M

Magazines, Maps in. See Journalistic Cartography

Mairs Geographischer Verlag (Germany). Kurt Mair was an enthusiastic traveler and travel writer in the period between the two world wars, when he camped throughout Europe and Africa traveling by car and motorcycle. He penned the frequently reprinted best seller *Die Hochstraßen der Alpen* (1st ed., 1930). Mair directed the Stuttgart office of the Swiss cartographic publishing house Hallwag until 1939 and produced the *Hallwag-Autoführer von Deutschland*. After World War II, he founded his own cartographic publishing company, the Kartographisches Institut Kurt Mair, in Stuttgart in 1948 and began working with the Deutsche Shell AG, which had been reestablished in 1947. Thus began a success story of more than fifty years based on Germany's "economic miracle," when automobile ownership increased substantially across Europe and workers enjoyed longer paid vacations and increased leisure. The first Shell atlas appeared in 1950, becoming one of the most widely circulated publications in the world until it was discontinued by Shell in 2003. The first maps for the Allgemeiner Deutscher Automobil-Club (ADAC), the largest German auto association, also appeared in 1950. The ADAC Atlas and the ADAC Alpenbuch were published as a joint venture from 1972 until 1998, when antitrust authorities forced the dissolution of Mairs and ADAC. In 1952 the Kartographisches Institut Kurt Mair was renamed Mairs Geographischer Verlag. The twenty-six-sheet *Deutsche Generalkarte* 1:200,000 was produced between 1954 and 1957. Expressly not offered as a free road map at gas stations, it was Germany's most widely sold map.

After Mair's sudden death in 1957, his son, Volkmar Mair, took over leadership of the firm. The publishing and printing house relocated to new production facilities in Kemnat, near Stuttgart, in 1972, where the firm remained into the twenty-first century. Grandson Frank Mair was named director of cartography and electronic media in 1999. Relationships between road and guidebook mapping firms and agencies involved in travel more generally were customary in the industry, but Mairs achieved its superior position as a result of its excellent and constantly updated cartography. In addition to Shell and ADAC, Mairs worked with the long-established battery manufacturer VARTA (Varta Führer or Varta Guides), Lufthansa, the tire manufacturer Continental (Conti-Atlas), Allianz-Versicherungsgesellschaft, and the Deutsche Bundesbahn. Mairs successfully took over a number of reputable map and travel guide companies with established brand names and kept them in business. In 1951 it started a joint auto-guide venture with the Baedeker publishing house, which had moved from Leipzig to Freiburg. Following the death of the previous owner, Karl Friedrich Baedeker, Mairs eventually took complete control of the Baedeker firm and relocated it to Kemnat. Mairs enjoyed similar success in concentrating the mapmaking efforts of the Munich-based IRO-Verlag in 1992, Ferdinand Ranft/Marco Polo in 1995, KOMPASS-Kartenverlag Fleischmann in 1997, and HB-Bildatlas-Verlag in 2000. The purchase of the Falk-Verlagsgruppe from Bertelsmann in 1998 had a spectacular impact on the industry. Falk-Verlag had been founded in 1945 by Gerhard Falk and with its Falk maps had become the most well-known cartographic product in Germany and beyond. The heirs sold Falk to Bertelsmann in 1997, which merged its subsidiary RV Reise- und Verkehrsverlag with Falk to form Falk-Verlag AG. Eventually this group also included the Geodata Geographische Datenbanken, which had been founded collaboratively by Bertelsmann and Falk. Falk became Mairs' top map brand, which ultimately resulted in the withdrawal of Shell from Mairs. Mairs bought the Berlin-based map division of the StadtINFO-Verlag from Bertelsmann in 2001. In the same year, Mairs acquired the majority of shares of Hallwag Kartographie, after Hallwag AG had already merged with the bankrupt Swiss publisher Kümmerly+Frey AG to form Hallwag Kümmerly+Frey AG. In 2005, after taking over the Cologne company DuMont Reiseverlag, Mairs became MairDumont.

JOACHIM NEUMANN

SEE ALSO: Marketing of Maps, Mass; Topographic Mapping: Western Europe

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Maling, D(erek) H(ylton). Born in Corbridge, Northumberland, on 8 May 1923, Derek Maling began his education locally, but was called up for military service in World War II. Serving with distinction in the Royal Air Force as a navigator, he was shot down in occupied Yugoslavia but rescued by partisans. After the war he served in the Falkland Islands Dependencies Survey, where he mapped Signy Island from 1947 to 1950. Resuming his studies, he took a BA in geography at King's College, Newcastle, in 1951 and went on to a PhD in 1956 on local glacial geomorphology. Maling began his academic career at University College Swansea. After retiring from a regular faculty position in the early 1980s, he remained with the University of Swansea (as it was later renamed) as an honorary research fellow until 1997. He died on 22 September 1998.

It was as a pioneer in promoting graduate training for cartographers that he first made his mark on the profession. Charged with creating courses within a geography department that produced general science geographers as well as more specialized graduates, Maling devised training that was academic yet embraced both the theory and the practicalities of map production. Criticisms of this approach by W. D. C. Wiggins, deputy director of Overseas Surveys, and Maling's rebuttals played out in the *Geographical Journal* from 1957 to 1959. Undeterred, he added a postgraduate diploma course to the undergraduate specialization in cartography, which was one of the first such courses in Britain. Individual students who embraced his courses and teaching enthused about his tutorial and pastoral skills.

A founding member of the British Cartographic Society (BCS), he naturally shouldered the task of elaborating his view of cartography as a university discipline rather than a craft-based technology focused on government institutions and commercial publishers. He soon became involved as a member of BCS committees responsible for the society's lecture programs and annual symposia. He retired from Council in 1971, and was named the society's third honorary fellow in 1981.

During these early days Maling found time to teach himself Russian in order to translate Soviet studies of map projections and to familiarize himself with the USSR's approach to cartographic research and training. He was also consulted by the Royal Society's working delegation to the International Cartographic Association's (ICA) working party on technical terms in cartography and prepared a study of terminology of map projections for the ICA's *Multilingual Dictionary of Technical Terms in Cartography* (1973). This effort bore further fruit in his book *Coordinate Systems and Map Projections*, published in 1973 and revised in 1992.

Maling's second book, *Measurements from Maps: Principles and Methods of Cartometry* (1989), distilled many years of reflection on the generalization and measurement of features on maps and provided a basis for later research on the application of automation and artificial intelligence to map generalization and pattern recognition. His scientific approach to the inherently artistic subject of map design, however idiosyncratic, was informed by a wide reading of work by scholars in Russia, Germany, France, and North America.

An early supporter of ICA endeavors, Maling rarely left his study in the forests of South Wales, where he honed his remarkable ideas. Although eagerly involved in establishing the BCS, he increasingly put his efforts into research papers, books, and teaching. Easily mistaken for an absentminded university educator, Maling was a significant figure in the development of cartography as an academic discipline in the second half of the century.

CHRISTOPHER BOARD

SEE ALSO: Cartometry; Education and Cartography: Cartographic Textbooks

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Map.

DEFINITIONS OF MAP
MAP TYPOLOGIES
PRINTED MAP
IMAGES AS MAPS
MAP AS METAPHOR
ELECTRONIC MAP
SENSE OF PLACE AND THE MAP

Definitions of Map. Geographical maps and mapping (the activity of making maps) are situated at the heart of the traditional definition of the word *map*. Considered from that viewpoint, map-like graphic displays, such as gene maps, or mapping-like activities involving nonspatial content, such as mapping out a course of action, can be regarded as peripheral. Despite excluding nongeographical uses of "map" and "mapping" in fields such as genetics, physiology, mathematics, linguistics, athletics, and dance, J. H. Andrews still found 320 definitions of map to review, concluding, "We all know what 'map' means sufficiently well to make ourselves understood" (1996, 7). Approaching the map as a lexicographer, not as a cartographer, he may have been right to argue that degrees of "mappiness" form a continuum, such as that between realism and abstraction. But in treating so many definitions as if they were equivalent and without examining connections, if any, between them, he could conclude only that they made "an interesting historical source" (1996, 7). Further conclusions could have been drawn, as the following selected and coordinated view of the evolution of definitions of map in the context of the history of cartography in the twentieth century shows.

After reviewing changing definitions of map for the first volume of *The History of Cartography*, J. B. Harley and David Woodward (1987, xvi) decided, for the purposes of a general history of cartography, on the following: "Maps are graphic representations that facilitate a spatial understanding of things, concepts, conditions, processes, or events in the human world." Their strongly representational definition could have applied in the early 1900s but, although popular in the 1980s and later, it had by then become insufficiently general. Nevertheless, "spatial," in preference to "geographic(al)," avoided confusion with the latter discipline with which maps had long been intricately related. Many cartographers preferred to add "are intended to" or "are designed to" before "facilitate." Definitions of map discussed in volume 2.3 of the *History of Cartography* (Bassett 1998, 24–25; Woodward and Lewis 1998, 537) demonstrated the robustness of that decision.

In the year 1900 cartography was about mapmaking. Map appeared to require no formal definition. Maps were representations according to most commentators. Hugh Robert Mill's unpublished "Dictionary of Geographical Terms," ca. 1900–1910, defined "map" as: "A representation of the earth's surface or a part of it, its physical and political features, etc., or of the heavens, delineated on a flat surface of paper or other material, each point in the drawing corresponding to a geographical or celestial position according to a definite scale or projection" (Stamp and Clark 1979, 321). For Mill, geography and maps were inseparable; if something could not be mapped it was not geography. Note that the definition above referred to visible and invisible features, a flat surface, and a tangible medium. The use of definite scale ruled out variable-scale products. It apparently excluded globes but could include plans and charts. It seems that military users of that time favored a definition that was stricter, because they required a more accurate and precise product. Geographers like Mill were content to follow them by accepting standards adopted by military organizations, which were often the national mapping agencies.

The representational definition held sway until the mid-twentieth century. Few authors felt obliged to define map. For Herbert George Fordham (1921) a map was both pictorial and scriptorial, a juxtaposition that not only drew attention to both graphic and the lettering elements but also introduced the notion of convention, related to long-standing practice in the use of symbols. For Edward Dalrymple Laborde (1928) a map was a representation of all or part of the earth's surface, not a picture, scaled and in plan. By the 1920s the air photograph had become more familiar, and a proper distinction from pictures had to be drawn to deny it the status of a map.

Just before World War II Erwin Raisz published the first broad-ranging cartography textbook in English, *General Cartography* (1938). Regarding the map as "the chief instrument" to reveal the earth's pattern, he defined it as "a conventionalized picture of the earth's pattern as seen from above, to which lettering is added for identification" (Raisz 1948, xiii; 1938, 1). War and economic stringency delayed the full impact of Raisz's work until the 1950s, when new textbooks in English were soon joined by others in French and German. Postwar cooperation among mapmakers gave rise to international conferences, soon creating a demand for a multilingual glossary of cartographic terms. Not surprisingly there was a greater consensus about *map* than *cartography*. One of the earliest tasks of the fledgling International Cartographic Association (ICA) was to create a multilingual dictionary of technical terms for cartography beginning in 1964 (ICA 1973). The British put forward: "Map. A conventional representation, normally to scale and usually on a flat medium, of a selection of material or abstract features on or in relation to the surface of the Earth or of a heavenly body" (British National Committee for Geography 1966, 25). It was accepted with minor modifications by cartographers in the ICA, although the general public remained untouched by such nuances.

The ICA's final definition of map in 1973 was a cartographer's definition. It naturally furnished an opportunity to analyze exactly what map meant and to place it in context with cartography. Although J. S. Keates (1982) and others remained faithful to the map as fundamentally a representation of the reality of the earth, their representational view was soon challenged by a newer theoretical framework, the communication paradigm.

The communication approach was articulated by academic cartographers during the 1970s and early 1980s. Meanwhile, Arthur H. Robinson and Barbara Bartz Petchenik (1976, 16) clearly focused on the map as the way to arrive at a general theory of cartography. They defined map as "a graphic representation of the milieu" and avoided reference to the medium, aware that traces on a cathode ray tube (CRT) and raised patterns on plastic in Braille maps would need to be included. Their book marked a shift to the communication paradigm in cartography but also recognized the importance of cognitive aspects of mapping. Theirs was probably the most influential statement about maps before the arrival of computer assistance on a commercial scale.

Despite the increasing separation of cartography from its parent geography, some authors remained firmly within the latter discipline. Bewailing the unnecessarily restrictive and counterproductive definitions of map, Phillip Muehrcke (1981, 15) proposed "an image of the environment."

Despite his lack of concern with the ICA, Howard T. Fisher (1982) chose to follow ICA practice. A designer and architect, he devised a very early computer-assisted mapping system (SYMAP) at Northwestern University. In his posthumously published *Mapping Information* (1982) he began by answering the question "What is a map?" Although no concise definition emerged, he saw a map as a spatial analog, conventional, representing geographical and abstract space.

The arrival of computer-based mapping finally prompted a radical reassessment of what maps were. In the late 1970s Harold Moellering began questioning the usefulness of simpler models of cartographic processing due to the wider range of products, signaling "a need for a broader definition of the concept of the map" (1980, 13). Maps were virtual as well as conventional: virtual maps could either be directly viewable, or permanently tangible, or neither.

The benchmark study (Taylor 1980) of the changes wrought in cartography by the rapidly increasing use of computers examined many ways in which computers assist map production. Joel L. Morrison (1980), who addressed issues of cartographic methodology, still treated the map as the end product but mentioned new products and map-like images used in medical and other sciences. His keynote address at Auto Carto London (1986) pointed out that cartography for some could be defined without reference to the map. Quoting Stephen C. Guptill and Lowell E. Starr (1984, 3), he said that for them it was "an information transfer process that is centered about a spatial data base which can be considered, in itself, a multifaceted model of geographic reality." Such a definition, radically opposed to the popular concept of the paper map, was too general to be helpful.

The arrival of off-the-shelf geographic information systems (GIS) and statistical packages with associated mapping programs provoked international debates about producing an up-to-date definition. Led by D. R. F. Taylor, the newly elected ICA president, a working group on cartographic definitions was set up in 1987 and reported in 1989 and 1991. The British Cartographic Society produced three definitions of cartography, all including maps. However, the final definition did not mention maps, due in large part to a paper by Mahes Visvalingam (1989). The report made to ICA in 1989 summarized Visvalingam's arguments, widening the concept of map to spatial as well as geographical subject matter. The following definition was proposed: "*Map*. A holistic representation and intellectual abstraction of geographical reality, intended to be communicated for a purpose or purposes, transforming relevant geographical data into an end-product which is visual, digital or tactile" (Board 1989, 15). However, the second report on the work carried out between 1989 and 1991 was published only in May 1992. The following definition of map was offered: "A representation or abstraction of geographical reality: a tool for presenting geographical information in a way that is visual, digital or tactile" (Board 1992, 12). After discussion at the Bournemouth conference of ICA, a final report was published; it defined map as "a conventionalized image representing selected features or characteristics of geographical reality designed for use when spatial relationships are of primary relevance" (Board 1991, 17). The definition was modified by the ICA Executive Committee adding that it was "resulting from the creative effort of its author's execution of choices" (Grelot 1992, 3). In May 1994 the ICA Executive incorporated that definition of map in its mission statement.

Clearly the impact of technological change led to a reevaluation of the meaning of "map" during the twentieth century. Even though geography and spatial relationships remained parts of the definition, some exploration of the peripheries of "mappiness" took place. The last third of the century saw the definition expand to take in types of map hitherto excluded. That expansion generally benefited the discipline of cartography, which still focused on the map and its creation, properties, and functions. Since the ICA's definition was rather abstract and needed some explanation to the wider public, the definition in the first volume of *The History of Cartography* also remained in use.

CHRISTOPHER BOARD

SEE ALSO: Academic Paradigms in Cartography; Electronic Map

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Map Typologies. Map typologies distinguish groups of maps with something in common. Although typologies are based on various criteria, including content, conceptual form, type of measurement of the data, and map form, the exact nature of within-group sameness and between-group differences is not always straightforward. Ideally, typologies would comprise all maps, and their categories would be mutually exclusive. Again, the ideal is elusive. Nevertheless, for pedagogical and general communication purposes, typologies have been widely used.

