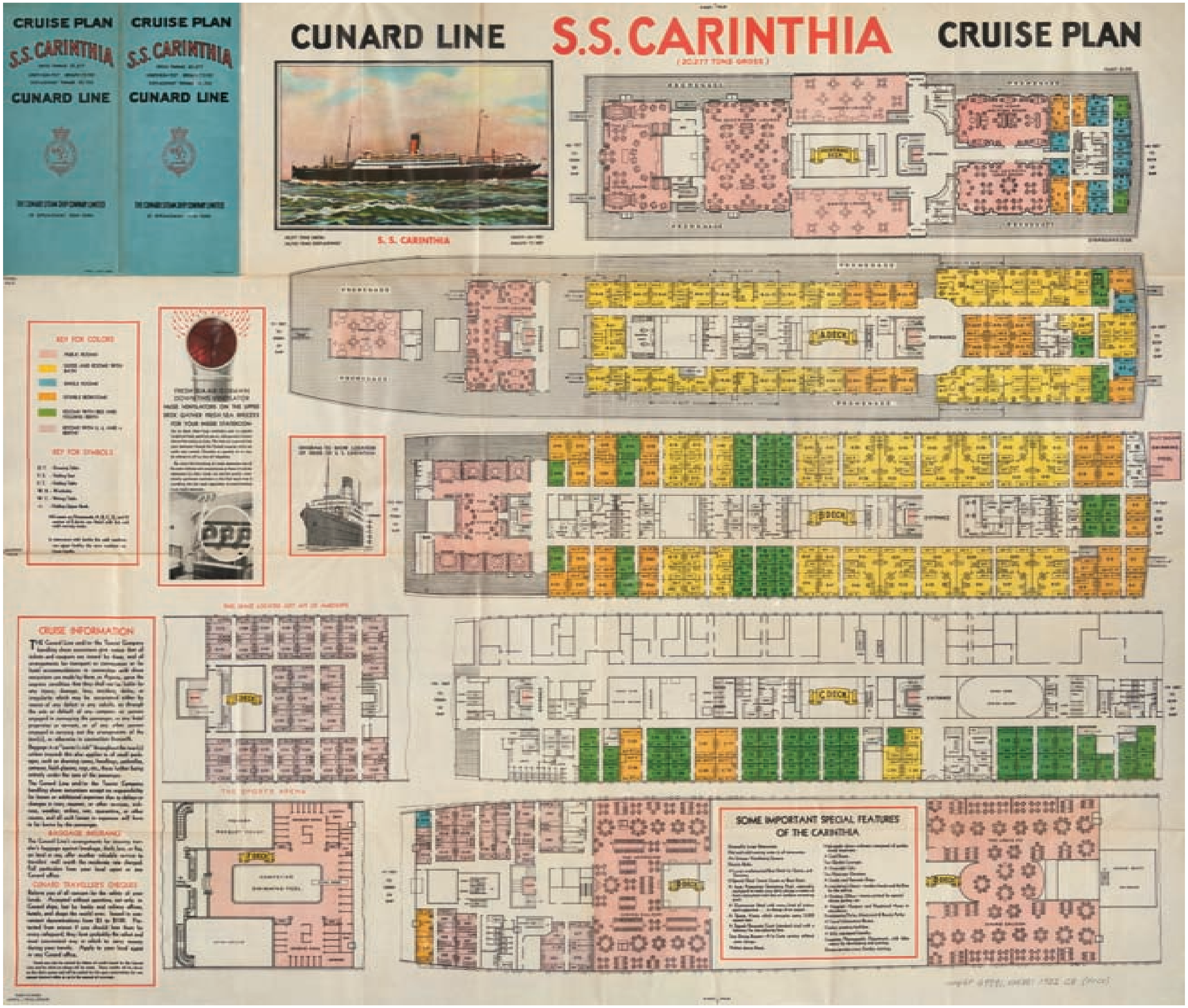
CRUISE PLAN
S.S. CARINTHIA
CUNARD LINE
CRUISE PLAN
S.S. CARINTHIA
CUNARD LINE
CUNARD LINE
S.S. CARINTHIA
(20,277 TONS GROSS)
CRUISE PLAN
S. S. CARINTHIA
A DECK
B DECK
C DECK
KEY FOR COLORS
KEY FOR SYMBOLS
CRUISE INFORMATION
BAGGAGE INSURANCE
CUNARD TRAVELLER'S CHEQUES
THE SPORTS ARENA
SOME IMPORTANT SPECIAL FEATURES
OF THE CARINTHIA


FIG. 1042. *CANADIAN PACIFIC RAILWAY AND STEAMSHIPS SPAN THE WORLD* ([MONTREAL]: CANADIAN PACIFIC RAILWAY COMPANY, 1937). Railway and steamship lines are shown in red. Size of the original: 44 × 98 cm. Image courtesy of the Newberry Library, Chicago. Permission courtesy of Canadian Pacific Archives, Montreal.


FIG. 1043. *FLY WITH ME ON THE ROUTES OF MY JET CARPET*, AIR INDIA (SWEDEN: ESSELTE MAP SERVICE FOR AIR INDIA, CA. 1970). Air India flight routes are shown with red lines, red circles indicate airports served by Air India. Size of the original: 42 × 90 cm. Image courtesy of the Newberry Library, Chicago.

Automobile travel required much more of tourists, who doubled as the pilots of their vehicles. Travel by car could be slow and deeply immerse travelers in the passing landscape, or it could proceed at paces rivaling trains. Consequently, while the design and means of distribution of automobile road maps varied from continent to continent, all required a high level of attention to navigational details such as highway designations, the quality and character of roads, and distances between towns and cities. The greater navigational engagement of the automobile tourists with their maps created opportunities for map publishers and sponsors to insert promotional content, such as specific highway services and attractions, directly onto the maps. Navigational content could also be colored by interpretations of the landscape (see figs. 1038 and 1052) (Akerman 2002).

The relationship between the touring experience and variations in the mode of transportation may be discerned from the mapping strategies of guidebook series published over the course of the twentieth century. Early in the century guidebooks reflect an orientation to the railroad traveler. The 1909 Baedeker guide to *Central Italy and Rome* boasts nineteen maps and fifty-five plans and views in a volume of 527 pages. These include a small *Carta Ferroviaria d'Italia* and a larger general reference map that delineates roads but gives greater visual prominence to railroads, which are delineated in bright red. The largest complement of maps depicts travel destinations, primarily cities. Detailed plans, intended primarily to support walking through the narrow streets of these towns, are carefully framed to include the nearest rail stations, which are rarely within the confines of smaller towns. The plan of the hill town of Montepulciano includes an inset map provided to show the nearest rail line and stations (fig. 1044). This cartographic emphasis on cities and rail travel remained largely unchanged for several decades, though notable nonurban landscapes such as mountains, lakes, and seashores received some attention in the form of district maps and panoramas. By the 1950s guidebooks to European destinations usually added regional maps that represented roads on an equal footing with railroads, though the overall cartographic component continued to focus on localized places of interest at the expense of cartographic engagement with the journey to these destinations.

The maps incorporated in more explicitly automobile-oriented guidebooks introduced significant innovations. The earliest Michelin guidebooks were no less focused on the depiction of cities than their railroad-oriented contemporaries, but the maps were considerably simplified and oriented toward motorists passing through a city, seeking services and only the most salient landmarks, rather than toward tourists making extensive exploration on foot. There were more maps as well, including those for smaller cities and towns that a traditional guidebook would have overlooked but through which motorists would have to navigate (Olson 2010). In the aftermath of World War I, Michelin published a series of guides to battlefields and campaigns on the Western Front, capitalizing on interest in the region among British, American, and French tourists. The maps in these guidebooks took full advantage of the automobile's ability to tour country roads over large expanses of territory so that tourists might grasp the complexities of battlefield terrain and tactics while envisioning battles


FIG. 1044. *MONTEPULCIANO*, 1909.
Size of the original: 14.8 × 9.7 cm. From Karl Baedeker, *Central Italy and Rome: Handbook for Travellers* (Leipzig: Karl Baedeker, 1909), opp. p. 48.

from a variety of viewpoints (fig. 1045). Michelin's later series of regional "green" guides not only incorporated many of the cartographic features of the traditional guidebook, including detailed city and building plans, but also included a larger complement of regional and district maps that supported exploration outside of cities (see fig. 878). These features recognized that a major part of the attraction of automobile tourism lay in the free-ranging nature of car travel.