The basic typology that dominated cartography in the twentieth century was the dichotomy of general (or general reference) and thematic, the latter term coined in the 1950s (Creutzburg 1953). General maps (e.g., topographic and general atlas maps) were often described as suitable for multiple purposes and for showing a variety of phenomena, whereas thematic maps (e.g., population or agricultural production maps) were described as "special purpose" or as showing a distribution rather than the locations of specific features. Such descriptions were problematic because some distributional information is available from maps classified as general and some location information is clearly evident on maps classified as thematic. Furthermore, some maps defy classification in such a scheme; navigation maps, for example, have a very special purpose, yet show the locations of a variety of features. The nature of general and thematic mapping was a major theme in *The Nature of Maps*, in which the authors argued that logical and infralogical operations underlie these categories (Robinson and Petchenik 1976).

The troublesome nature of the definitions influenced the development of task classifications, that is, the categorization of what users do with maps. A hierarchical task typology might suggest that a reader could look at a map and identify symbols, look for specific locations, observe relative location, find distribution or pattern, or hypothesize about the relationships between features or distributions (Board 1978; Olson 1976). Yet maps themselves do suggest categories, and speculation about the development of maps may reflect what separates one category from another. The earliest maps most likely depicted the relative location of one feature to another, and what we would call general maps and navigation maps thus came into use. Much later, an intellectual focus on specific phenomena likely led to inventory maps (maps showing where each known instance of a phenomenon was located) and location maps (maps showing where data such as temperatures or wind directions had been gathered). Those, in turn, were followed by the more abstract distributional maps in which every instance of an item figured into the counts or relative numbers represented on the map, but locations of individual instances were either not represented or were not the main feature of the map. By the twentieth century, typologies were needed and their terminology was becoming part of the discourse in cartography.

Further breakdowns into categories have been especially well developed within thematic maps. Such terms as choropleth, dasymetric, graduated symbol, flow, cartogram, and isarithmic map were widely used in the twentieth century and were familiar to students in cartography classes. The definitions of these terms involved data types (most basically qualitative and quantitative) as well as the conceptual form of the phenomena (point, line, area, and volume, sometimes expressed as dimensions and later including fractional dimensions such as 2½), form of the distribution (noncontinuous or continuous, the latter of which might be stepped, smooth, or a combination), and symbol form (points, lines, and areas; or spots, bands, and fields) (Fisher 1982, 60–115). A choropleth map, for example, was generally understood to show quantitative information and, furthermore, mapped values were generally ratios affected by the enumeration unit being used—e.g., population density, corn production per acre, or tractors per farm; the phenomenon was conceptualized as a stepped continuous surface; and the depiction was by areal units (such as counties). By contrast, an isarithmic map assumed a smooth and continuous surface and used lines of equal value for representation, and it was called isometric if the data existed at points (e.g., temperature) or isopleth if data required area in the calculation (e.g., population density). In the early days of using computers to produce maps, Howard T. Fisher (1982) proposed alternative terms based on the physical form of the map. The same computer algorithm could be used to map any data by areal unit, and he called that type of map conformant. Any map with lines of equal value he called contour, a term that had previously referred specifically to maps of land elevation.

Late in the twentieth century, the use of terms for types of maps was largely abandoned in some of the major geographical information system software. Users of Environmental Systems Research Institute (ESRI) products could very easily produce choropleth (conformant) maps, yet there was no use of the term within the software. The vocabulary of traditional typologies continued in use in classrooms and writing, though gaps and inconsistencies persisted.

Map typologies expanded as animation and interactive mapping increased in use (Lobben 2003). The terms static, animated, and interactive were categories that overlay onto other typologies, as the maps that are changing or with which the user is interacting also fit into other categories.

JUDY M. OLSON

SEE ALSO: Education and Cartography: Cartographic Textbooks; Modes of Cartographic Practice

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Robinson, Arthur H., and Barbara Bartz Petchenik. 1976. *The Nature of Maps: Essays Toward Understanding Maps and Mapping*. Chicago: University of Chicago Press.

Printed Map. When the twentieth century dawned, the printed map (created by impressing an inked printing image onto paper) had dominated map reproduction for more than four hundred years and gave no hint of impending decline. Although revolutionary when introduced, printing methods changed little until the nineteenth-century industrial revolution brought rapid technological change. By the early 1900s cheaper printing processes, both relief (raised image) and planographic (chemically differentiated image), had largely replaced expensive intaglio copper engraving (incised printing image). Partial compensation for the coarser linework of the new processes was their ability to print tones and colors. Mapmakers tried one new printing process after the other (Robinson 1975, 15). Wax engraving, popular in America but declining, lingered into the mid-1900s with map publishers heavily invested in equipment and plates. Photoengraving became the favored relief process everywhere for reproducing maps with letterpress text, while photolithography (planographic) took over the printing of sheet maps.

The tide of innovation rolled into the twentieth century without abating, but the focus shifted from printing to the preprinting stage, largely because of photography. Now that map artwork was being drafted for photography, control over the look of the printed map had passed from the printer to the draftsman (Robinson 1975, 21). Although a trained draftsman could achieve good results, amateurish "sketch maps" copied by the undiscriminating lens of the camera also began appearing in geographical journals around 1900.

Line photolithography for map reproduction had spread from Australia in 1859 to Europe and America (Nadeau 1989–90, 2:374). The halftone photographic screen, perfected in America in the 1890s, could also transform tonal images into printable patterns of black dots or lines. By the early 1900s halftoned photographs of three-dimensional terrain models were illustrating geography books and atlases. Soon thereafter came the photomechanical separation of colored images for printing in cyan, yellow, magenta, and black, the four process colors (fig. 487), a method soon used to reproduce bird's-eye views. By about 1930 photoengraving

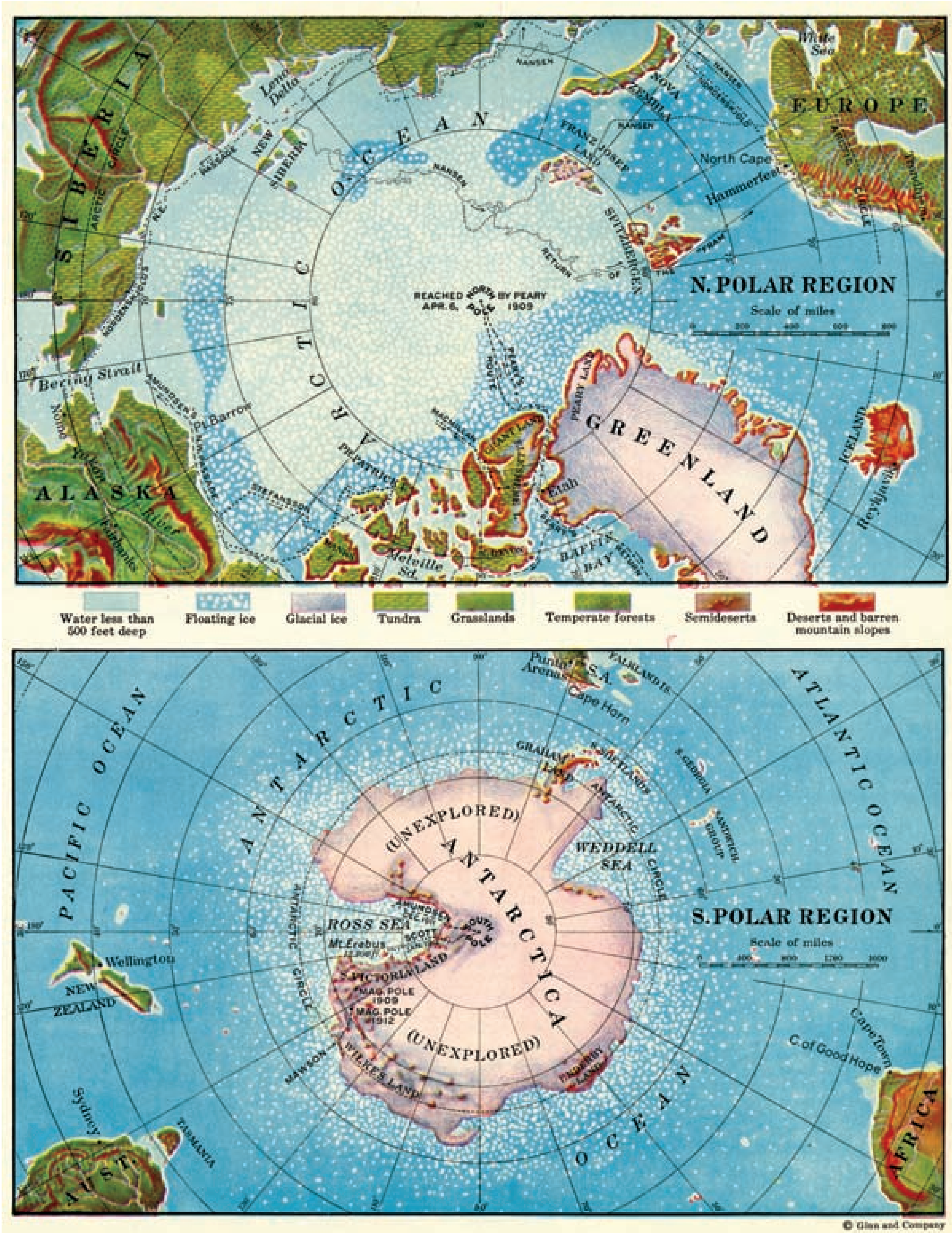

FIG. 487. COLOR MAPS OF THE POLAR REGIONS, 1920. This page of polar regions maps is an example of reproduction by photoengraving printed in process colors from photographic color separations of watercolor drawings and separate black negatives of pen drawings. When reproduced in Louis Flader, comp. and ed., *Achievement in Photo-Engraving and Letter-Press Printing* (Chicago: American Photo-Engravers Association,1927), 351, the maps were captioned "The Last Word in Color Maps."

Size of the original: 24.3 × 18.9 cm. From Wallace Walter Atwood, *New Geography, Book Two* (Boston: Ginn, 1920), 267.

processes, requiring costly plate work by the printer, began yielding to cheaper photolithography for both text and graphic reproduction (Claybourn 1927, 156–57). Maps and other photolithographed illustrations became common in magazines and newspapers, while the free oil-company road map became the ubiquitous icon of midcentury America's emerging automobile-centered lifestyle. While decorative covers lured map customers, improvements like waterproof paper also made these maps more practical.

During World War II mechanization enabled map production to meet demands for faster reproduction of military maps. Pen-and-ink drafting for photolithography was made easier by new tools (such as reservoir pens in standard sizes) and materials (such as preprinted adhesive-backed lettering, point symbols, patterns, and tints). Cartographers were able to write map specifications that draftsmen in another building could follow with reliable results. Postwar, the new techniques continued in government use but also spread into the public sector. For example, direct scribing of photographic negatives (using sharp tools to remove actinically opaque coating from transparent plastic backing) was in general use by the 1960s. Scribing, offering a quality of line comparable to copper engraving, became the acme of map production, but only for a decade or two.

Other reproduction methods and map formats were already infringing on the domain of the printed map. The economy of scale achieved by large press runs could leave publishers holding stocks of aging unsold maps (Monmonier 1985, 144–45). Strategies like overprinting interim updates in magenta on U.S. Geological Survey topographic maps reduced but did not solve the problem. Other government agencies began to store and update full-size master maps, duplicating them on demand by one-to-one processes such as Ozalid, invented in 1917 (Nadeau 1989–90, 2:353), while microphotography allowed storage of miniaturized map images. Spirit duplicating processes and, later, electrostatic copying were employed to copy small maps for temporary uses. Meanwhile the 35 millimeter slide projector, movies, television, and radar displayed maps even more ephemerally.

All of these developments nibbled away at the market for the conventionally printed map, but it was the computer revolution that swallowed cartography (as well as photography) whole during the late twentieth century and began a process of digestion still under way in the early twenty-first century. As predicted decades earlier, by the 1990s geographic information systems (GIS) had shifted the focus from the fixed cartographic end product, the printed map, to the spatial database that software can transform into different visualizations and formats (Anonymous 1965). A. G. Hodgkiss's prediction in 1981 (p. 69) that 90 percent of all maps would be computer generated by 2000 has probably been exceeded. Maps printed lithographically from computer-generated printing plates remained cost-effective and convenient for some purposes but have become only one among many options.

KAREN SEVERUD COOK

SEE ALSO: Reproduction of Maps: Reproduction of Maps by Printing

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Robinson, Arthur H. 1975. "Mapmaking and Map Printing: The Evolution of a Working Relationship." In *Five Centuries of Map Printing*, ed. David Woodward, 1–23. Chicago: University of Chicago Press.

Images as Maps. The image—defined here as a photograph, drawing, or print not explicitly designated as a map—began to occupy a prominent place in cartography during the twentieth century. An abundance of aerial images mushroomed following the invention of photography in the late 1820s, and the airplane and airship in the early 1900s, in addition to the continued use of kites and hot air balloons as overhead platforms. Partly because cameras set visible patterns mechanically through their lenses' geometric transformations of light, photographs were believed to communicate geographic relationships and empirical data more realistically than traditional maps, and they began to be adopted for cartographic purposes in many regions. In 1876 Aimé Laussedat, a colonel in the French army, exhibited the first maps made from photographs taken from elevated points on the ground, while Cesare Tardivo, an Italian military surveyor, directed the first geographic survey by plane in the early 1900s (Birdseye 1940, 2–5).

Aerial images soon began to accompany articles in the popular and scholarly press. The first photograph ever published in *National Geographic Magazine*, in 1889, was an overhead view of a miniature topographic model of North America that boldly provided readers a sense of visual ownership of the entire continent. Building directly upon developments in surveillance technology during World Wars I and II, private and government surveys embraced the use of overhead imaging as well.

In 1929 C. H. Birdseye, chief topographic engineer at the U.S. Geological Survey (USGS) and founding president of the American Society of Photogrammetry, conducted an extensive aerial survey of the future site of the Hoover Dam (Birdseye 1940, 3, 11). In 1934, Harriet Shanks Platt and Robert S. Platt completed some of the first academic experiments with the new media, employing photographs they captured from the windows of commercial flights across Central America (Platt 1934).

Nevertheless, photographic images highlight only the visible features of the landscape, and these vary widely depending on weather and other factors. Therefore, interpretation and annotation, including the addition of labels and boundaries, are often necessary to distinguish photographs in their capacity as maps. By the 1930s the use of photographs for cartography had enabled a much greater role for land cover and sea surface maps, including depictions of built-up areas, vegetation, ocean level, and clouds. Simultaneously an entire body of research emerged to analyze mosaics of overhead images in order to describe relationships between visible features and underlying soils (McCracken and Helms 1994, 301–4).

One way to standardize the use of images as maps is to recast the image within a geographic framework. Orthophotographs are corrected so that they exhibit a uniform scale and plane projection, similar to a map. Ongoing development of the orthophotoscope starting

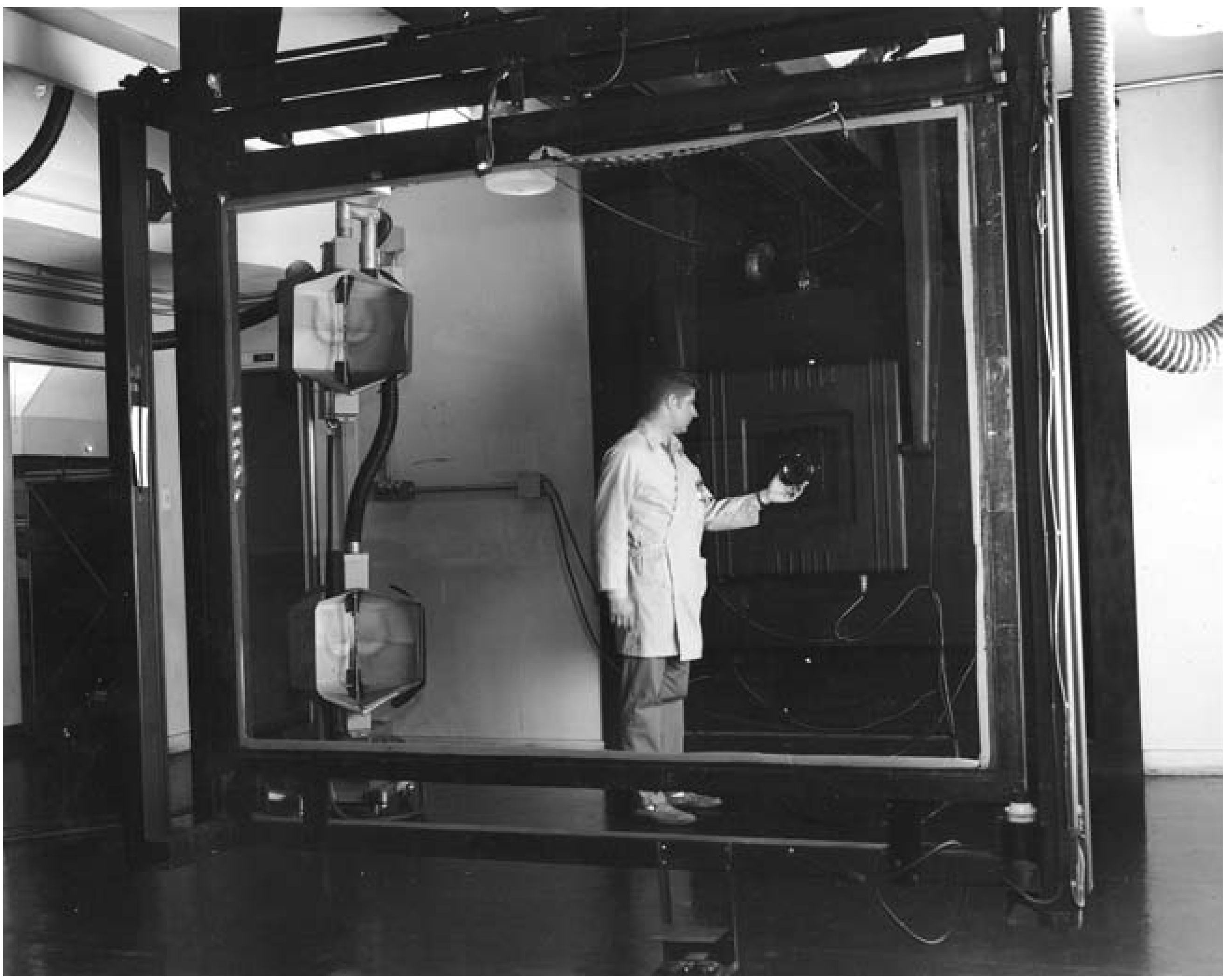

FIG. 488. ROBERTSON COPY CAMERA, 1 JANUARY 1965. The camera was installed in 1959 at the U.S. Geological Survey Western Region, Menlo Park, California. It was used for transforming the scale of images during the production of orthophotographs, and is seen here being adjusted by photographer Jay Prendergast. The sheer size (48-inch lens, 4.5 tons) and cost of the analog machinery initially developed to produce high-resolution orthophotographs was one reason that a full orthophoto series for the United States was not near completion until 2002.
Image courtesy of the U.S. Geological Survey.

in the 1930s led to the automated production of orthophotographs, and in 1965 the USGS began publishing a series of 7.5-minute orthophotoquadrangle maps, sometimes called orthophotoquads. However, the process was labor intensive and required massive machinery (fig. 488), and a series of high-resolution orthophotos for the entire United States was only near completion in 2002, roughly a decade after the introduction of digital orthophotography (USGS 2002).

Satellites developed in the context of Cold War surveillance allowed for imaging at much broader scales as well as the collection of data outside the spectrum of visible light. After the 1960 launch of the Television Infrared Observation Satellite (TIROS), the U.S. Weather Bureau provided cloud cover data free of charge, and photographic images began to replace maps in weather forecasts. In the early 1990s the artist Tom Van Sant led a team that pieced together 35 million separate pixels of satellite data to create the first high-resolution aerial image of a cloudless globe bathed entirely in sunlight (Pickles 2004, 62–63). As Internet maps proliferated, the composition of diverse data proved to be a persistent challenge. By 2011 most virtual earth maps included an overlay that was labeled only as a satellite layer despite the fact that it generally contained a patchwork of both satellite and aircraft imagery; often the seams were even visible as the user zoomed in toward ever finer scales (Taylor 2009).

The resolution of geospatial data grew exponentially during the 1990s, and raster images—grids in which each pixel represents a numerical value—began more closely to resemble photographs, which are essentially rasters that depict visible light (fig. 489). As a type of graph scaled to a map of the region it portrays, a raster is reminiscent of Argentinean essayist Jorge Luis Borges's apocryphal description of a map of an empire that coincides "point for point" with the empire itself (Borges 1999). Nonetheless, the widespread use of images as maps is one of the most significant developments in twentieth-century cartography, a process that productively blurs the boundaries between graphs, maps, and images.

JESS BIER

SEE ALSO: Anaglyph Map; Globe: Views of Earth from Space; Photogrammetric Mapping: Orthophotography and Orthophoto Mapping; Photography in Map Design and Production; Software: Image Processing Software

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Map as Metaphor. The metaphoric use of the word *map* to refer to an object or process that is not cartographic in nature precedes the twentieth century. *A New English Dictionary* (1888–1928; later to become *The Oxford English Dictionary [OED]*) defined the noun *map* as "a circumstantial account of a state of things." In addition, it defined the verb *to map out* as "to plan out (a course of conduct or behaviour), to divide up." This latter definition can be traced back to the seventeenth century.

The Century Dictionary (1911), published in New York, offered a lengthy literal definition of *map* as "representing a part or the whole of the earth's surface . . . ," followed by the much shorter figurative definition: "a distinct and precise representation of anything." Similarly, the first edition of the *OED* (1933) defined *map* figuratively as "a mental conception of the arrangement of something." *Map* was also defined there as "a figure resembling a map in form or outline," or "the embodiment or incarnation (*of* a virtue, vice, character, etc.)." The second edition of *Webster's New International Dictionary* (1934) was far more strict and provided only literal definitions.

The *OED* took several decades to update its 1933 version. Delayed by World War II and a particularly thorough and laborious expansion process, the second edition was not finished until 1989. During the interim, other, more compact dictionaries assimilated the *OED*'s characterizations, based on its research in the late 1950s and published in supplements during the 1970s and 1980s. For instance, *The Random House Dictionary* (1966) defined *map* metaphorically as "a maplike delineation or representation of anything," or simply as "the face" (slang). It also offered some figurative definitions of its own, for idiomatic phrases that included the word *map*. For example, *off the map* was defined as "out of existence; into oblivion"; to *put on the map* as "to bring into the public eye; make known"; and *to map out* as "to sketch or plan" (as in a career). *Webster's Third New International Dictionary* adopted similar phrase-definitions in its 1976 and 1983 supplemental versions.

The enormous and expansive *OED (Online)*, available since 2000, offers a whole slew of additional metaphorical definitions. For example, *to map* can be: "to be spread out to view like a map"; "to colour or shade in patches"; "to plan or devise (a course of action, etc.)"; "to plan or project"; and "to divide (a country, etc.) as

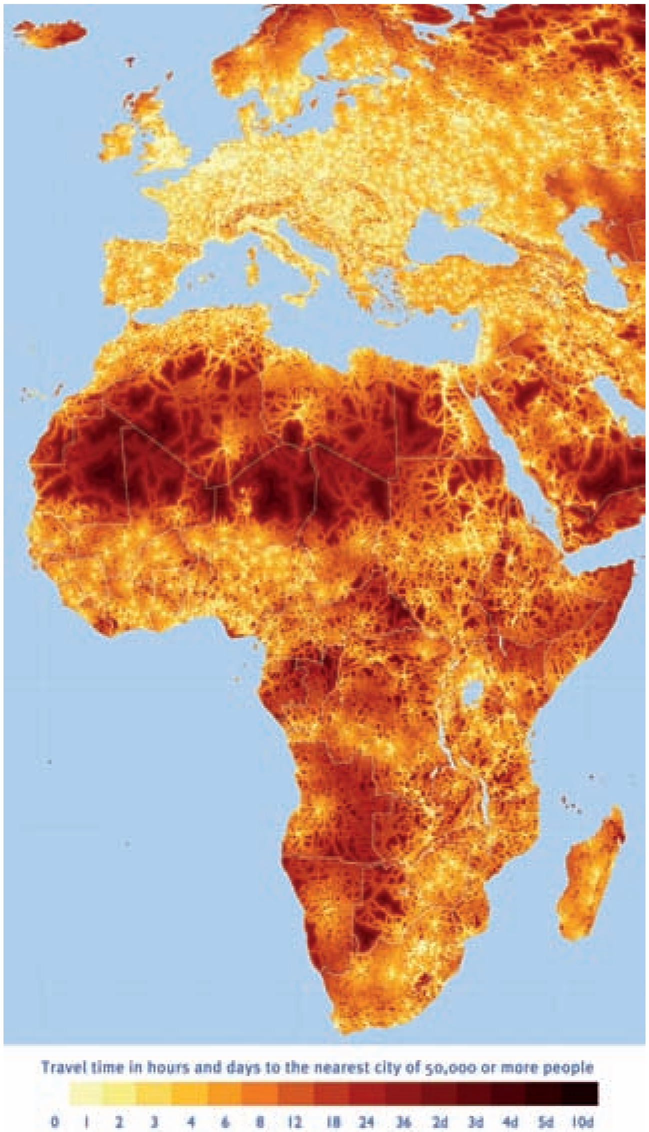

FIG. 489. DETAIL OF AFRICA FROM *TRAVEL TIME TO MAJOR CITIES*, IN THE YEAR 2000. The map shows estimated travel time to the nearest city of 50,000 or more people by A. Nelson, 2008. ESRI Grid format, 30 arc seconds resolution. Images have become so influential in cartography that maps have begun to mimic images; despite consisting of a map that contains no aerial image data, this raster plot of accessibility estimates in Africa distinctly resembles a nighttime satellite photograph.
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by lines on a map." It also specifies definitions of *to map* within the fields of linguistics ("to associate [a linguistic element or group of these] with another element or group of elements by the application of a rule") and mathematics ("to associate [an element] with one or more others"). In addition, the *OED (Online)* defines the noun *map* as "a conceptualization or mental representation of the structure, extent, or layout of an area of experience, field of study, ideology, etc." and also as "a shape or pattern resembling a map in form or outline." Moreover, a phrase like *all over the map* can mean "widely distributed, in many different places."

In a formal sense, the word *map* began the twentieth century with some basic, if limited, metaphorical possibilities. But by the end of the century, it embodied a remarkable breadth of metaphorical directions. It is doubtful that many other words in English with so specific (and unambiguous) a central literal meaning evoke such a wide array of metaphorical meanings.

The mass media's use of *map* as a metaphor suggests a somewhat different historical trajectory. In the absence of a comprehensive study on the specifics of the popular use of the word *map*, a look at *New York Times* headlines from 1890 through 2006 provides a general picture, at least for the United States. The word *map* obviously offers all sorts of advantages to the headline writer: besides evoking a whole plethora of meanings (as indicated above), its mere three letters make efficient use of limited space. Curiously, the metaphorical use of *map* was largely absent from *New York Times* headlines from 1890 through the late 1920s. But between about 1929 and 1968, the popularity in headlines of *map* as a metaphor exploded, particularly for articles on politics or fundraising. For example, one "mapped out" or simply "mapped" a campaign drive. One also "mapped" a plan, a war, tactics, a program, a strike, or simply an action. After 1968, these uses of *map* suddenly disappeared from headlines, as if the metaphor were no longer fashionable. Even so, the 1990s and early years of the twenty-first century witnessed a growing popularity of "road map" to refer metaphorically to any kind of official plan of an unusually complex, fluctuant nature.

Within academia, the specific ability of *map* (or, for that matter, *cartography*) to conjure up the notion of rendering decipherable a complex, multilayered, and seemingly random set of relations has been of particular value, especially since the "postmodern turn" of the 1980s. Influential scholars in diverse fields have included *map* and *cartography* figuratively in the titles of numerous books and articles. This trend seems to have been instigated by a concern, typically associated with feminist critique, over the multifaceted construction of identity. Literary critic Joanne Feit Diehl's "Cartographies of Silence" (1980) is perhaps the earliest use of *cartography* as a metaphor in an academic title. The trend soon spread to other segments of the humanities. For instance, noted historian of German philosophy and social criticism Andreas Huyssen published "Mapping the Postmodern" (1984), while the widely influential French theorist Félix Guattari published his *Cartographies Schizoanalytiques*

(1989), a landmark treatment of modern social psychology. Perhaps unsurprisingly, more traditional disciplines such as history, which often use actual maps as evidence, have been more hesitant to adopt this practice.

In sum, over the course of the twentieth century, the use of *map* as a metaphor has evolved differently in different realms of discourse. While dictionaries of the English language have gradually expanded their collections of figurative definitions to be relatively all-encompassing, mass-media headlines seem to have made use of such figurative definitions only during the middle third of the century. By contrast, the metaphoric use of *map* in academia did not catch on at all until the 1980s, but remained fairly popular into the following century.

JACOB SHELL

SEE ALSO: Social Theory and Cartography

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Electronic Map. The advent of electronic computing in the twentieth century presented an opportunity to create a new map form, the electronic map. A marked departure from maps printed on tangible surfaces, the electronic map offered a range of possibilities not yet fully realized at the outset of the twenty-first century.

Electronic maps changed the definition of the map as well as some of its basic characteristics. *Electronic* implied nontangible and possibly nonvisual (Moellering 1984). Although map data had been processed digitally in the 1950s, computer hardware and applications developed in the 1960s and 1970s allowed mapmakers and other users to access, transform, and display the data electronically (fig. 490). These early developments were severely constrained by existing technology, but improvements in computing and electronic display in the 1980s greatly expanded the options for displaying electronic maps. As new capabilities evolved, the simple, monochromatic renderings of geographic data gave way to innovative cartographic designs, which changed the nature of traditional cartography.

Early criticism of the electronic map often reflected a reluctant acceptance of the product's appearance (Rhind 1977). Computer-assisted cartography, sometimes called "the new cartography," was considered artistically inferior to hand-crafted maps insofar as a machine could not draw or etch a fine curved line with the same precision and quality as a cartographer. Indeed, replicating manual processes was far from straightforward. Frustrated efforts to imitate manual methods led to new approaches, which eventually expanded user capabilities and involvement. Placing names, designing symbols, applying basic concepts of generalization, and integrat-

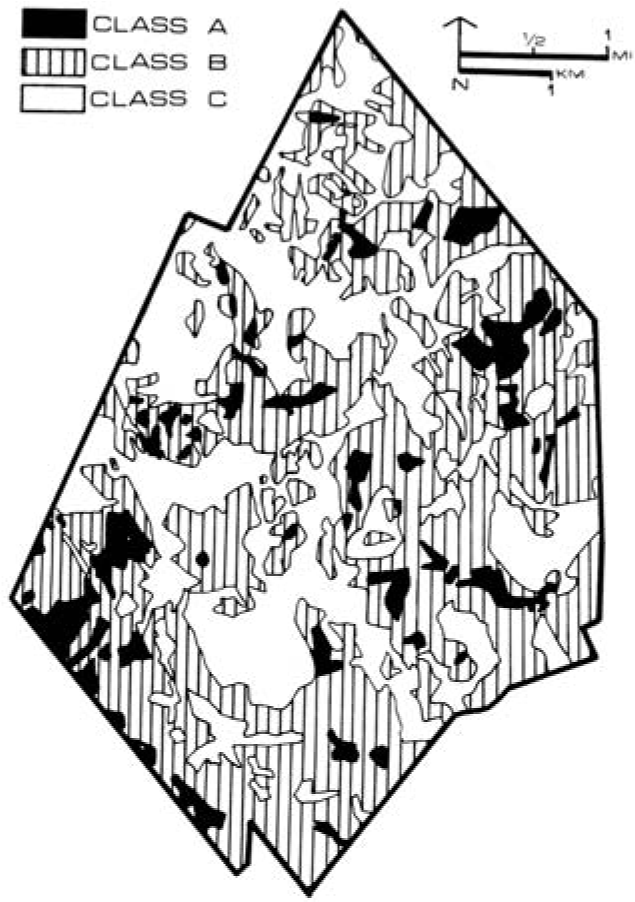

FIG. 490. EARLY EXAMPLE OF ELECTRONIC MAP, BURLINGTON, MASSACHUSETTS. Original data (on soils, land use, topography) were digitized, and source maps and overlay maps were produced culminating in this composite topoclimatic map to evaluate suitability of the area for development. The resulting categories were: A. most suitable; B. marginally suitable; and C. least suitable.
Size of the original: 15 × 10.5 cm. From Spencer A. Joyner, Raymond S. Bradley, and Robert E. Reiter, "Topoclimatic Aspects of Developmental Suitability in the Metropolitan Landscape," in *Proceedings of the Conference on Metropolitan Physical Environment* (Upper Darby: Dept. of Agriculture, Forest Service, Northeastern Forest Experiment Station, 1977), 163–71, esp. 169 (fig. 2).