After World War II the global reach of air travel expanded the scope of guidebook series to embrace almost every part of the world. The cartographic component of these guidebooks continued to emphasize large-scale maps of cities and districts of specific interest, often indicating with numbers the locations of points of interest, recommended hotels, and restaurants. But maps of recommended walking and driving routes were now common as well. In fact, guidebook series devoted entirely to tours came into print by the 1980s and 1990s.

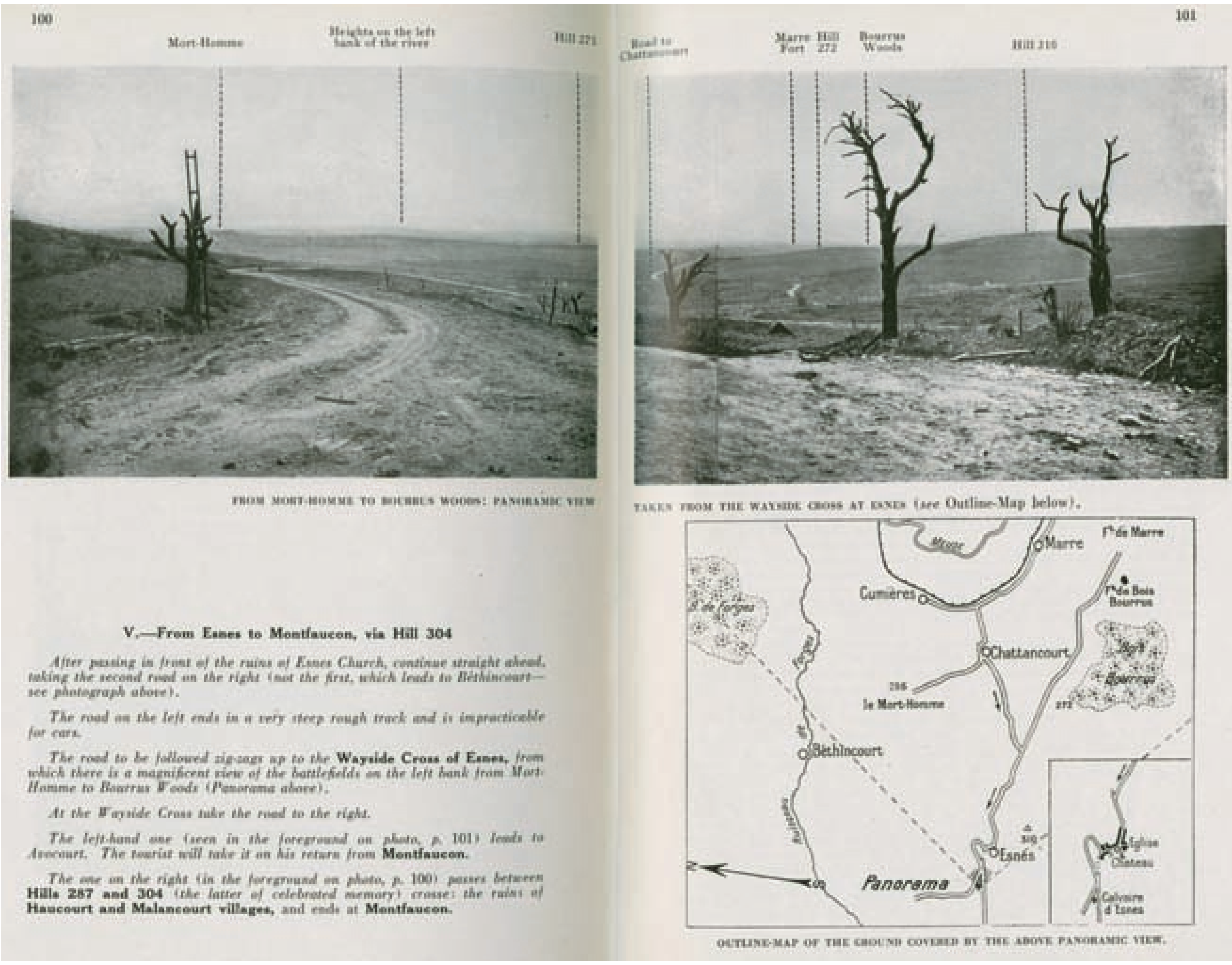


FIG. 1045. PANORAMIC PHOTOGRAPH AND OUTLINE MAP, 1920.
Size of the original: 21 × 28 cm. From *Verdun and the Battles for Its Possession, Michelin Illustrated Guides to the Battlefields (1914–1918)* (Clermont-Ferrand: Michelin, 1920). 100–101. Image courtesy of the Newberry Library, Chicago.

The Eyewitness guides inaugurated by Dorling Kindersley (DK) in 1988 adopted a mapping strategy that emphasized vision. A 1993 DK guide to Paris fairly bristles with maps, alongside photographs and views, while giving relatively less space to text. Illustrations include traditional neighborhood index and reference maps as well as the oblique view, street-by-street maps of the most popular touring districts, which exemplify the series' claim to "show you what others only tell you." DK's map of the Ile de la Cité in Paris (fig. 1046) uses perspectival views of facades set back from streets widened for clarity, so as to better relate the plan of the island to what the tourist sees from the ground. A walking tour suggests particular sites worth seeing, and to make sure that the tourist sees them, photographs and drawings of noteworthy sites are keyed to locations on the map. This approach effectively integrates navigation and description, perhaps at the highest level possible with a printed map. It also codifies the walking experience that previous generations of tourists had worked out on their own. In this respect it mimics the way that twentieth-century automobile road maps integrated interpretations of place into the process of navigation. Earlier guidebook maps largely left description and interpretation to accompanying text. Late-century guidebooks worked these interpretations into the very fabric of their maps.

## The Destination: Mapping and Marketing Place

Almost by definition, maps made for travelers and tourists during the twentieth century were engaged in place marketing, that is, the broad use of all manner of media to promote localities, regions, and countries through the development of attractive images, both graphic and