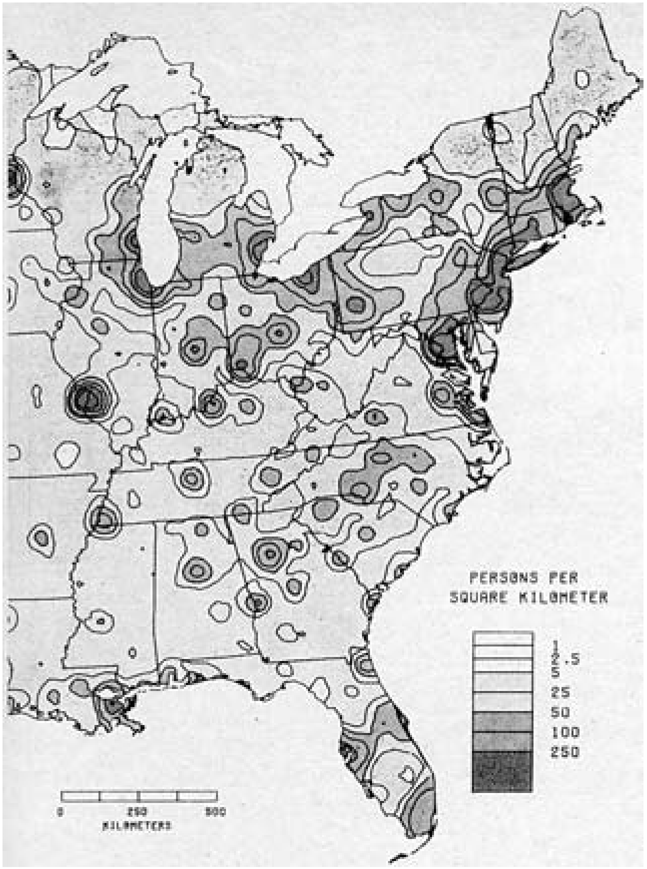

FIG. 491. PORTION OF AN EARLY COMPUTER GENERATED MAP SHOWING POPULATION DENSITY. Prepared in the University of Wisconsin Cartographic Laboratory in Madison in 1972. The linework was done on a Calcomp plotter and the tones added photomechanically.
Size of the original: 11.3 × 8.4 cm. From Joel L. Morrison, "Changing Philosophical-Technical Aspects of Thematic Cartography," *American Cartographer* 1 (1974): 5–14, esp. 9 (fig. 1). Reproduced by permission of Taylor & Francis.

ing complex data elements traditionally done by intricate reasoning of the cartographer was now the work of a machine driven by algorithm, but the interaction at workstations or personal computers allowed human intervention at various stages (fig. 491).

Practical applications evolved slowly from rudimentary prototypes, but their potential to transform mapping was recognized decades in advance. In the early 1950s researchers at the Massachusetts Institute of Technology demonstrated computer graphics with points of light focusing on a cathode ray tube in the Whirlwind computer (Hurst et al. 1989). This discovery presaged a new form of map that would dominate the latter part of the century. In 1959 geographer Waldo R. Tobler suggested the idea of cartographic automation in which the map was not only a form of data storage but also a computer input and a data-processing output. At the time, computers were capable of reading coordinates from punch cards and reproducing a simple outline map as a set of straight-line segments connecting the coordinates. Tobler envisioned a series of stored programs whereby computers could not only reproduce an existing map but also change the map projection and the scale as well as generalize cartographic features.

In the 1960s the idea of using a computer to produce maps was beginning to take hold within the cartographic community (Rhind 1977). But there were pockets of resistance, and some cartographers even believed that computers had no place in geography. At this time there were two different approaches to computer mapping. One used computers as a means of what Canadian systems consultant Roger F. Tomlinson (1988, 251), an early developer of electronic maps, described as "the use of computers to make hardcopy maps, or put differently, the process of using computers in automating the cartographic compilation process." The other approach focused on geographic information systems (GIS) with "geographical data handling and analysis capabilities that could be used on a growing digital database for repeated geographical problem solving of different kinds over time" (Tomlinson 1988, 252). Work on the Canada Geographic Information System (CGIS) began in the early 1960s and the system was fully functional by 1971. GIS developments initiated in this early period include the Minnesota Land Management Information System (MLMIS), Harvard University's SYMAP (synagraphic mapping system), and the topological file structure of the GBF/DIME (Geographic Base File/Dual Independent Map Encoding) files at the U.S. Census Bureau.

In the 1960s digital map data were rare, and creating a cartographic database was an involved, time-consuming process. Even so, several cartographic databases were developed, most notably by federal agencies in the United States. U.S. examples include the Dahlgren database, a file of shorelines and international boundaries developed at the Navy's Dahlgren Laboratory; the Census Bureau's DIMECO database, consisting of county boundaries and U.S. coastlines; and the Central Intelligence Agency's World Data Bank, which contained world coastlines and international boundaries (Robinson et al. 1995, 223).

In the 1970s and 1980s many systems were designed with the ultimate goal of reducing the high cost of mapping. Automated scanning digitizers were developed to reduce labor cost and ensure uniformity (Robinson et al. 1995, 190–93). Automation offered new research and development opportunities that supported the electronic map through advances in computer mapping. The orthophoto, a photogrammetric product dependent on computer processing, not only served as a highly accurate source of information for map compilation but in many cases became the electronic map. Map animations displaying data changes over time provided another new electronic map form.

During this time, improved data structures led to different approaches for capturing, storing, processing, and displaying data. Two main types of systems existed (Tomlinson 1988, 258): the cartographic system, based primarily on data structures, provided mapmakers with sophisticated techniques for graphic editing, while the commercial, off-the-shelf GIS combined topological data structures with analytical capabilities. The commercial GIS was usually a turnkey system, that is, a fully integrated, stand-alone configuration of hardware and software components. Turnkey systems typically were not designed to work with other systems, and this incompatibility was characteristic of electronic maps created by software that supported a single fixed data format. These limitations resulted in an untenable position for customers who had invested significantly in one technology only to find it rapidly superseded by another design that was not readily adopted because of conversion costs and operational work flow commitments. As a result, consumers demanded a different approach, which prompted the federal government to develop spatial data standards, including an information transfer standard for cartographic data. Industry responded with its own standards for the exchange of spatial data and its own (often proprietary) electronic map file formats. Efforts at open source applications arose to challenge proprietary approaches designed to protect a vendor's market share.

Eventually, these systems converged, with the content and design of the cartographic database reflecting printed map characteristics, while the GIS focused on encoding real-world features to support multiuser interests and needs. This usually meant that cartographic decisions, rules, and fixed content and design were no longer explicit in the source database but had to be specified, calculated, extracted, and evaluated. This led to renewed interest in a separate cartographic database concept in the early twenty-first century in order to reduce the time and cost of processing, to ensure data quality, and to complement cartographic production needs.

The electronic map changed some constraints imposed on conventional cartography. Pen-and-ink manuscript maps were normally compiled at the scale of the final map. Photographic processes allowed reductions in scale, thereby sharpening linework and text by creating a much finer higher-resolution cartographic image. The electronic map allowed for scale changes in both directions. Users could zoom into a map for greater cartographic detail or reduce scale by zooming out to provide a generalized view of a wider area.

Automotive navigation systems entered the user market in the late 1980s and early 1990s. Honda installed the first car navigation system with a map display (see fig. 1108); it made use of an accelerometer and gyroscope—the commercial Global Positioning System (GPS) was not yet available—in the Accord (French 2006, 277–79). Pioneer Electronics released the world's first in-car GPS navigation system in 1990. Car navigation created a new user community of electronic maps as both a technological marvel and a practical wayfinder.

The Internet drastically altered mapmaking and map use in the last two decades of the twentieth century. As public access widened in the 1990s, the Internet exploded map use by making available—free to anyone with online access—an enormous array of maps, many of them interactive, and impelling a renewed interest in cartography. MapQuest, a direction finder, exploited available government data like the U.S. Census Bureau's TIGER (Topologically Integrated Geographic Encoding and Referencing) system to create a revolutionary web mapping service. Early in the twenty-first century Google Maps and Google Earth gave users an even greater ability to individualize mapmaking. Organizations and government agencies published maps and map services online, and some applications allowed users to select data themes and change legends. In addition, handheld GPS captured geographic coordinates that could be displayed on an electronic map, used by an amateur navigator to mark or retrace routes, or uploaded to a website. Growth of the mobile telephone industry led to color screens sufficiently large for viewing electronic maps—delivered by a wireless connection to the Internet. Automotive navigation systems expanded mapping capabilities and led to new markets for collecting and managing spatial data.

In conventional mapping, maps were designed with the final output device—the printing press—in mind. Computers altered this centuries-old approach to maps and mapping as the electronic map developed along various paths but often incorporating properties of the conventional map. Through time, technology and the adaptability and ingenuity of the cartographer accommodated and exploited the capabilities of electronic maps. Although cartography as a discipline struggled with its own identity as well as with terms like *computer-assisted cartography* and *automated cartography*, by the end of the twentieth century electronic maps in all of their forms had become commonplace.

TIMOTHY F. TRAINOR

SEE ALSO: Electronic Cartography; Geographic Information System (GIS): Computational Geography as a New Modality

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Tomlinson, Roger F. 1988. "The Impact of the Transition from Analogue to Digital Cartographic Representation." *American Cartographer* 15:249–61.

Sense of Place and the Map. "Sense of place" describes the emotional attachment between an individual and a locality. An affective bond develops between people and locations through time and can include both individual and group identifications with place. "Place" as used here is more than a distinct portion of geometric space—it is a location imbued with meaning by those who occupy it or interact with it. D. J. Walmsley and G. J. Lewis, writing in 1984 (Matthews 1992, 201), described the importance of sense of belonging or place-rootedness in our understanding of this phenomenon, while Yi-Fu Tuan (1974) adopted the more generic term, topophilia. Noel Castree (2003) identified serious consideration of this subjective phenomenon with the humanistic movement in geography starting in the 1970s (for example, the work of David Ley, Gunnar Olsson, and E. C. Relph). However, their interest in place had roots in the ideographic approach, concerned with the uniqueness of place, championed by Carl Ortwin Sauer in the 1930s (in contrast to the nomothetic approach of spatial science, the search for spatial laws) and evident in E. Estyn Evans' concern with the "personality" of place in his explorations of Wales and Ireland (Meinig 1983). The adoption of humanistic approaches in the 1970s was a reaction to the dehumanizing nature of spatial science and a concern to foreground human experience, but it also built on those earlier studies.

Human geographers and others have used cognitive mapping techniques to explore perception, image, and sense of place. Much of that work emerged from the insights provided in the 1950s by Kevin Lynch's work, which explored people's perceptions of U.S. cities, especially the importance in the cityscape of key elements, such as landmarks, paths, and edges. In the 1960s there followed a number of innovative "mental mapping" projects, including Florence C. Ladd's work in Boston and Peter Orleans's composite maps of Los Angeles based on interviews with a wide range of respondents (Gould and White 1986). Geographers, psychoanalysts,

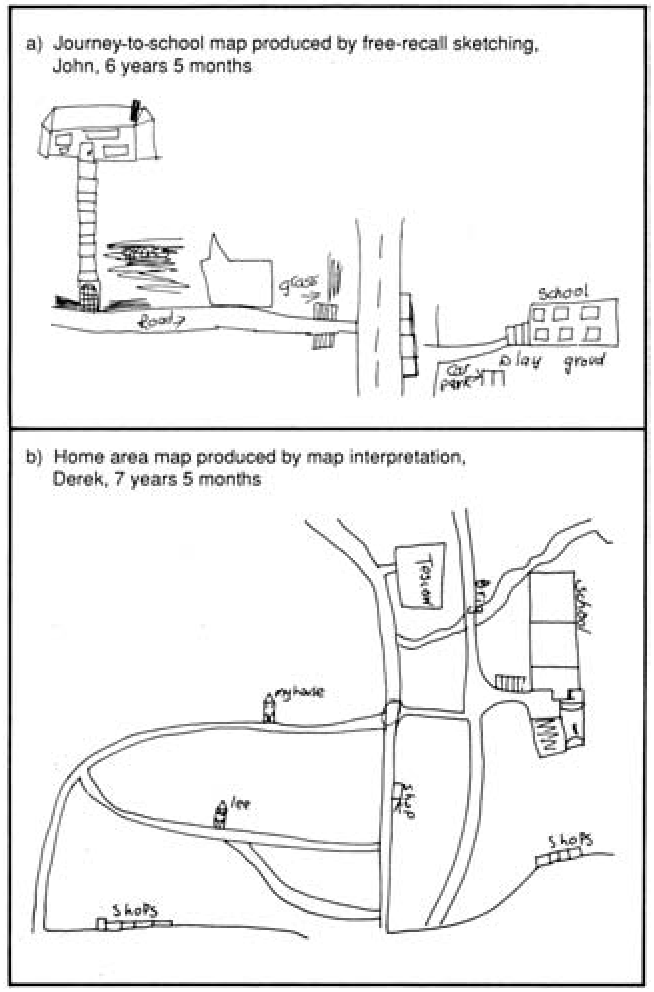

FIG. 492. CHILDREN'S "FREE-RECALL MAPS." Matthews shows young children's free-recall maps of their neighborhood and journey to school.
Size of the original: 17.4 × 11.3 cm. From Matthews 1992, 91 (fig. 5.2). Permission courtesy of Barnes & Noble.

and others working in this field recognize the importance of affinities with place developed during early and middle childhood and have studied those groups (fig. 492). Specific emotional ties may develop at a range of geographic scales and individual experience, from the home and the immediate neighborhood to the city or region and beyond. However, various studies have shown that individual emotional ties to places tend to decline in relation to the subjective estimate of distance (Gould and White 1986, 22–23). Depictions of mental maps, while technically simplistic, are often a complex mixture of cartographic elements, text, and pictograms. Sense of place and Lynch's ideas concerning place perception and image of the city were mirrored in cartographic practice during the mid-twentieth century. An example was Lance Wyman's design of the Mexico City Metro map following the 1968 Olympics; his map used pictograms to symbolize key landmarks near each station in the system.

Sense of belonging can involve multiple levels of identification with place, ranging from the neighborhood and the region through national identity to a sense of global citizenship, and hence, multiple levels of both formal and informal graphic representation, including maps. At all scales, cartographic representations may play a significant role in creating and reinforcing emotional bonds to place but may also be manipulated for propagandist purposes. Place-rootedness and its representation help people to define themselves and to form communities (although this can have unfortunate effects if it creates exclusive domains that exclude or demonize others). This place-rootedness is reflected in distinct cultural terms, such as *Heimat* in German or *bro* or *cynefin* in Welsh (King 1991). Pyrs Gruffudd (1996, 421), for example, draws attention to the use of maps as elements within representations of the "contested terrain of Welshness" in the period between the two world wars. Maps and mapmaking related to place-rootedness may also have spiritual significance in non-European cultures, for instance, contemporary Australian Aboriginal bark paintings, which serve both as maps of clan homelands and as religious icons (Watson, with the Yolngu community at Yirrkala, 1989).

Celebrating sense of place and communal or individual identities through maps took many forms and connected with other cultural discourses, such as literature and landscape art, during the nineteenth and twentieth centuries. Some literary maps were purely fictional (e.g., J. R. R. Tolkien's Middle-earth or Robert Louis Stevenson's Treasure Island), but others represented the author's emotional bonds with real places. For example, the map of Wessex included in Thomas Hardy's novels helped draw his readers into intimate relationship with Hardy's world by providing opportunities to explore it in reality. Hardy had preferred that his readers not believe in a real existence for his imaginary settings, but eventually acceded to their wishes by publishing the map (including both real and fictional place-names) and by references to his literary topography in prefaces to later editions of his work (Birch 1981). The maps drawn by the illustrator Ernest H. Shepard as endpapers for the classic children's books by A. A. Milne (*Winnie the Pooh*) and Kenneth Grahame (*The Wind in the Willows*) also evoked the sense of place that inspired the authors, for example, for Milne the rural landscape around Cotchford Farm and the Ashdown Forest in Sussex. It can also be argued that many tourist maps are also strongly imbued with their author's sense of place. For example, Alfred Wainwright's famous pictorial guides to the Lakeland Fells (U.K.) (begun in 1952) were as much intimate expressions of place as practical guides, and their popularity resulted from the way they connected emotionally with their readers.

Other cartographic representations of place were created by communal effort. Relph (1976) and others have expressed concerns that modern living, planning, and architecture have dehumanized places, undermining place experience through the creation of bland uniformity. Castree (2003), however, suggested that such concerns underestimate the persistence of place identity and the ability of people and communities to incorporate change as part of a process of glocalization—in which hybrid identities form through negotiation between the local and the wider global context, for example, through immigration and changing patterns of consumption (e.g., popular media, exotic foods). Recapturing sense of place by mapping it, as a foil to poor planning, was part of the philosophical underpinning of the innovative Parish Maps Project launched by Common Ground (U.K.) in 1985—"In an age of 'Walkmans,' multi-national companies and hypermarkets, the parish has survived as a unit that is both understandable and human in scale." "The process of making a Parish Map will encourage people to discover what is already known about their place and to demand that it is made accessible to them in an attractive and approachable manner" (Greeves 1987, 3, 5). Resultant maps (fig. 493) created by community groups sometimes working with local artists ranged in form from traditional paper maps to murals and quilts. Maps were produced for both urban and rural "parishes," although the latter predominated and often tended to idealize the countryside and village life. The project tapped into a deep sense of need to celebrate local identity, with some 1,000 maps created during the first five years of the project (King 1991, 40).

Another innovative communal cartographic project aimed at understanding the nature of neighborhoods, sense of place, and identity was Denis Wood's mapping of Boylan Heights (Raleigh, North Carolina), initiated in 1974. Wood's students mapped a wide range of cultural and economic factors, from real-estate values to the location of pumpkin lanterns at Halloween. The resulting maps documented not only local tradition but also social segregation; the pumpkin map, for example, showed that artifact to be characteristically found "on the porches of the big houses at the top of the hill" (Harmon 2004, 104).

Through distinctive, often subversive, mappings individual graphic artists challenged both the growth in place uniformity and the tendency for communities to become introverted in their sense of place. Saul Steinberg, for example, famously satirized the Manhattanite's view of the world in his 1976 cover for the *New Yorker* (see fig. 655). Earlier examples, including Daniel K. Wallingford's *A New Yorker's Idea of the United States of America* (ca. 1939), were less place-rooted—

FIG. 493. GARTMORE VILLAGE IN THE UNITED KINGDOM. The map was created by the Gartmore Heritage Society in 1994 as part of the Parish Maps Project. Size of the original: 64 × 60 cm. Image courtesy of the National Library of Scotland, Edinburgh.

adopting a bird's-eye view. *Spade & Archer's 50 Maps of L.A.* (1991) is a series of distinctive graphics challenging or exploring specific Los Angeles place images, such as the biker's map of L.A. and Zsa Zsa Gabor's tour of Rodeo Drive in Beverly Hills by U.S. artist Istvan Banyai (Holmes 1991, 82–84). A local authority, Doncaster and District Development Council (U.K.), used a satirical mental map to show how Londoners supposedly perceive the north of England (Gould and White 1986, 22).

Other artists used maps to examine and explore their own place, including ephemeral elements important to emotional connection. Gwen Diehn's "artistic maps" of the Swannanoa River (North Carolina) captured not only the local topography but also the shifting elements of the local landscape, including the movement of a herd of cattle observed over several days from her house (Turchi 2004, 94–97), while Simon Lewty's map of the Warwickshire (U.K.) countryside incorporated images of derelict farm buildings (Greeves 1987, 16). Not all maps related to sense of place portray real landscapes. A number of individual mapmakers have retreated into imaginary worlds that were, nevertheless, based on a strong sense of place-rootedness. For example, Katharine A. Harmon (2004) discussed the work of Adolf Wölfli, who was diagnosed with schizophrenia at age thirty-one. While confined to an asylum, Wölfli produced writing and images of an imaginary life story that included maps of distant places but was based on the topography of the Swiss countryside around Bern. She also described the case of Mark Bennett, who watched endless hours of television to escape an unhappy childhood in Chattanooga, Tennessee. Bennett then meticulously mapped the environs of the television series he watched over a twenty-year period.

Another important relationship between cartography and sense of place was that of maps that, although not originally representations of an individual's emotional associations, became deeply embedded as iconic and communal representations of place. The classic example was Henry Charles (Harry) Beck's topological transformation of the London Underground system (see figs. 482 and 483). His design for the London Underground map or diagram, from its first incarnation in 1933, became synonymous with London. Despite the fact that Beck disposed of true geographic representation for the simplicity of a circuit diagram, it soon became the iconic representation of London for both denizens and visitors alike, representing the city as experienced by those who traveled, mole-like, under the ground. In a manner, it also represented sense of place from Beck's perspective. Beck, an electrical engineer, experienced and envisaged the system as a series of connections and nodes, leading him to represent graphically what might be reasonably construed as his mental map of the city. The adoption by other cities of comparable map diagram styles led to similar iconic status and impact on sense of place; examples were the highly distinctive but stylized circles of the Berlin S-Bahn (*Stadtbahn* or city railway) and U-Bahn (underground railway) diagrams from the 1930s and the Moscow Metro diagrams of the 1980s.

While some mid-twentieth-century geographers investigated the subjective characteristics of place in opposition to the impersonal statistical approach to geography, the sense of place also had wide popular appeal. Community members and individuals explored and shared their spatial identities by creating cartographic expressions that not only portrayed the geographical particularity of localities but also evoked their emotional qualities. One person's mental map could and did become the icon for an entire city.

PETER VUJAKOVIC

SEE ALSO: Travel, Tourism, and Place Marketing

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Map Pin.

Map pins—small metal devices designed for pushing into maps—came into widespread use in the twentieth century. The original pushpin, designed by Edwin Moore in 1899, was an improvement over the nineteenth-century carpet and shoe tacks that had been adapted for fastening paper items to cork or wood. The success of Moore's pushpin led to the invention of various subtypes of pin, including one specifically designed for map annotation. The mass production of this design resulted in an entire industry dedicated to supporting map interaction via pins.

The industry was founded on an old concept. Pins have been employed with maps for at least two hundred years. In the late eighteenth century, Napoleon Bonaparte pinned maps to help him visualize military

FIG. 494. ADVERTISEMENT FOR RAND MCNALLY MAP-TACK SYSTEM.
Size of the original: 16.5 × 10.4 cm. From *Rand McNally Boston Guide to the City and Environs* (New York: Rand McNally, 1919), unnumbered advertising page at end.

movement (Wairy 1895, 3:310). By the mid-nineteenth century, maps of battlegrounds were popular with civilians, who mimicked the interactive mapping techniques of military commanders in the field. Some followed the military movements with pencils, others with color-coded pins.

In the early twentieth century, pin maps were successfully marketed to business and sales executives as an effective means of tracking employees and assets (fig. 494). Several companies sold various types of map pins, tacks, and supplementary devices such as map cord, which was strung pin-to-pin to delineate boundaries. New maps were printed on woven paper with light colors and subdued content to enable repetitive pinning on an image that was clear, yet separate from postproduction user annotations. Rand McNally championed this growing trend by developing an entire Map-Tack System (or Map System) that included all the necessities for interactive mapping, as well as the furniture (map cabinets with multiple drawers) to house it.

By the 1920s, pin maps were a standard method for tracking geographical data. Research institutes monitored the location of employees' fieldwork; law enforcement tracked crime; and, all manner of businesses continued to use map pin systems for both spatial management and reference. Best-practice guidelines for pin maps (e.g., how to prepare a cork and cellular board backing [Brinton 1914, 193–95], what colored pins to use to represent certain demographic phenomena [Swarts 1917]) were published widely in graphic communication literature throughout the first half of the century.

At the end of the century, the use of pin maps had extended from the business world to the general population. Pin maps were a common sight at roadside attractions and restaurants, as patrons were eager to mark their hometowns and marvel at the far-flung pins of other visitors (fig. 495).

In the 1990s, when mapping and map reading began transitioning to the Internet, the fate of pins as a primary tool for map interaction was uncertain. Initially, interactive mapping platforms did not implement digital metaphors for map pins. By the early 2000s, however, evidence of a deeply ingrained perception of pins as interactive mapping tools became apparent. Web maps grew increasingly robust, and digital map pins began to appear. The suite of digital pins introduced by Google Maps and Google Earth in 2005 solidified the map pin's digital place in the graphical vocabulary of a

FIG. 495. PIN MAP AT ROADSIDE ATTRACTION. Photographed in Seattle, Washington.
Image courtesy of Timothy R. Wallace.

new geospatial web, just as its analog ancestor did in the minds of sales managers a century earlier.

TIMOTHY R. WALLACE

SEE ALSO: Administrative Cartography; Crime Map

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MapQuest.com (U.S.). Launched in 1996 by GeoSystems Global Corporation, formerly the cartographic services subsidiary of R. R. Donnelley & Sons, the MapQuest website popularized online interactive street mapping. Although address-matching systems had been in use for over two decades and interactive street atlases on CD-ROM had existed since the late 1980s, MapQuest brought this technology to millions of users through the World Wide Web. The website also implemented a routing technology that allowed users who entered a pair of addresses to find both the shortest and the fastest routes between two locations. By 1997 the website was responding daily to 700,000 map requests. Usage increased to five million requests by 1999 and twenty million by 2001 (Peterson 2003, 13). By 2006 there were forty million unique visitors every month. Despite competition from somewhat similar websites maintained by Yahoo!, Microsoft (MSN), and Google, MapQuest remained a favorite with users and during this decade was consistently ranked among the top thirty websites by Media Metrix, a search-engine rating service. British, French, and German versions of the website were also offered. The phrase "I'll MapQuest it!" was in popular usage to find any location. In 1999 GeoSystems Global Corporation was renamed MapQuest.com, and in 2000 the firm was purchased by AOL (America Online), part of the AOL Time Warner conglomerate. In 2003 the company began a cell phone–based mobile phone map service, and in 2005 it entered into an agreement with the Dutch company TomTom Inc. to include its database on TomTom's $700 mobile device designed primarily for car navigation.

Address matching had its beginnings with the Dual Independent Map Encoding (DIME) system developed by the U.S. Census Bureau for the 1970 census. The purpose was to identify the location of every address in the country. Individual street segments, delineated by a pair of street intersections, were encoded with the address ranges for both sides of the street. In this way, the location of a particular address could be approximated along the street segment. With the addition of latitude and longitude information for the street intersections, the absolute location of the address could be determined through a process called geocoding. The map database used by MapQuest and other online street-mapping sites is based on the databases developed by the U.S. Census Bureau and subsequently modified by private companies. An important enhancement for routing purposes was the addition of directional information on one-way streets.

MapQuest used a series of servers to respond to user requests. These servers matched the address provided by the user with the appropriate street and address range in the database, and the bounding intersections provided the corresponding geographic coordinates. The map, stored in vector format, was drawn into a GIF (Graphics Interchange Format) raster picture file centered at the address. This temporary GIF file was then inserted into a web page that was returned to the user. The user then had the option of changing the scale (zooming) or shifting the area shown to the north, south, east, or west (panning). Each of these actions returned a request to the server, which then generated a new map in the GIF format in a new web page displayed for the user.

Routing information represented a greater challenge than address matching. A variety of routing algorithms are used to find the best route between two locations. MapQuest offered three options: the shortest route, the fastest route, and the best route with no tolls. All three methods required enhancing the database with additional information, such as speed of travel, for each street segment. An optional verbal description of the route was provided as a list of distances, highway numbers, and turning directions so that users could navigate between the two locations without consulting the map—an option that could undermine the formation of a mental map useful in subsequent navigation.

The MapQuest web services business model was based on providing free access to maps while charging businesses and other establishments for special placement on the map and adjacent areas on the web page (fig. 496). MapQuest modified its business model for mobile phone services by initially requiring wireless users to pay a subscription fee. While mass acceptance of the pay service did not occur, an important enhancement was the ability to identify the user's current location and provide contextual information such as the location of nearby restaurants or gasoline dealers. This ability to link a mobile telephone's current location to a variety of facilities, including potential advertisers, led to a new industry called location-based services (LBS). Technical and legal problems hindered the widespread adoption of such location-centered services, and the anticipated LBS revenue stream was slow in meeting the expectations of the telecommunications industry.

In the end, MapQuest's "server-side" mapping solution was plagued by slow response times during periods

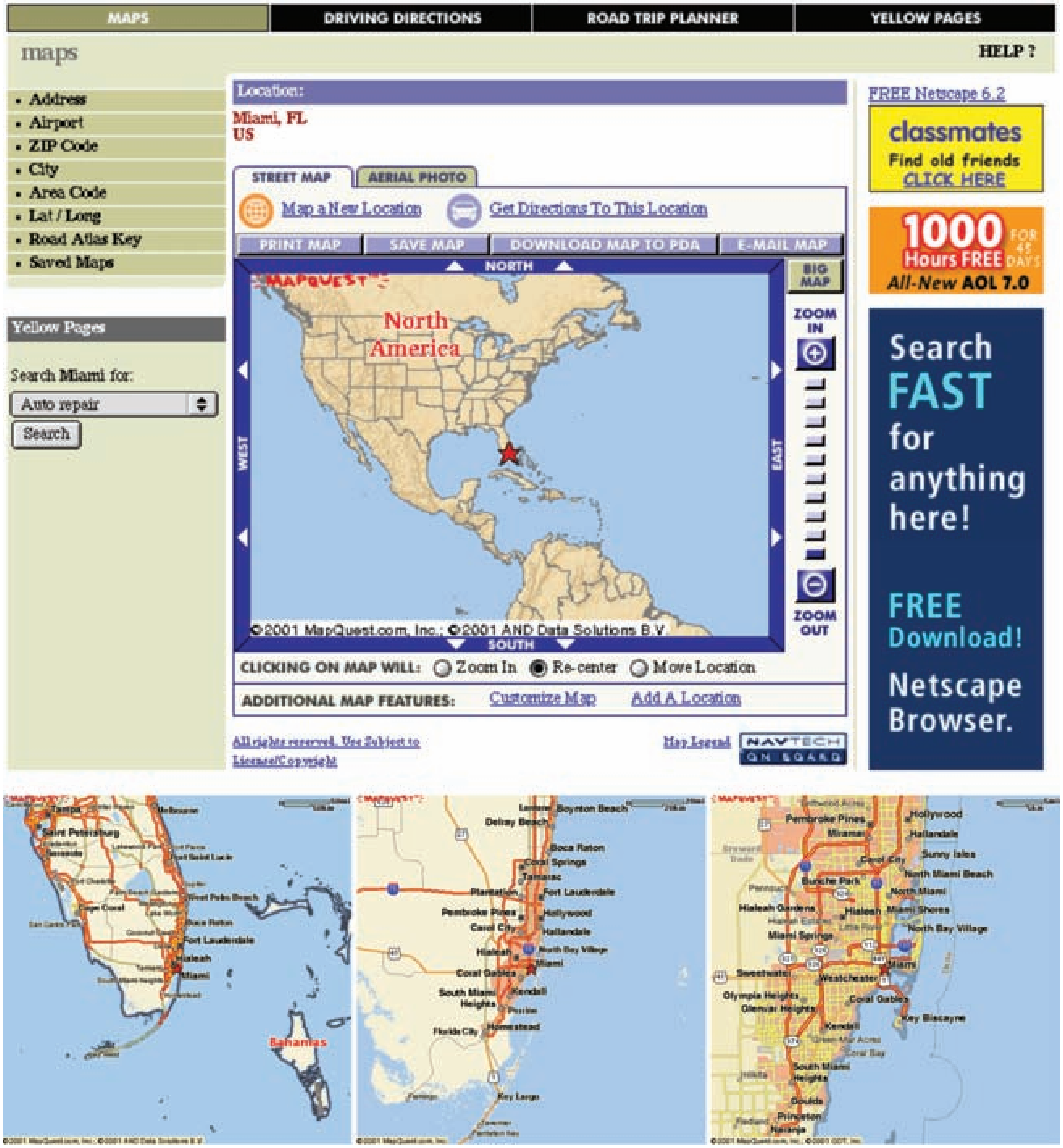

FIG. 496. 2001 VERSION OF THE MAPQUEST WEBPAGE. Dominated by ads, the map constitutes only a small part of the webpage. The maps of southern Florida are at three different zoom levels (ten zoom levels were available).