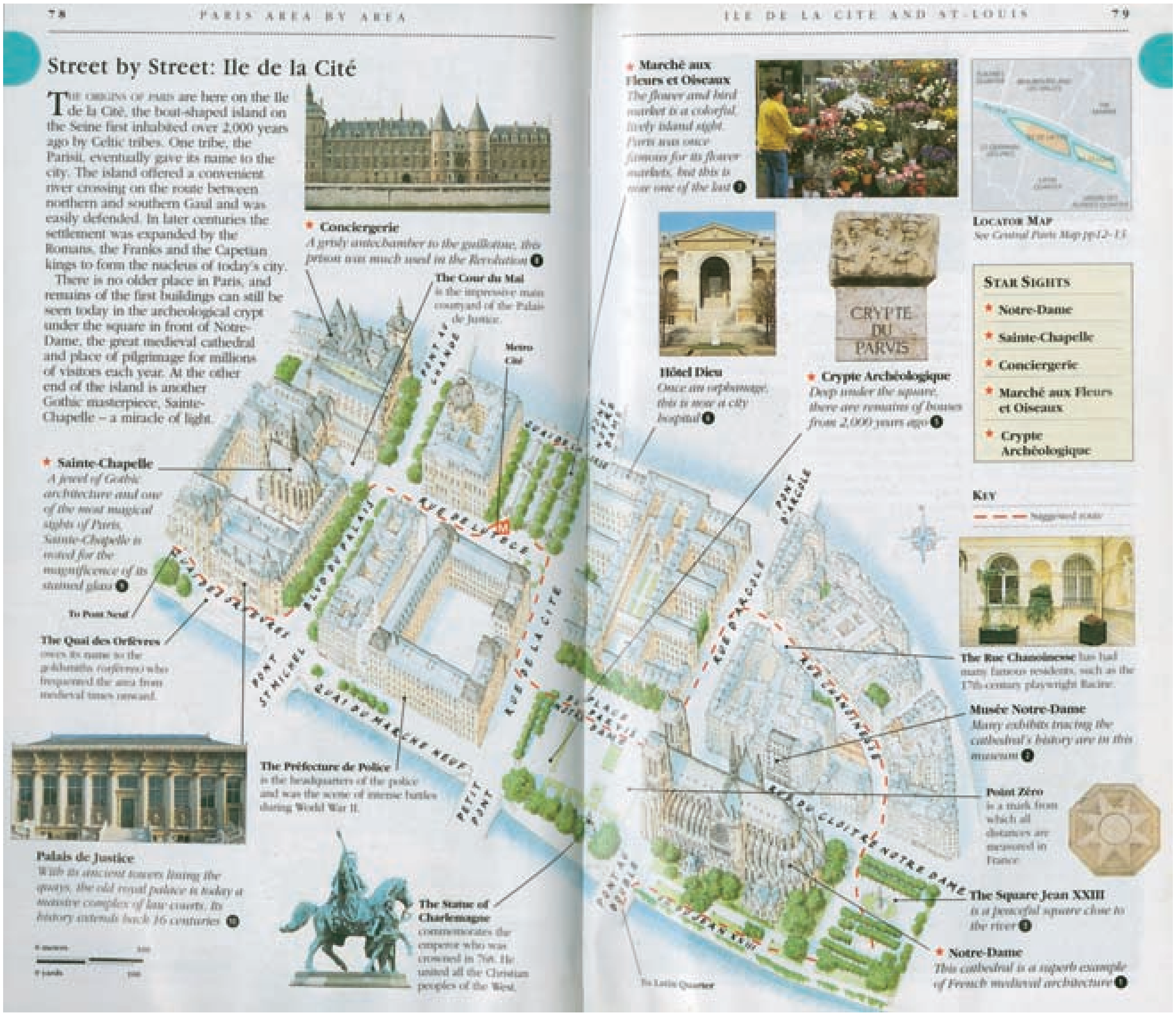


FIG. 1046. *STREET BY STREET: ILE DE LA CITÉ*, 1993. Size of the original: 20.9 × 24.2 cm. From *Paris*, first American edition (New York: Dorling Kindersley, 1993), 78–79. Image courtesy of James R. Akerman. Permission courtesy of DK Publishing, New York.

otherwise (Gold and Ward 1994; Ward 1998). Though getting away from the city to a spa, the seaside, or a similar destination had been a frequent goal of turn-of-the-century tourism (Ward 1998, 29–82), guidebook writing and cartography continued to reflect the traditional tastes of the Grand Tour, including its focus on cities. Even so, rapid worldwide urbanization, the decline of European imperialism, and the disruptions of two world wars brought to the fore new thematic interests reflected in maps and views published to market places to tourists. These included a broadening of the urban ideal; a sharpened sense of the relationship between tourism and the nation; and a general expansion, thematically and geographically, of what might be considered culturally and historically interesting to tourists.

The attraction of urban places as touring destinations reflected in railroad-era guidebook cartography remained undiminished into the air age. Nineteenth- and early twentieth-century international expositions, though heavily overlain by international competition and Western cultural imperialism, also promoted the idea of the city (represented by the host city) as a global cultural and economic metropolis (Rydell 1984). Just before the turn of the century, the organizers and exhibitors at Chicago's World's Columbian Exposition of 1893 aggressively used maps to market all manner of prod-

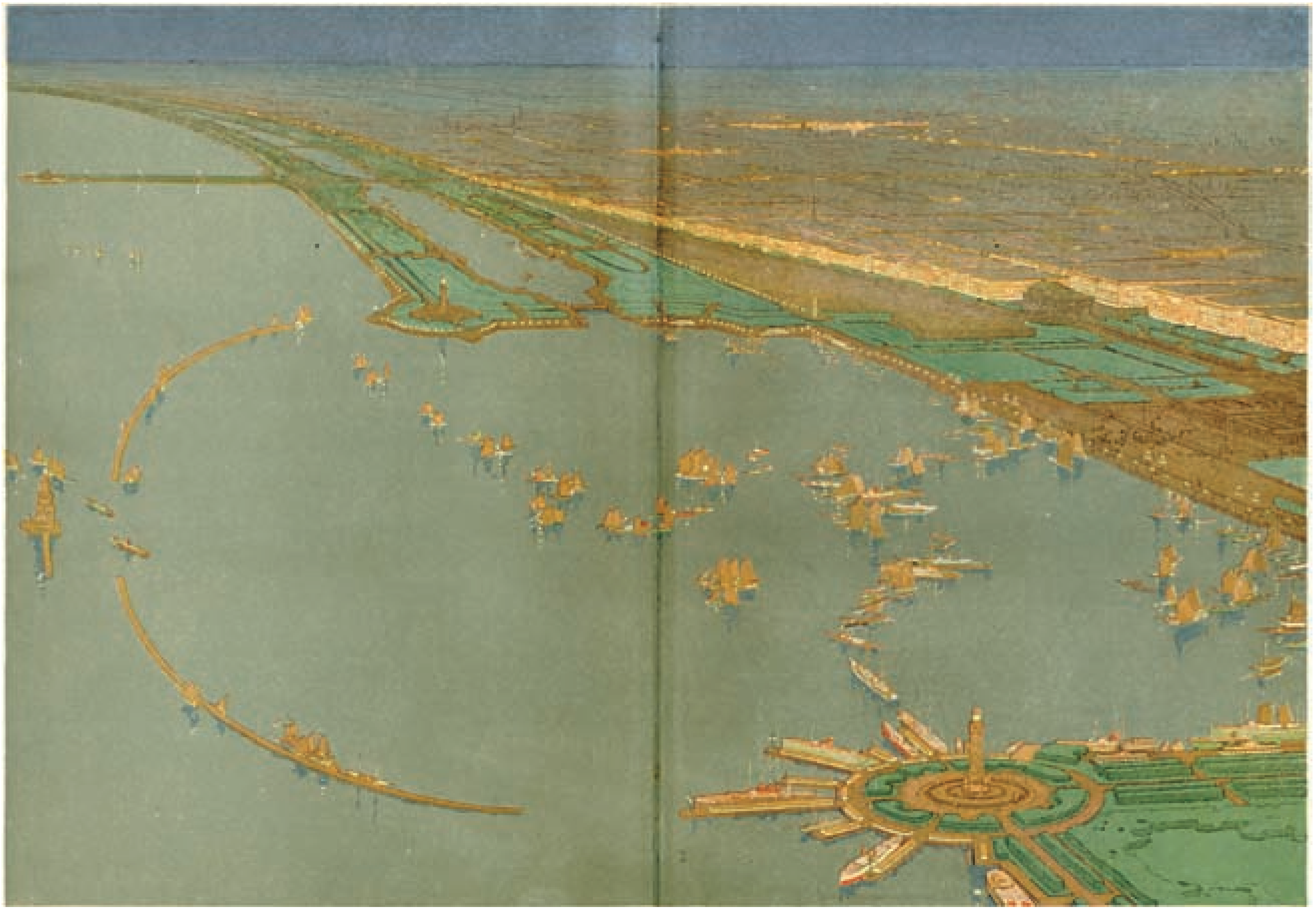

FIG. 1047. JULES VALLÉE GUÉRIN, *CHICAGO: BIRD'S-EYE VIEW AT NIGHT OF GRANT PARK, THE FAÇADE OF THE CITY, THE PROPOSED HARBOR, AND THE LAGOONS OF THE PROPOSED PARK ON THE SOUTH SHORE*. (See also fig. 725.) Size of the original: 25 × 36 cm. From Daniel H. Burnham and Edward H. Bennett, *Plan of Chicago* (Chicago: Commercial Club, 1909), pl. CXXVII (between 112 and 113).