Image courtesy of Michael P. Peterson.

of heavy usage and was challenged by Google Maps AJAX (Asynchronous JavaScript and XML) technology, which maintained a constant connection to the server while downloading adjacent map tiles and maps at different scales. Google was also able to use its search engine to lead users to Google Maps. In April 2009, Google overtook MapQuest as the major provider of online maps (Dougherty 2009).

MICHAEL P. PETERSON

SEE ALSO: Road Mapping: Canada and the United States; Wayfinding and Travel Maps: Web-Based Wayfinding; Web Cartography

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Marine Chart. The function of a marine chart is to cartographically portray a portion of the world's surface that is covered by water. Until the twentieth century, the main use for such charts was for marine navigation, and the paper product was designed primarily to satisfy the needs of the navigator. It had the additional role of a legal document.

At the beginning of the twentieth century, marine charts started to show a broader range of subject matter as scientific interest in the oceans grew. The foremost resulting product was the General Bathymetric Chart of the Oceans (GEBCO) (Scott 2003), initiated by Prince Albert I of Monaco in 1903 (see figs. 280–81 and 634). During the twentieth century this trend continued as marine charts continued to add more diverse sets of features. In the first half of the century such charts were often bound together as atlases, and several major publications were produced, most notably by the Soviet Union (fig. 497). In the second half of the twentieth century, the development of digital processes for producing marine

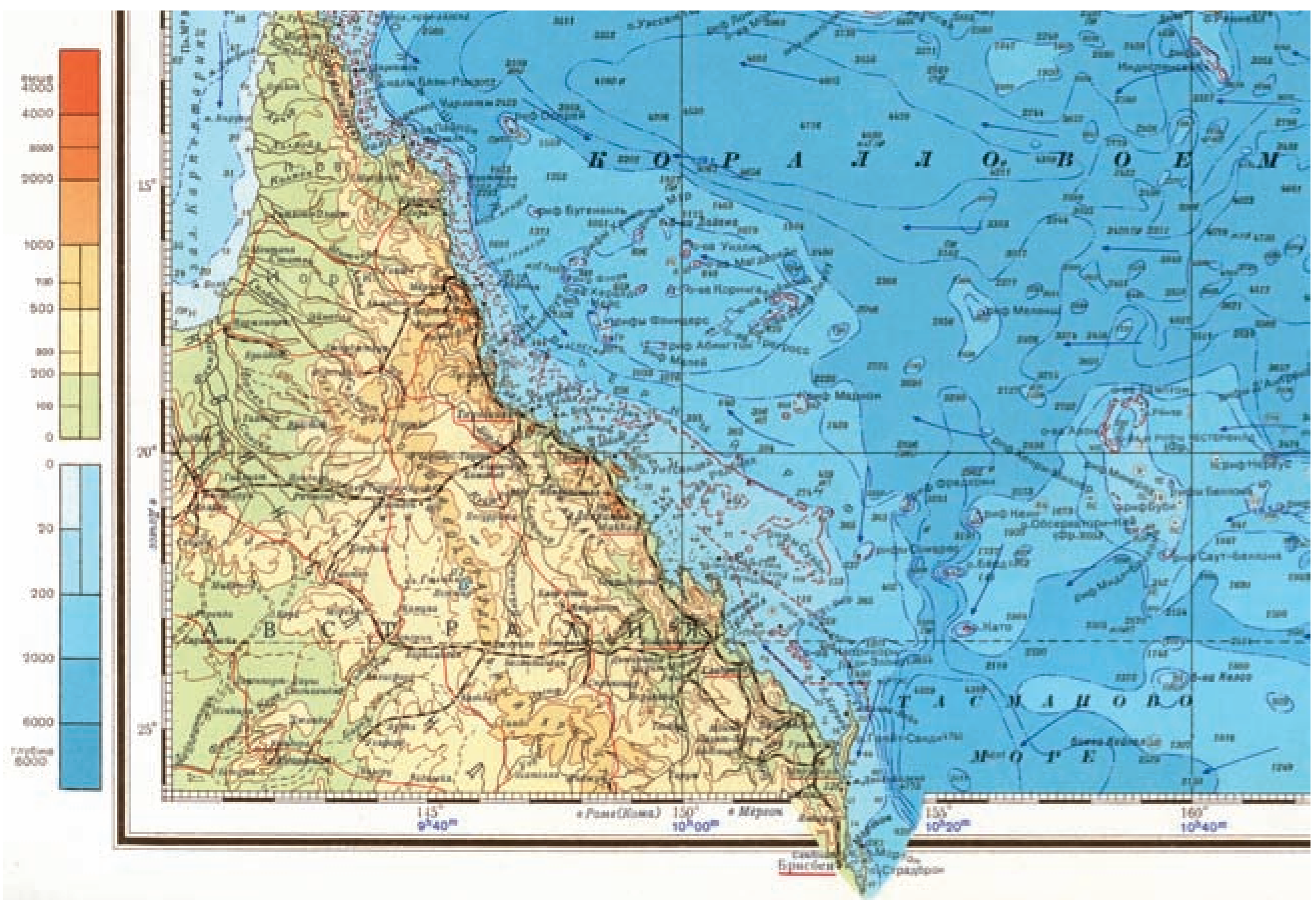

FIG. 497. BATHYMETRY OF THE GREAT BARRIER REEF FROM A RUSSIAN MARINE ATLAS. Section of the South Pacific, *Okeaniya* sheet, 1:10,000,000.
Size of the entire original: 47.9 × 71 cm; size of detail: 13.8 × 20.2 cm. From I. S. Isakov et al., eds., *Morskoy Atlas*, 3 vols. ([Moscow]: Izdanie Morskogo General'nogo Shtaba, 1950–58), vol. 1, pl. 47.

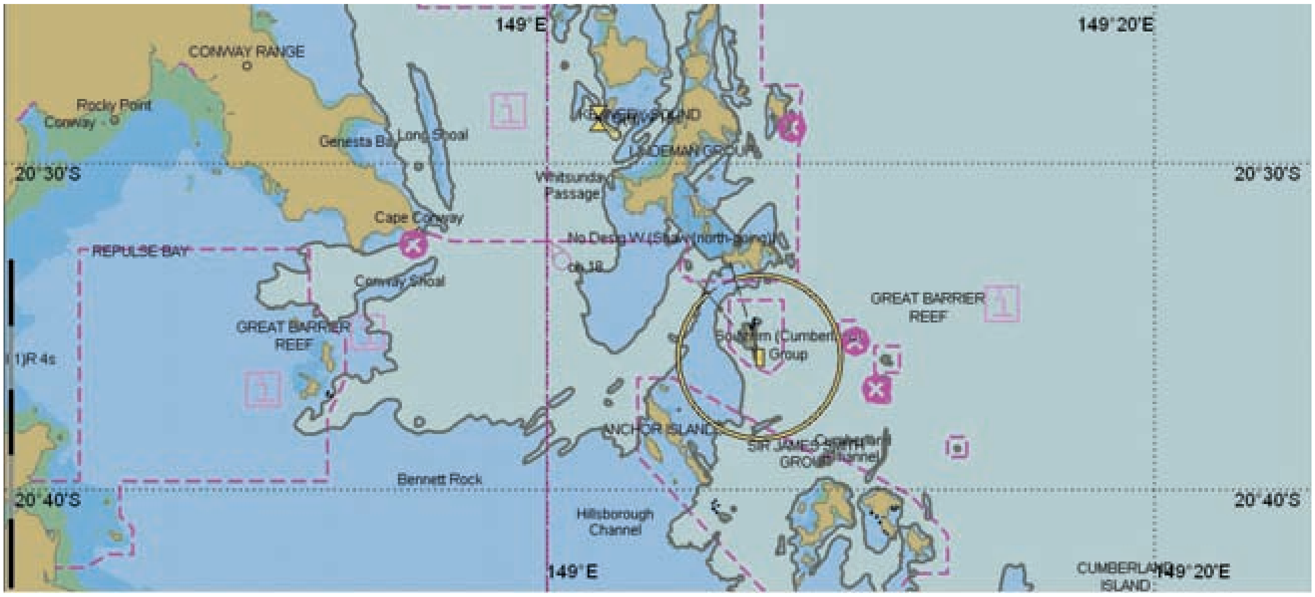

FIG. 498. DETAIL FROM AUSTRALIAN HYDROGRAPHIC SERVICE ENC CHART, WHITSUNDAY PASSAGE AREA. Certain material in this product is reproduced under licence by permission of The Australian Hydrographic Service. © Commonwealth of Australia 2013. All rights reserved. In a standard disclaimer, the publisher advises that the chart is "not to be used for navigation."

charts allowed an even greater degree of flexibility in both the information and its presentation. By the end of the century digital products could be displayed on computer screens and digital data could be used interactively with geographic information system (GIS) software.

For navigation, the availability of digital methods resulted in the production of electronic or digital charts. These developed in several specific forms. The equipment used for manipulating and displaying the navigational data for the official charts was termed Electronic Chart Display and Information Systems (ECDIS). These charts were produced to accepted standards, and the databases used with ECDIS were called electronic navigational charts (ENCs) (fig. 498). Produced under the authority of national hydrographic offices, these databases had to meet rigorous standards (Hecht et al. 2006). It was a legal requirement for ships to carry official charts, in either paper or digital form.

The development of marine charts during the twentieth century was also associated with improved technical methods for precisely positioning the data. At the start of the century, methods were entirely visual, but during World War II electronic methods for positioning moving vehicles were developed. These included systems known as Decca and Loran (Nares 1946). During the 1960s satellite positioning was developed, first in the form of doppler measurements from polar orbiting satellites and later by trilateration from geostationary satellites (Eaton, Wells, and Stuifbergen 1976; Hill, Moore, and Ashkenazi 2000). The precise positioning and the navigation of vessels using these products improved during the century from a matter of several kilometers to several decimeters or even centimeters (Kerr 2000). While the positioning of the data was rapidly improving, so were methods for measuring the data. In particular, the measurement of bathymetry, the basic reference parameter for all marine charts.

At the start of the century depths were laboriously measured by some form of lead line, typically a marked line with a heavy weight (Shipman and Laughton 2000). Other parameters of interest, such as temperature, salinity, or biological data, were also measured by labor-intensive manual means. During the first decades it became possible to measure depths acoustically, even in the deepest ocean depths, and later to measure these depths continuously along a profile of the seafloor (fig. 499). However, acoustic methods required a knowledge of the water density structure through which the acoustic signal was transmitted. Single-beam acoustic methods remained in use through much of the earlier part of the century, but they only provided a measured profile. The spaces between the profiles were estimated by interpolation and therefore open to interpretation. During the 1960s digital methods for measuring and recording acoustic depth measurements were developed. This led to the possibility of merging precise position (x, y) and depth (z) into a form of three-dimensional (x, y, z) coordinates. In the second half of the century, anti-

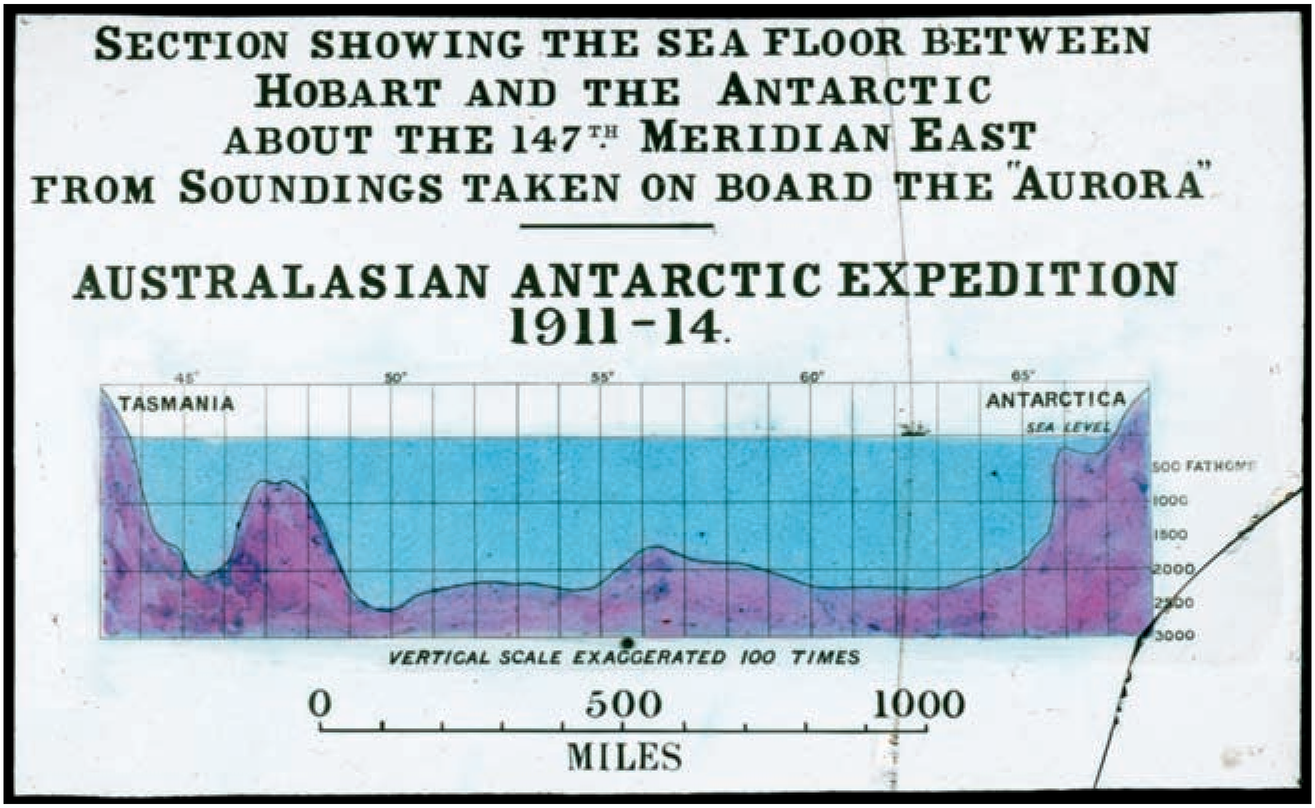

FIG. 499. PROFILE OF SEAFLOOR, HOBART TO THE ANTARCTIC, CA. 1913. The profile, created by Alfred James Hodgeman, shows the seafloor at about the 147th meridian east from soundings taken during the Australasian Antarctic Expedition, 1911–14.

Image courtesy of the Map Collection, National Library of Australia, Canberra.

submarine warfare encouraged the development of various approaches using oblique, as opposed to vertical, measurements downward through the water column. Instead of measuring a depth profile directly beneath a ship on passage, developments such as side-scan sonar, and later, multibeam echo sounding, made it possible to measure a swath, providing a strip of total depth measurement on each side of the measuring vessel (Hughes Clarke 2000). Airborne methods of measuring depth using lasers and other means also provided total seafloor coverage during the latter part of the century.

The presentation of geographic information in graphic form requires consideration of scale, projection, symbology, and the use of color. Marine charts used for navigation have made considerable use of the Mercator projection because a rhumb line, along which the navigator may steer a constant course, appears as a straight line on that projection. However, the shortest distance between two places is along a great circle. Ships on long voyages want to follow the shortest route. Charts have been developed on projections that show great-circle routes as straight lines, and the use of electronic computing has made this easier. Marine charts that are designed for purposes other than navigation may use a variety of other projections. Equal-area projections may be particularly useful for comparative studies. Although the availability of data in digital form has permitted users to access and display geographic information in whichever projection suits their need, the use of different projections has not changed appreciatively during the twentieth century.

With ever more precise data, marine cartographers have become increasingly concerned about datums, both horizontal and vertical. The fact that navigators using satellite systems can position themselves with an accuracy that is as good as, and in some cases even better than, the charted information has presented marine cartographers with a dilemma. In a world that is increasingly tied together internationally, the practice of different countries referencing their data to different datums is no longer acceptable. This is particularly true for navigation but also for the delimitation of international boundaries. Major conferences on the Law of the Sea took place in 1958, 1960, and 1982, and the resulting international treaties revealed an urgent need to have boundaries based and drawn on one international datum (Dodson and Moore 2000). Since 1982 the International Hydrographic Organization (IHO) has recommended that all charts be drawn on the World Geodetic System of 1984 (WGS84) datum.

Vertical datums are also the subject of increasing concern (International Federation of Surveyors 2006). Charts used for navigation have traditionally used a level of low water as the reference from which depths are measured. This provides a safety margin to navigators. The zero level, or low-water line, provides a separation between the drying and wet areas. Areas that are covered during higher stages of the tide are shown as drying heights and symbolized with a flat bar under the actual figure. With the increasing availability of color, the area between high and low tide is generally shown by a separate color. There are difficulties caused by the choice of differing low-water datums for marine navigation charts, however. One of these is the need, on international voyages, for a common international standard to satisfy ships that are increasingly larger and have a deeper draft. These ships need more marginal clearance between their keels and the seafloor. Early in the twentieth century several low-water datums, mean low-water springs (MLWS) and lower low water (LLW), were in use. In 1997 the IHO decided that the standard of lowest astronomical tide (LAT) should be used.

A second and more recent concern for the choice of vertical datums is that topographic maps of the land have elevations generally based on mean sea level (MSL). Considering that the tidal range in some parts of the world can be as great as 15 meters, the difference between the vertical datums on marine charts and topographic land maps can be as much as 7.5 meters. The second half of the twentieth century has seen increasing interest in improving knowledge of the coastal zones. As in most geographic studies, detailed base maps are essential. Coastal areas pose the challenge of merging marine elevations anchored to a sounding datum with onshore elevations referenced to a terrestrial datum. Fortunately, technology has provided "wet" and "dry" data in digital form, which facilitates adjusting elevations to a single vertical datum. Satellite measurements of vertical elevation can also be referenced to the geoid, which obviates the need to characterize elevations as either dry or wet. There has been an increasing interest in establishing a single vertical reference frame that has extended into the twenty-first century (FIG 2006; Parker 2002).

Cartographic methods of communicating three-dimensional information as a graphic image are of particular importance for marine charts. Since the middle of the century, when color printing became practical, the task has been easier. At the start of the century only monochrome reproduction was used in marine cartography, but the amount of depth data was also limited. Every depth measurement, so laboriously collected by lead line, would be drafted onto the plotting sheet with pen and ink (fig. 500). For inshore shallow waters draft charts included many of these small neat numbers, whereas in deep ocean waters, where a single measure-

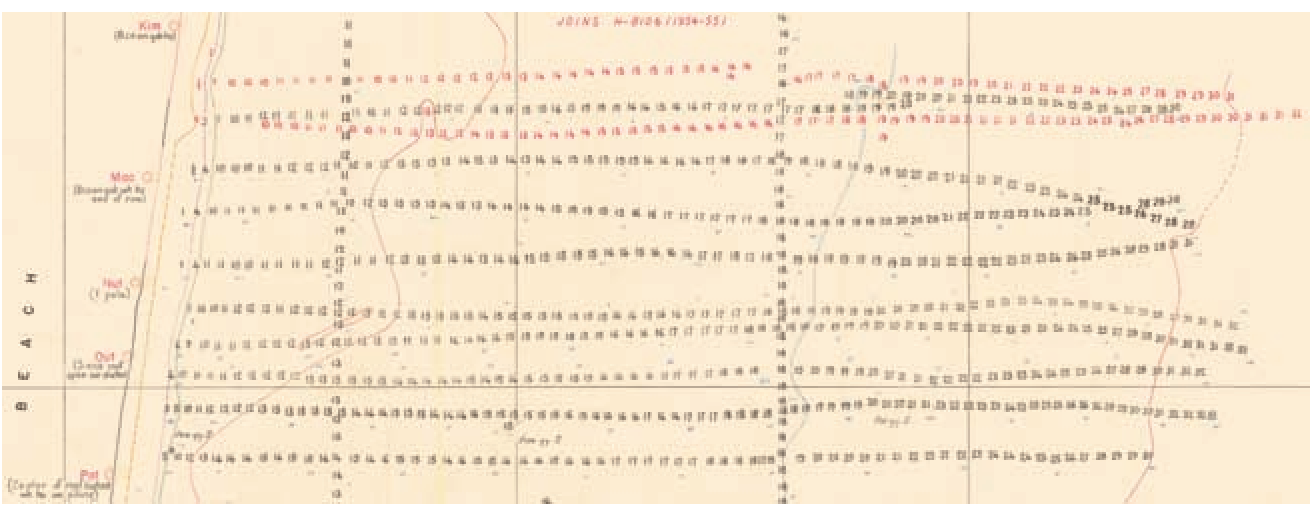

FIG. 500. DETAIL OF THE "SMOOTH SHEET" OF THE ATLANTIC OCEAN AT FERNANDINA BEACH, FLORIDA. From the U.S. Coast and Geodetic Survey Hydrographic Survey, no. 8179, February 1955, based on echo soundings using graphic recorders with boat-mounted transducers. The depths are handwritten in feet.

Size of the entire original: 137.4 × 91.4 cm; size of detail: 17.4 × 46.2 cm. Image courtesy of the National Oceanic and Atmospheric Administration, Washington, D.C.

ment could take many hours to collect, charts contained far fewer soundings. The marine cartographer's task was to illustrate to the user what lay between these isolated depth figures. Shallow waters required a representative selection of these figures so that the navigator could clearly see the critical information. From a navigator's point of view it was important to show explicitly where his vessel could venture safely. This was achieved by interpolating form lines between the depth points. In order to provide a safety margin, cartographers would always draw these lines on the deeper side of the actual measurement, a practice that tended to exaggerate the shallow water and diminish the deep water. This practice was unsatisfactory for geomorphologists, who wanted the real depth revealed. In charts and maps of the deep oceans, such as those published in the GEBCO series, the cartographers initially used few contours, but progressively during the century interpreted contours replaced point depths as the number of point depths increased.

With the advent of computers and digital data in the middle of the century, considerable effort was given to the automatic selection of the point values to be shown and used for drawing depth contours. Because the safety of navigators was foremost, complete automation proved difficult. As of this writing, human inspection and interaction continues to supplement automatic selection. Another area of investigation is the generalization associated with a change in map scale. Marine charts, particularly navigation charts, are plotted at scales that are convenient for the navigator or user. While charts of oceans may typically have scales of 1:10,000,000, charts of harbors are often produced at scales as large as 1:5,000. For paper charts these scales must be determined before charts are compiled and printed, but for digital products it is necessary to generalize the information for presentation at a smaller scale. This is normally achieved by omitting points along lines representing coastlines or depth contours. Although line generalization is an old problem in cartography, the use of digital methods has given a greater urgency to the task.

Symbolization is important for navigation charts, and the international nature of maritime navigation requires that symbols be standardized. Lengthy debates have occurred on matters of standardization such as the choice of units, metric or imperial. Concern for chart symbols has been at the heart of the early work of the IHO. The debates were compounded by the use of terms with a particularly nautical flavor, such as the knot and the cable. During the twentieth century, agreement was reached by most countries on standardizing to metric units, and the IHO decided in 1986 that the standard units for depths and heights would be meters and decimeters. Nautical charts produced in the United States retain imperial units, however. Because it is desirable that the chart not become cluttered with written information, many navigational features are symbolized. Several committees under the aegis of the IHO have produced publications that specify the design of symbols for marine charts. Earlier practice favored pictorial symbols that were visually comparable with the actual feature as seen by the naked eye, but the use of computer methods has led to more abstract symbols. For instance, a navigational buoy can be shown by a pictorial symbol similar to what the navigator sees, but electronic chart displays offer the choice of showing the buoy by an abstract symbol, such as a small red or green square, that may be interrogated by the system. The symbolization of depth contours has changed during the twentieth century. When only monochrome printing was available, the actual value of a contour was sometimes defined by a series of dashed lines and dots. For example, the ten-fathom line could be shown as alternate dots and dashes while the twenty-fathom line was coded as two dots and a dash. This approach was replaced by the actual value inserted in a break in the contour line. The development of chart symbol standardization culminated in the 1980s with the publication by the IHO of international chart specifications (IHO 1988).

The introduction of color in the middle of the century led to a richer range of chart symbols, particularly for representing depth. But color also led to new debates about its appropriate use. It became standard for depths between contours to be shown in a range of blue tones and for the land areas to be shown in buff on most national charts. In the areas between high and low tide lines the buff and the blue were mixed to provide green (fig. 501). This led to an interesting debate between navigational users and cartographers. Traditionally, the deeper areas of a chart had been left white, so that the navigator could annotate his position in pencil on the chart. Darker blue (or green) shades were used to warn the navigator of increasingly shallow and hence more dangerous water (fig. 502). The more scientific interests, particularly those involved in the GEBCO program, argued that deeper waters should be portrayed in deeper tones of blue, which are less defining than white, because the dangers in the deeper regions were fewer (fig. 503). There is no longer a need for the navigator to plot his position because electronically it is possible to display the current position on the navigation screen, but old ways die hard.

Various ingenious approaches have been taken to graphically show the three-dimensional nature of the sea and its bottom configuration. In particular, electronic cartography has provided truly dynamic displays in which the viewer's current position moves as the ship moves. While such methods can be advantageous for scientific studies of marine areas, the more conservative navigators were slow to fully accept dynamic interactive charts. Among the numerous studies intended to

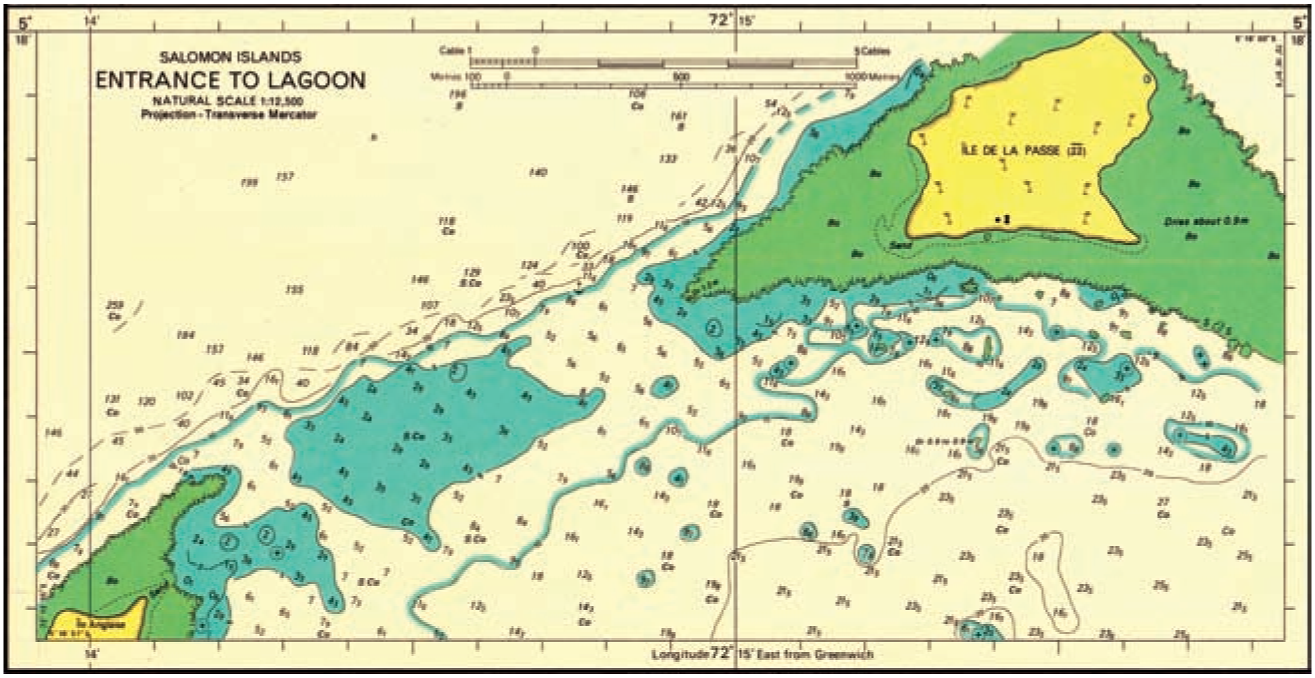

FIG. 501. NAUTICAL CHART WITH BLUES IN WATER, BUFFS ON LAND, AND GREEN BETWEEN. Inset map, *Salomon Islands: Entrance to Lagoon*, on *Plans in the Chagos Archipelago*, Naval Hydrographic Office, Government of India, compiled from British government chart of 1971 with corrections to 1983.

Size of the entire original: 51.7 × 89.2 cm; size of inset: 15.3 × 29.9 cm. Image courtesy of the Arthur H. Robinson Map Library, University of Wisconsin–Madison. Permission courtesy of the Chief Hydrographer of the Government of India, National Hydrographic Office, Dehra Dun.

establish specifications for the dynamic display of navigational information is one by the IHO (1996). These standards allow greater flexibility in symbolization and color, but chartmakers have had to consider the reluctance of navigators to abandon methods used on paper charts.

One necessary change with ENCs has been to provide different backgrounds for displaying information under different lighting conditions, namely, daylight, dusk, and darkness. The adoption of new symbols and colors for electronic charts has been made more difficult by the fact that radar displays have their own standardized symbols and colors. In merging radar displays and digital charts, compromises had to be made to satisfy both radar manufacturers and chartmakers.

The design of modern marine charts has had to accommodate the fact that ships have become larger, deeper, and faster. Decision making on the bridge must be quicker and more precise, and visual communication is essential. During the twentieth century an increasing array of systems have been developed that provide valuable information that must be digested quickly by the ship's navigator. Navigation systems not only provide more precise positioning, they also convert information into a form that makes decision making easier. The navigator no longer must laboriously plot the ship's position. Instead, critical data such as speed, course, and distance to a change of course are displayed directly on the electronic chart. Other information reaching the navigator from radar, automatic information systems, and other sources must be merged and digested. The electronic chart has become a critical system providing information upon which many decisions must be made. It is essential that its capacity to communicate critical information be immediate and without error.