ucts and services on exhibit at the fair while promoting the young and rapidly growing Chicago as the model of a modern world metropolis (Dillon 2003). Sixteen years later the definitive statement of the American City Beautiful Movement, the 1909 *Plan of Chicago*, coauthored (with Edward H. Bennett) by the 1893 fair's chief planner, Daniel H. Burnham, demonstrated how idealized maps and views might be deployed to present visions of urban futures (fig. 1047; and see fig. 725). Burnham's vision of the modern metropolis was nevertheless criticized for its reverence for classical and European architectural models, something that Grand Tourists would have appreciated but which stood at odds with the image of Chicago as, among other things, the birthplace of the skyscraper (Smith 2006). Indeed, the popularity of Hermann Bollmann's iconic 1963 axonometric view of New York, published in time for the 1964 New York World's Fair, rests on its dramatization of the modernity and verticality of that city's skyscrapers (fig. 1048). New York fostered its image as a modern cultural and commercial metropolis "at the crossroads of the world" to appeal to domestic and worldwide tourists (Taylor 1991). Hagstrom's ca. 1965 map of New York presents this distinctively twentieth-century urban landscape of supper clubs, theaters, stores, hotels, public buildings, and rapid transit subways (fig. 1049).

Pictorial maps and perspective views were especially powerful images of place, valued by local boosters as promotional tools and by tourists as souvenirs throughout the twentieth century (Holmes 1991). Panoramic or

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FIG. 1048. DETAIL OF MIDTOWN FROM HERMANN BOLLMANN, *NEW YORK* (NEW YORK: PICTORIAL MAPS FOR AMERICAN AIRLINES, 1963). Size of the entire original: 86 × 108 cm; size of detail: 24.4 × 29.5 cm. Image courtesy of the Newberry Library, Chicago.


PARK AVE

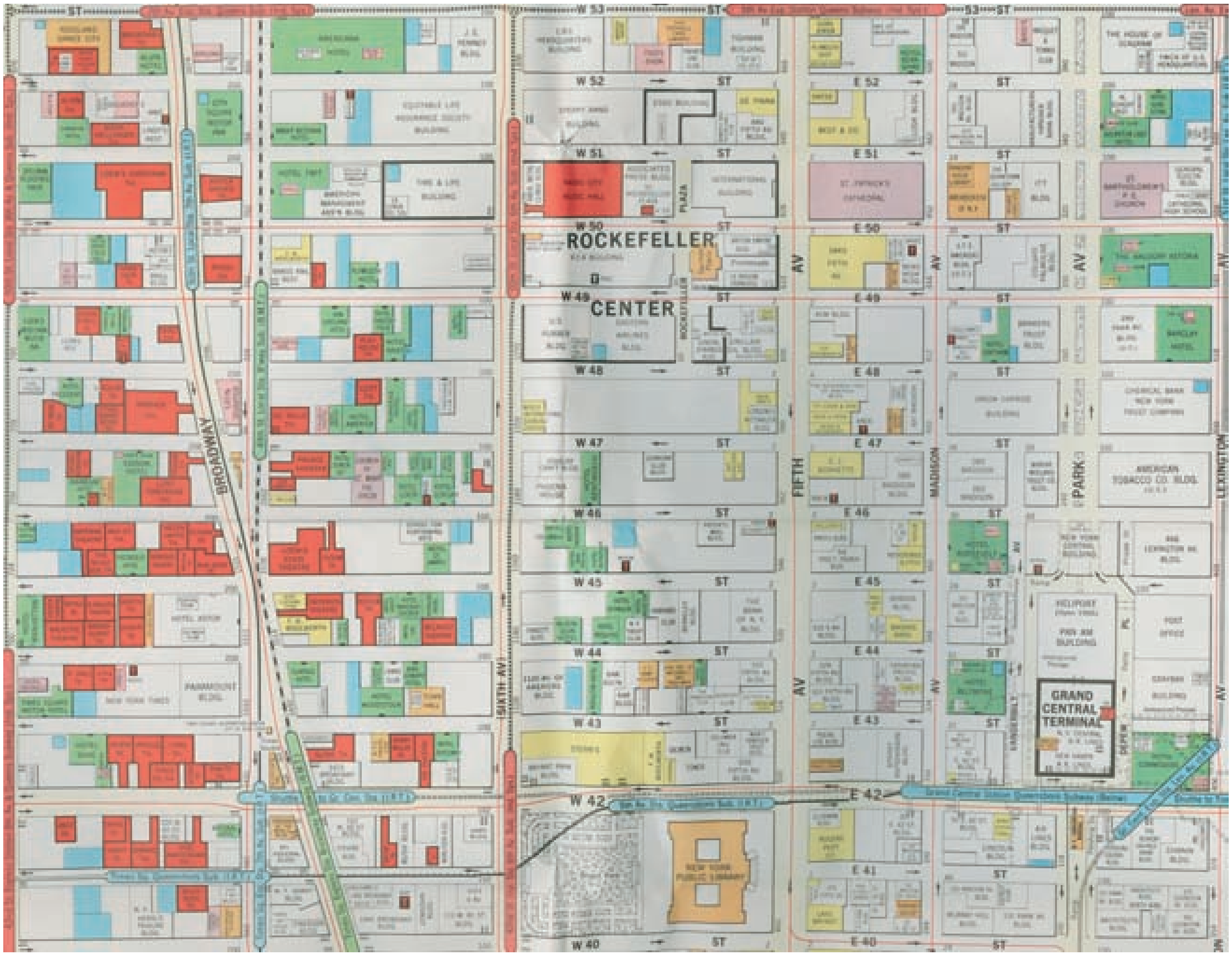


FIG. 1049. DETAIL FROM *HAGSTROM'S MAP OF NEW YORK'S AREA OF GREATEST INTEREST* (NEW YORK: HAGSTROM COMPANY, CA. 1965). Map includes theaters (red), hotels and motels (green), garages and parking lots (blue), prominent stores (yellow), churches, synagogues (dark pink), night clubs and supper clubs (pink), special points of interest (dark yellow), and bus and subway lines.
Size of the entire original: 67 × 67 cm; size of detail: 23.9 × 30.9 cm. Image courtesy of the Newberry Library, Chicago.

bird's-eye views of North American cities and towns enjoyed enormous popularity early in the century as representations of urban industry, vigor, and potential for growth (Reps 1984). By the 1930s a type of urban view-map had evolved in Britain and the United States that featured cartoons of human activity, textual inserts, and stylized images of landmarks. These appealed more directly (though probably not exclusively) to tourists, and offered a more selective view of the city, often one that had a specific cultural or historical narrative to offer—in this example developing the 1930s image of Chicago as a city of gangsters (fig. 1050). This selectivity could be commercial as much as it was historical and cultural. Tourist-oriented businesses often published pictorial views as souvenirs for their customers, but made sure that their services or locations were prominently pictured. A common late-century variant on the city pictorial map included images of businesses and other institutions that were willing to pay for their representation alongside other civic landmarks. Illustrated advertisers on a view-map of Dallas, Texas, are a very mixed bag, including oil corporations, colleges, hospitals, a soft drink distributor, hotels, churches, and a radio station (fig. 1051).

The marketing value of the pictorial or perspective map was also applied to settings beyond urban boundaries. One popular genre offered geographical inventories of literary landmarks of American states and regions (Hopkins and Buscher 1999), and pictorial representation was a favored technique for promoting mountain regions and ski resorts. Promotional interests used im-

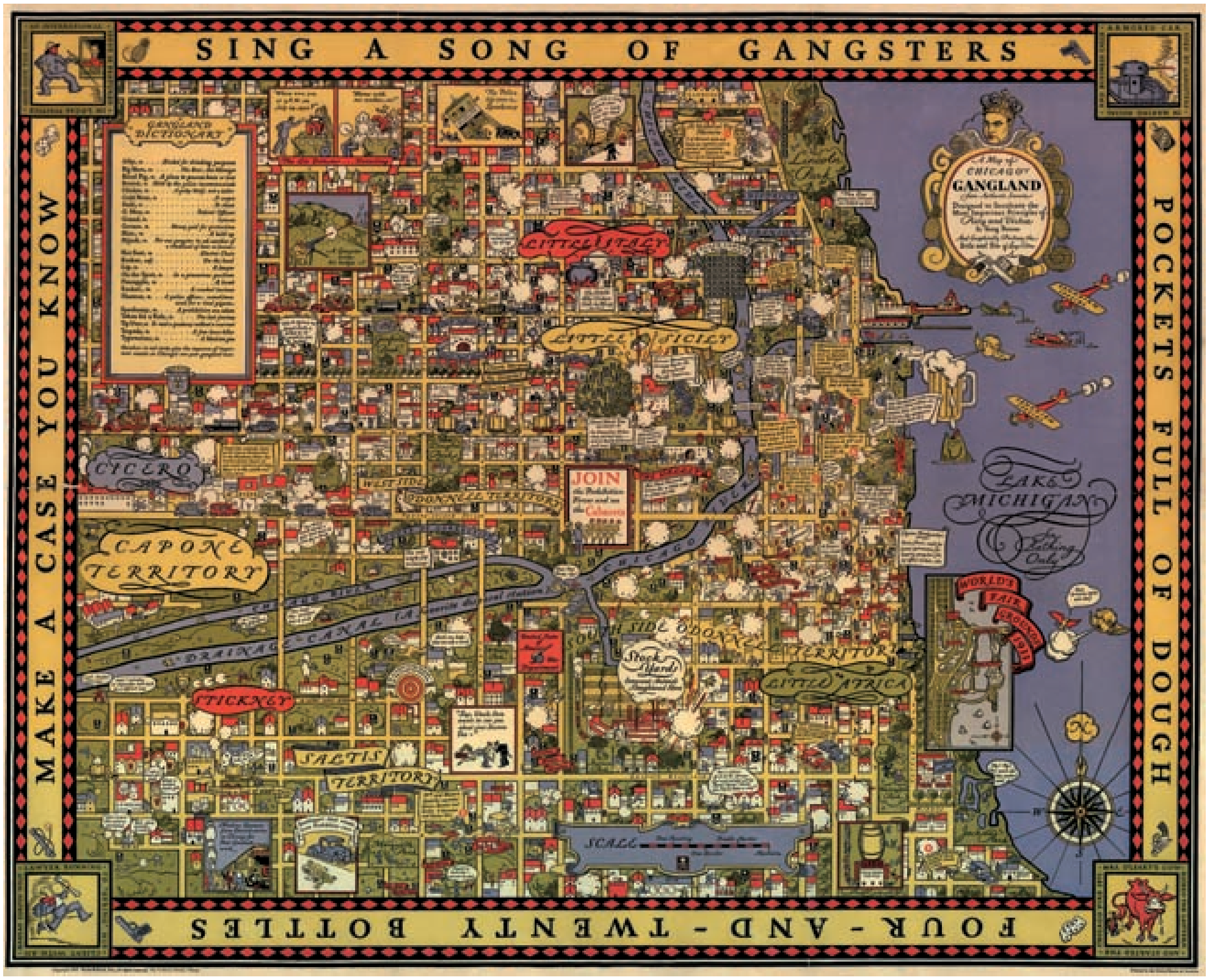


FIG. 1050. *A MAP OF CHICAGO'S GANGLAND FROM AUTHENTIC SOURCES: DESIGNED TO INCULCATE THE MOST IMPORTANT PRINCIPALS OF PIETY AND VIRTUE IN YOUNG PERSONS, AND GRAPHICALLY PORTRAY THE EVILS AND SIN OF LARGE CITIES* (CHICAGO: BRUCE-ROBERTS, 1931).
Size of the original: 58.5 × 79 cm. Image courtesy of the Newberry Library, Chicago.

ages to help establish regional historical and cultural touring themes, for example, by emphasizing the Spanish colonial heritage of southern California (see fig. 862). Similarly, panoramic maps of rivers have a long history in many parts of the world. Those published for travelers on Rhine cruises helped travelers identify the castles and cities encountered along the way, while distinguishing them as more significant than surrounding sites (see fig. 879). American road map publishers developed a specialized class of road map that interjected pictorial vignettes of historical events, landmarks, famous buildings, and sites of cultural and economic activities. A 1942 map of Puerto Rico by the General Drafting Company for the West India Oil Co., an affiliate of Esso (Standard Oil of New Jersey), and steeped in the island's colonial relationship to the United States, highlights the island's oldest church, the first landing of U.S. troops in 1898, banana cultivation, rum and sugar production, and fishing opportunities for visiting tourists (fig. 1052).

Descriptions of walking and driving tours were also effective map features favored by place marketers, particularly during the second half of the century. Whether offered in simple brochures or incorporated into guidebooks, these maps were heavily dependent on accompanying narratives, which supplied most of the historical, cultural, or scenic interpretations of the touring subject. Many of these tours provided little more than an effective geographic strategy for exploring otherwise discon-


FIG. 1051. *DALLAS* (WATERLOO, ONT.: CITYPRINT INTERNATIONAL, 1985).
Size of the original: 58 × 82 cm. Image courtesy of the Newberry Library, Chicago. Permission courtesy of Martin Johanns.

nected, though proximal, sites. For example, the DK walking tour of Paris's Ile de la Cité (see fig. 1046 above) charts a pleasant walk through the island but does not cohere thematically, except to suggest the character of an urban neighborhood. By contrast, a tour of Natchez, Mississippi, published in map form around 1980 (fig. 1053), more directly emphasizes the city's wealth of elegant older homes, though close scrutiny reveals that these are not the only points of interest identified on the map. Nonetheless, the map shows that Natchez is old by U.S. standards and that the part of town tourists should regard as historic is concentrated in a roughly twenty-five-block area in the center of the city. Though framed within a U.S. chronology, Natchez's selective walking tour, by ignoring most buildings and neighborhoods in the city while privileging others, differs little in inspiration from maps of Paris that privilege gothic cathedrals and churches or from maps of Rome that highlight the vestiges of ancient empire. Indeed, one of the major motivations of urban tour maps is to provide tourists access to a landscape that has been mostly erased physically. Writing about a map and brochure published in 1988 that describes a walking tour of Bodie, California, a mining ghost town revived and preserved as a state park, geographer Dydia DeLyser observes that "only a small portion of the buildings that once stood in Bodie" are shown on the map. These "stand in for all that Bodie is thought to have been in the 1880s." The map, she argues, amplifies the remains of the town, which take on greater meaning (DeLyser 2003, 86–88).

The most apparent work of a twentieth-century walking or driving tour map was to ensure that tourists did not lose their way. A well-designed map achieved this with a succession of numbers, directional arrows, and, in some instances, images. The modest but clear Natchez map also demonstrated that by century's end anyone with some drafting skill and design sense could produce such a map at minimal cost to its publishers. This ensured that


FIG. 1052. *GUIA ILLUSTRADA DE PUERTO RICO*, [1942].
Size of the entire original: 19.5 × 38.5 cm. Extract from *Puerto Rico y sus Carreteras* (New York: General Drafting Co. for West India Oil Company [P.R.], [1942]). Image courtesy of the Newberry Library, Chicago.

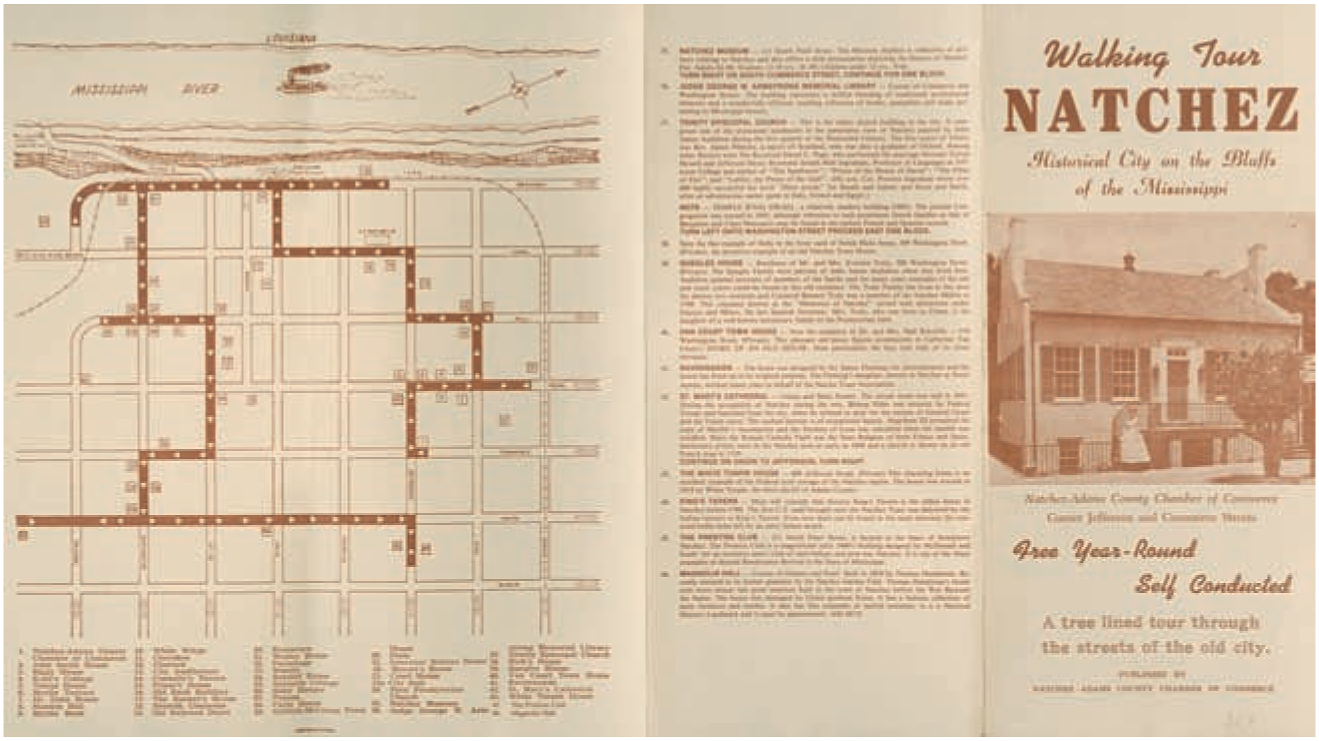


FIG. 1053. *WALKING TOUR, NATCHEZ, HISTORICAL CITY ON THE BLUFFS OF THE MISSISSIPPI* (NATCHEZ: NATCHEZ-ADAMS COUNTY CHAMBER OF COMMERCE, CA. 1980). Size of the original: 22 × 39.5 cm. Image courtesy of James R. Akerman.

even lightly funded local voices had a role in mapping and shaping tourists' perceptions of the places they visited.

By the 1920s a new cadre of map authors, motivated by more than local boosterism and the pursuit of commercial gain, had taken up tourism mapping and place marketing. National governments, which had previously played a minimal direct role, turned to the promotion of tourism as a form of community building on a national scale in the aftermath of the Great War. Early stirrings of this development may be seen among turn-of-the-century Progressive reformers, who advocated on behalf of the masses for restorative days—and places—of leisure. National parks had been created in several countries by the turn of the century to preserve places of extraordinary beauty that might provide respite away from the pressure and unhealthy environment of industrial cities. In the United States they were formally brought under the control of a unifying National Park Service in 1916, and the parks became a focal point of a patriotic national promotional campaign encouraging American tourists who might normally have been inclined to visit Europe to "See America First" (Shaffer 2001). The initial thrust of this campaign was railroad oriented and coordinated with the United States Railroad Administration, under which American railroads were nationalized between 1917 and 1920. National park maps published during this period were oriented to the railroads that were Americans' primary means of reaching the parks: they combined small-scale maps of the railroad system with larger-scale maps meant to enable localized exploration of the parks. As aggressive programs of road building made the parks more accessible, the patriotic themes of "See America First" shifted to motor touring. In 1933, for example, Standard Oil of New Jersey (Esso) partnered with the General Drafting Company to produce a *Map of the Principal Events in the Life of George Washington*, which encouraged motorists to visit sites associated with Washington in honor of the bicentennial of his birth. Maps outlining patriotic itineraries became a mainstay of patriotic tourist promotion in the United States for the balance of the century (Akerman 2006a).

Nationalistic strains were equally strong in Europe in the decades following the Great War, reaching a fever pitch in the 1930s. The war itself fostered a brief spike in guidebooks and maps published to support battlefield tourism (see fig. 1045 above), more as a form of pilgrimage and remembrance by survivors rather than as recreation (Lloyd 1998). In the 1920s and 1930s the rapid growth of regional and provincial guidebooks and maps did much to promote the development of local and regional identities. But, much as road maps did in the United States, these also helped build a complicated national touring ethos that measured the vitality of the nation by the strength of its traditional cultures. For example, the attention of Michelin Red Guides to provincial cuisines not only promoted the gastronomic virtuosity of France but also served to strengthen the connection of motoring tourists to the nation beyond the metropolis, in much the same way that motoring tours prescribed by the Green Guides wove local and rural landscapes into the national tapestry (Harp 2002). Separately published maps of the microgeographies of French *vignobles*, while aligned with promoting connoisseurship and local economic development, also reflected the increasing mobilization of national constituencies of tourists to discover what their entire country had to offer (fig. 1054). The automotive rediscovery of traditional and local cultures was also a well-developed theme on road maps issued by petroleum companies operating in 1930s Germany (fig. 1055), at a time when the Nazi government was aggressively promoting automobility as a national virtue (Koshar 2002a). Nationalistic strains in the mapping of places for touring were no less developed in postwar Europe. For example, the Ordnance Survey developed a series of touring maps highlighting the "visible" antiquities of the British landscape from the Neolithic Age to the Norman Conquest (fig. 1056). It is perhaps ironic that the citizens of the country that once sent Grand Tourists to the Continent in search of antiquities should be encouraged by these maps to find antiquity at home, although exploration of the traditional and rustic landscapes of the countryside had long been a theme of British tourism.

At the close of the century, enabled by air travel and encouraged by international developments such as the creation of United Nations Educational, Scientific and Cultural Organization's (UNESCO) World Heritage Site program in 1972, the global exploration of cultural diversity had come to rival nationalistic tourism themes. The cartographic profile of publications promoting this strategy followed patterns consistent with those established earlier in the century. Guidebook series such as Lonely Planet, which catered to travel outside the usual comfort zone of Western tourists, were still dominated by city maps (some with walking tours) and general index maps to road and rail systems. State agencies, airlines, cruise lines, and oil companies produced brochures that singled out cities as well as historic and scenic localities for pictorial renderings and more detailed maps, mostly in isolation from the now-marginal maps that guided travelers to these locations. The places marketed by these maps reflect substantially widened horizons for tourists, but perhaps because they continued to appeal to Westerners and their habits of travel, what is most notable about these late-century tourism maps is how similar they looked from place to place.

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SEE ALSO: Advertising, Maps as; Airline Map; Map: Sense of Place and the Map; Michelin (France); Wayfinding and Travel Maps: (1) Indexed Street Map, (2) Web-Based Wayfinding

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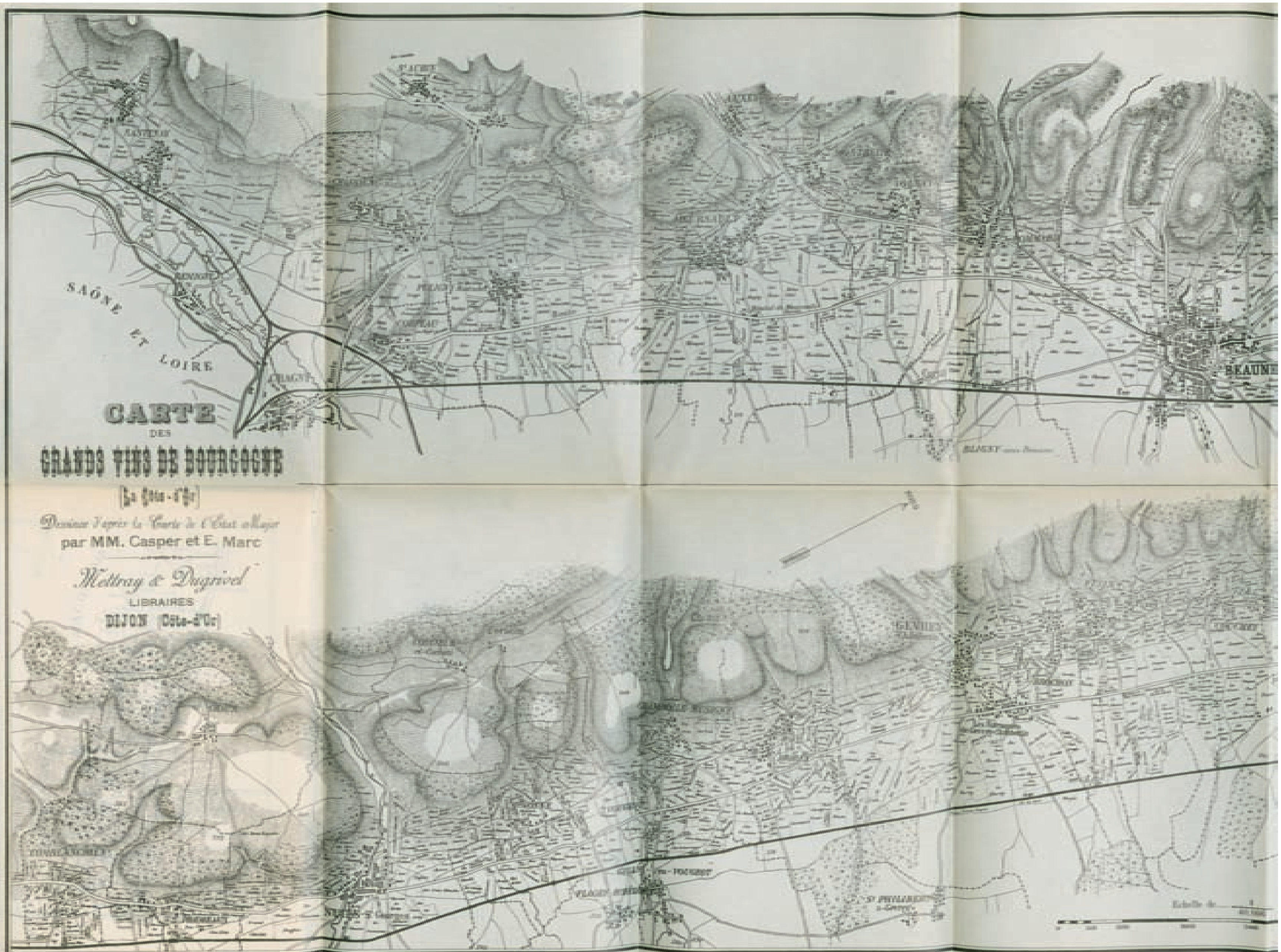


H. ARMAND-GERIN, Éditeur, 66, Rue la Liberté — DIJON.


FIG. 1055. DETAIL OF COVER ART AND TEXT FROM *SHELL STRAßENKARTE NR. 11: THÜRINGEN-MITTELDEUTSCHLAND* (FRANKFURT AM MAIN: WÜSTEN & CO. FOR SHELL, 1938).
Size of the original: 22 × 46 cm. Image courtesy of the Newberry Library, Chicago.

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***Trench Map.*** See Warfare and Cartography; World War I

***Tsentral'nyy nauchno-issledovatel'skiy institut geodezii, aeros"yëmki i kartografii (Central Research Institute of Geodesy, Air Survey and Cartography; Russia).*** The Gosudarstvennyy institut geodezii i kartografii, founded in Moscow in 1928 (headed by geodesist Feodosiy Nikolayevich Krasovskiy), added an air survey research branch in Leningrad in 1929. The latter became the independent Institut aeros"yëmki in 1931, but they reunited in 1934 as the Tsentral'nyy nauchno-issledovatel'skiy institut geodezii, aeros"yëmki i kartografii (TsNIIGAiK). Important geodetic and cartographic problems occupied TsNIIGAiK scientists throughout the twentieth century.

In 1940 Krasovskiy and A. A. Izotov defined the reference ellipsoid (later named after Krasovskiy) used for the Union of Soviet Socialist Republics (USSR) until the 1990s. M. S. Molodenskiy's geodetic gravitation measurements unified the system of geodetic coordinates. TsNIIGAiK photogrammetric research led to the compilation of topographic maps from air surveys.

Krasovskiy supported a surveying methodology review (1928–33), asserting that "to proceed from the survey materials to the topographical map, and, more importantly, the basic geographical map, one should understand the region in the geographical sense during the survey itself" (Postnikov 2002, 252). Geographical expeditions (1935–37) concluded that scientific under-

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FIG. 1054. DETAIL FROM *CARTE DES GRANDS VINS DE BOURGOGNE (LA CÔTE-D'OR)*, [1926?]. Dijon: Mettray & Dugrivel.
Size of the entire original: 38.5 × 74 cm; size of detail: 38.5 × 49.5 cm. From *Le vin de Bourgogne*, vol. 3 of *Monseigneur le vin* (Paris: Établissements Nicolas, 1926?), at end. Image courtesy of the Newberry Library, Chicago.

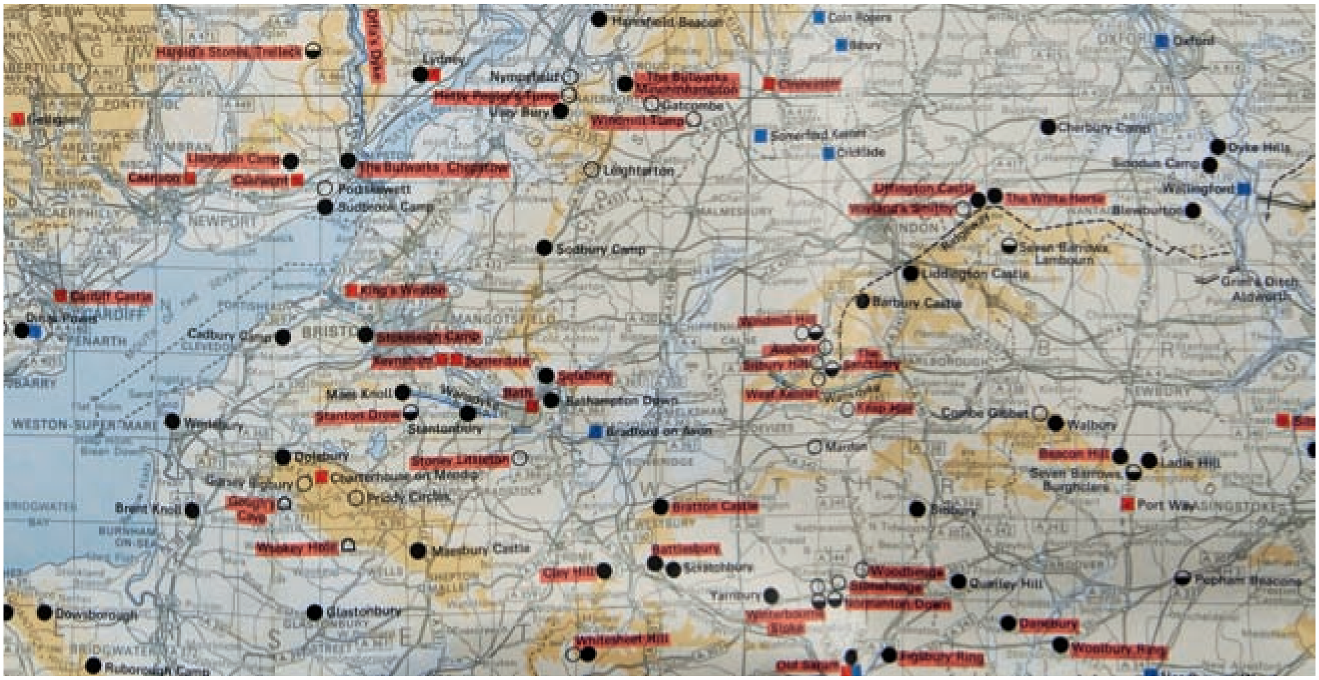


FIG. 1056. DETAIL FROM *ANCIENT BRITAIN, SOUTH SHEET*, 1982. From *Ancient Britain: Map of the Major Visible Monuments*, 3d ed. (Southampton: Ordnance Survey, 1982).

Size of the entire original: 84 × 124 cm; size of detail: 9.1 × 17.5 cm. Image courtesy of James R. Akerman. © Crown Copyright. Reproduced by permission of the Ordnance Survey.

standing of physical landscape types should guide selection of features to map. Those recommendations were approved by the TsNIIGAiK's scientific council, led by geologist A. E. Fersman. Guidelines were compiled by I. P. Zarutskaya, later editor-in-chief of the 1:2,500,000-scale map of the USSR and professor of cartography at Moskovskiy gosudarstvennyy universitet (Moscow State University).

The guidelines emphasised personal observations (field notes, drawings, and sketches) as data sources. Geographers were to visit characteristic locales in different landscapes, relating ground features to air photographs, as well as interviewing inhabitants about seasonal phenomena, such as river freezing, thawing, and flooding. Resulting thematic maps would better reflect the regional character.

New higher-education curricula for cartographers also resulted. In 1936 the Soviet government proclaimed that cartographic education should focus on physical, social, and regional geography (Decree No. 637). The curricula had to cover physical, biological, social, and economic geography and their histories, both regional and international, as well as the methodology of field investigation, statistics, and cartography.

Between 1943 and 1953 TsNIIGAiK scientists and faculty of the Moskovskiy institut inzhenerov geodezii, aerofotos"yëmki i kartografii (MIIGAiK), Voyenno-inzhenernaya akademiya imeni V. Ya. Kuybysheva (a military engineering academy), and Moscow and Leningrad state universities published manuals of topographic map surveying and compilation. Yu. F. Filippov published a book on generalization of relief portrayal in 1946; V. I. Sukhov did likewise for representation of populated areas in 1947. Drawing upon research on 1:1,000,000- to 1:4,000,000-scale maps, Filippov and colleagues published a book on generalization for small-scale geographic maps in 1955, and N. S. Podobedov published about geographical field editing of topographical maps in 1950.

TsNIIGAiK, the Akademiya nauk SSSR, and Glavnoye upravleniye geodezii i kartografii (GUGK) collaboratively studied complex mapping methods for the *Fiziko-geograficheskiy atlas mira* (1964) and the two-volume *Atlas Antarktiki* (1966–69). Those studies, as well as cooperation among TsNIIGAiK, the institutes within the academy of sciences, and leading Soviet universities, resulted in publications about editing and compiling thematic maps for world and regional atlases (e.g., Isachenko 1958–61; Isachenko et al. 1961).

The *Bol'shoy sovetskiy atlas mira* (*BSAM*) project had a long-lasting influence on Soviet and Russian cartographic science, education, and practice, and the *BSAM* became the standard for later complex regional atlases. Some *BSAM* project professionals later researched theory and methods of socioeconomic cartography for TsNIIGAiK. Their leader, Nikolay N. Baranskiy, and A. I. Preobrazhenskiy wrote a university textbook laying the foundation of the Soviet school of socioeconomic cartography (1962).

M. I. Nikishov supervised the study of agricultural cartography, a TsNIIGAiK priority in the 1950–60s. Nikishov wrote books on agricultural maps and atlases (1957, 1961) and edited the atlas of USSR agriculture (1960).

TSNIIGAiK's department of scientific cartographic information and geographical names, Otdel nauchnoy kartograficheskoy informatsii i geograficheskikh nazvaniy, dealt with data analysis and compilation of maps (especially of foreign countries); history, linguistics, and Russian transcription of geographical names; and compilation of geographical names gazetteers for countries of the world. Department head Anatoliy Markovich Komkov was for many years the Soviet representative on the United Nations Group of Experts on Geographical Names.

Existing criteria for appraising map accuracy were further developed during the 1950s and 1960s by Georgiy Aleksandrovich Ginzburg and A. I. Shabanova of TsNIIGAiK, thus influencing research on map projection theory. A department of mathematical cartography was founded at MIIGAiK in the 1930s. A comparable research department, founded in 1938 at TsNIIGAiK, was first supervised by M. D. Solov'yev and later by Ginzburg. Its laboratory calculated projections for most Soviet maps and atlases. Projections unique in world cartography included N. A. Urmayev's projections with equidistant parallels, Krasovskiy and Vladimir Vladimirovich Kavrayskiy's conic equidistant projections for maps of the USSR and the European USSR, Solov'yev and Urmayev's pseudocylindrical projections, and Ginzburg's pseudoazimuthal projection.

In the 1960s the Soviet government forced TsNIIGAiK scientists to undertake mathematical-cartographic research for distorting large-scale maps for ordinary consumers. For instance, a 1:100,000-scale map was classified secret and could not be used for any general purpose map. Maps for the public had to be derived from the Soviet 1:2,500,000-scale map enlarged to the needed scale. The resulting 1:600,000-scale tourist maps showed main towns, villages, and roads only in general. Maps for tourists classified roads only by administrative importance (national, provincial, regional, or local) rather than by pavement type (macadam, stone, dirt, etc.). No geographical coordinates were shown, and the maps performed poorly as orientation aids for travel. In the 1970s, the 1:2,500,000-scale base map was also deliberately distorted by order of the GUGK's higher authorities. Ginzburg, the leading mathematical cartographer of TsNIIGAiK, received the state prize for a special cartographic projection producing random distortions in map coordinates, distances, and directions.

In addition to TsNIIGAiK's scientific cartographic research, it participated in many international projects and meetings, most importantly the Eighth International Cartographic Conference of the International Cartographic Association in Moscow in 1976. The scientific program of the conference was organized by academics Konstantin Alekseyevich Salishchev and Komkov, while Alexey V. Postnikov, then employed by TsNIIGAiK, was the conference's scientific secretary.

ALEXEY V. POSTNIKOV

SEE ALSO: Geodetic Surveying: (1) Europe, (2) Russia and the Soviet Union; Glavnoye upravleniye geodezii i kartografii (Chief Administration of Geodesy and Cartography; Russia); Topographic Mapping: (1) Eastern Europe, (2) Russia and the Soviet Union

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***Types of Map.*** See Map: Map Typologies; Modes of Cartographic Practice