Warfare, and national defense in general, has been a driving force in this evolution of the use and design of marine charts. During the earlier part of the twentieth century the design of the navigational chart satisfied the needs of both naval and merchant vessels. Later in the century national hydrographic offices were established in many countries as part of their Ministry of Defense, and their products have been directed at diverse defense needs. Products of a classified nature were produced to satisfy the particular needs of submarine warfare, beach assaults, and other uniquely military interests. In recent years certain national navies, in particular that of the United States, have promoted digital technology and a paperless bridge (fig. 504). Systems such as WECDIS (Warship Electronic Chart Display and Information Systems) provide an opportunity for charts to be enhanced for military purposes (Hecht et al. 2006).

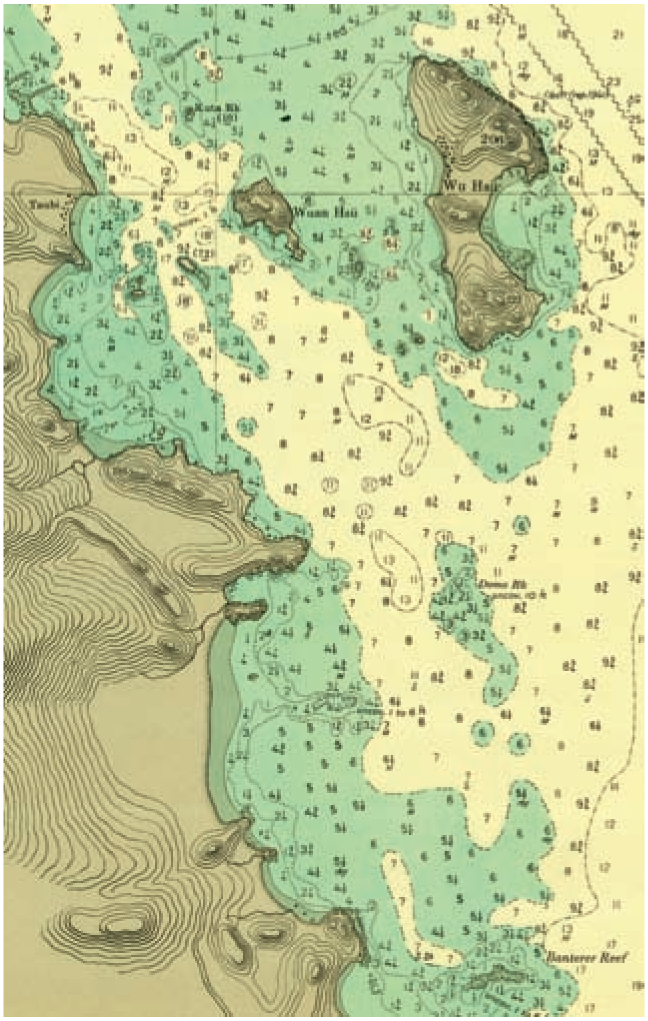

FIG. 502. NAUTICAL CHART WITH GREEN FOR SHALLOW WATERS, LIGHT BEIGE FOR DEPTHS. Detail from *China—East Coast: Approaches to Amoy Harbor*, no. 1322, 14th edition (Washington, D.C.: Hydrographic Office, 1945). Size of the entire original: 67.8 × 98 cm; size of detail: 21.2 × 13.4 cm. Image courtesy of the Arthur H. Robinson Map Library, University of Wisconsin–Madison.

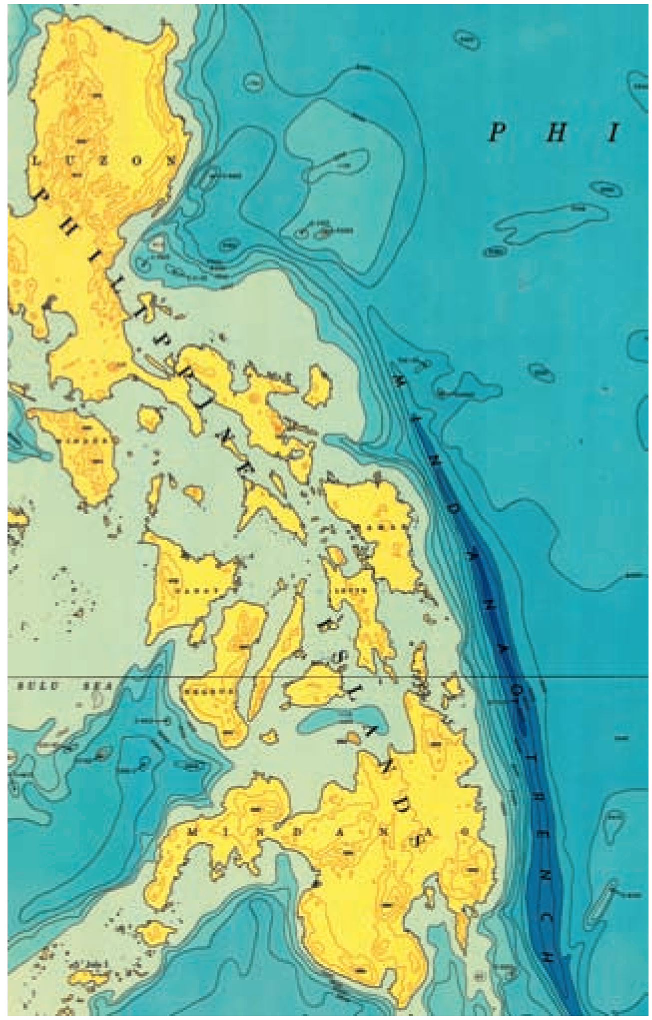

FIG. 503. NAUTICAL CHART WITH WHITE-GRAY FOR SHALLOW WATERS, BLUE FOR DEPTHS. Detail from *Bathymetric Chart: Korea to New Guinea including the Philippine Sea* (Washington, D.C.: Hydrographic Office, 1946). Size of the entire original: 118.7 × 80.9 cm; size of detail: 35.2 × 22.3 cm. Image courtesy of the Arthur H. Robinson Map Library, University of Wisconsin–Madison.

The development of marine charts for scientific and nonnavigation purposes has embraced digital methods. As of the turn of the twenty-first century, the GEBCO series has been produced in digital form as the *GEBCO Digital Atlas* (Jones 2003). The increasing interest in the coastal zones has led to increased use of hydrographic data in GIS. The ability of computers to compare different data sets and identify differences has become a key part of such systems, and these differences are often exhibited in a graphic form.

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SEE ALSO: Geographic Names: Gazetteer; Hydrographic Techniques; Marine Charting: Overview of Marine Charting; Projections: Projections Used for Marine Charts

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FIG. 504. INTEGRATED BRIDGE SYSTEM WITH ENC AND OTHER DISPLAYS.

Image courtesy of Kongsberg Maritime.

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Marine Charting.

OVERVIEW
CANADA
UNITED STATES
ARGENTINA
GREAT BRITAIN
FRANCE
EUROPEAN NATIONS
RUSSIA AND THE SOVIET UNION
JAPAN
AUSTRALIA

Overview of Marine Charting. Marine charting provides information about that part of the earth's surface covered by water through the use of graphics and other forms of presentation. In addition to the oceans and seas, this activity also covers the larger freshwater lakes and river systems. Marine charting has occurred for over a thousand years, but during the twentieth century it underwent significant changes.

Historically the main users of marine charts were navigators. The adjectives *navigational* and *nautical* are often used with the word *chart* to reinforce this purpose of the product. During the twentieth century, marine charting began to address a wider interest in the sea than simply navigation (Monahan et al. 2001). Scientific and economic interests in the oceans increased and graphics were developed to illustrate the information necessary for these pursuits (Carpine-Lancre 2003).

The users of marine charting require the information to be analyzed and presented in ways that are different from those required for maps of the land. For example, the Mercator projection, developed in the sixteenth century for use by navigators, remains to this day the basic projection used for marine charts. The same properties that make the Mercator projection of considerable use to navigators—conformality and rhumb lines maintained as straight lines—greatly distort the land areas for users interested in the land. In photogrammetry, the difference between marine charting and land mapping is that every point on land is measurable with photogrammetric tools whereas underwater it is seldom possible to measure every point. The area between points on a chart must be interpolated or interpreted. A final major distinction is that land areas are divided into national territories, each with its own set of laws that govern activities that take place within it. Much marine charting takes place in international space with users in transit from one country to another. This has led to a greater concern about international uniformity and standards in nautical charting. In turn, this has resulted in the development of international organizations whose task it has been to develop these standards. The prime organization is the intergovernmental International Hydrographic Organization (IHO), formed in 1921. The IHO has a membership of over seventy countries that includes all of the world's major seagoing powers (IHO 2007). It has developed and published numerous standards dealing with every aspect of marine charting, and although it is a consultative rather than regulatory organization, it has great influence.

Marine charting traditionally focused on navigational or nautical charts. For centuries an important user of these charts was the navigator of a warship. Strategically these vessels needed to move about the oceans safely and expeditiously. Certainly a driving force in the formation of the major hydrographic offices of the world was the need to provide charts for their country's warships. Fortunately, the navigational needs of all types of ships are not significantly different, and marine charting to support a navy was in most cases suitable to support merchant shipping. Special versions of the navigational chart fulfilled the needs of specialist users, such as fishermen or recreational craft operators.

Submarine warfare, developed first during World War I, required additional highly sophisticated technology and information. The requirement for detailed bathymetry and reflectivity of the bottom at considerable depth and details of the water density structure were important to the success of submarine missions. In recent years the technology used for such strategic purposes has led to an interest in information being added to digital charts. These additional military layers have since been specified under a system called WECDIS (Warship Electronic Chart Display and Information Systems), which is the military counterpart to the civilian ECDIS (Electronic Chart Display and Information Systems) (Hecht et al. 2006).

The development of marine charts to describe the environment for scientific or engineering purposes initially took a different direction. While hydrographic offices stressed the need to provide products that were biased to enhance the safety of the navigator, the scientists were more concerned with the best and most truthful interpretation of the data. The graphics used to display this non-navigational information, however, were modeled along the lines of the navigational products, particularly when the aim was to show bathymetric information (Carpine-Lancre 2003). This was due to the dominance and expertise of government hydrographic offices in producing charts for navigation. With increasing involvement of scientists in marine studies greater attention was given to cartography that would most effectively show scientific parameters (Monahan 1977). One interesting anecdote illustrates the difference between navigational and scientific needs. The depths on navigational charts are always referred to a low-water datum and thus generally show shallower water than is actually present. On the other hand, geomorphologists wish to know as precisely as possible the true shape of the seafloor and focus their interest on the most accurate and unbiased shapes and depths.

One particular debate concerned the use of color on the respective products. Cartographers producing navigational charts traditionally showed the safe navigable areas (deep areas) in white and the shallower areas in progressively deeper tones of blue. Scientists producing bathymetric maps believed that it was more realistic to show deeper water in tones of blue and make the more easily accessible shallower areas white. Interestingly, the development of the digital chart settled the debate. It was found that the large areas of white showing deeper safer areas, when projected on a computer monitor, blinded the navigator working on a dark ship's bridge at night. The solution adopted was to have three different tones of background color that could be used in conjunction with the ambient light conditions on the bridge (Hecht et al. 2006, 80).

Marine charting is considered to include the total process of gathering information, digesting it, and presenting it to the end user. This led to several identifiable practitioners. Data are typically gathered by hydrographic surveyors. After the data are analyzed and compiled by cartographers, the information is drawn and graphically presented by draftsmen. A major change in this structure took place during the twentieth century. The introduction of increasingly complex technology required a range of specialists from geodesists to electronic engineers. Likewise, the introduction of acoustic methods of depth measurement required the use of acoustic specialists and ocean physicists (Crease, Laughton, and Swallow 1964).

Arriving in the middle of the twentieth century, computers were initially used for complex geodetic calculations. In the 1960s computers began to be used to provide assistance in the analysis and graphic presentation of the data (Karo 1963; Thunberg 1968). While computer graphic systems were initially used to draw hyperbolae for specifically plotting on charts used with electronic positioning systems such as Decca and Loran (Nystedt 1957), computer use steadily turned to the analysis of the data. Computers were also programmed to do many of the tasks previously done by skilled cartographers (Murt and Brown 1981). The complete electronic or digital chart was born in the 1980s (Kerr 1990), when computer graphics provided the tools for tasks such as automated contouring and generalization and for presentation of the information to users on computer monitors.

During the twentieth century there were several technical improvements in measuring depths. Acoustic sonar allowed the measurement of depths invisible to the human eye. When first developed, acoustic sounding took the form of sampling, but during the latter part of the twentieth century, systems were developed that could provide almost total measurement of the seafloor. Lidar (light detection and ranging) and other methods used in airborne survey were developed that could be used to survey relatively shallow areas. Remote sensing by acoustics, lasers, and other means made great strides from its initial use in 1922 (Bates 2005, 24) to the modern multibeam echo sounding systems (mbes) (Hughes Clarke 2000).

Other basic changes occurred during the twentieth century. Copperplate engraving was replaced by the use of plastics and zinc printing plates (Medina 1951). Multicolor printing presses changed charts from monocolor to multicolor. Administrative changes saw greater emphasis being placed on standardization (Ritchie 1983; Newson 1984) and in particular, the international system of metric units was adopted.

During the century the education of personnel evolved in parallel with the type of practitioners needed by the profession. Until the middle of the twentieth century the workforce could be divided into hydrographic surveyors, marine cartographers, and draftsmen. The discovery and subsequent development of oil reserves in the North Sea required more hydrographic surveyors, most of whom were trained by naval hydrographic offices and were frequently specialist naval officers. Essentially they were navigators who had been given specialized courses in hydrography. In some countries, notably the United States, these specialists may also have had a university background in civil engineering. With the further need for hydrographic surveys as part of hydrocarbon exploration in the Gulf of Mexico and in the North Sea in the 1960s, the need for hydrographic surveyors to work in the civilian sector increased. Some were recruited from retired navy personnel and in some cases, personnel with backgrounds as merchant master mariners were developed on the job. Several schools, the North East London Polytechnic (now a university) and the Department of Survey Engineering at the University of New Brunswick, Canada, recognized the need for more formal training and arranged courses in hydrographic surveying. In 1972 a determined effort was begun by several international organizations to develop international courses and standards for hydrographic surveying training and education. This resulted in the establishment of the International Federation of Surveyors (Fédération Internationale des Géomètres, FIG) and International Hydrographic Organization (IHO) Advisory Board on Standards of Competence for Hydrographic Surveyors (Kapoor 1980).

Training and education for marine cartographers took a different path. Normally these persons had a university background in a closely related field, such as geography, engineering, or one of the physical sciences. Specific training in cartography took place on the job. In a relatively recent development to formalize training in marine cartography, courses and standards have been set by the FIG/IHO Advisory Board in conjunction with the International Cartographic Association (ICA) (Astermo 2004).

As the production of charts evolved from copperplate engraving through the use of plastics and zinc plates to computer graphics, the need for engravers, scribers, and skilled draftsmen practically disappeared. The development of the great diversity of backgrounds necessary to effectively use the new technology available has complicated the training needs of marine charting. No longer is there a neat separation between data collection and data management. Moreover, the personnel involved must have at least some general knowledge of all the processes involved. Course syllabi recommended by the FIG/IHO/ICA Advisory Board may be listed under a specialization but will include coverage of all topics that make up the activity of marine charting. Supporting this core of marine charting personnel are persons with a broad management background. These persons will normally enter the profession with qualifications ranging from mathematics to ergonomics or experimental psychology.

Marine charting for navigational purposes provides a key ingredient to the safe and effective movement of world trade. In so doing, marine cartography has contributed to the discovery and knowledge of the world. The marine charting discoveries of such eminent persons as Captain James Cook as well as companies like the East India Company in the eighteenth century are well known. Perhaps less well known is that exploration continues to this day through marine cartography. In spite of the advances of technology, the detailed knowledge that exists of many areas of the world's oceans is incredibly small compared with the mapping of the landmasses. Even in well-known and frequently traveled waters the seafloor is continually changing due to tidal currents and environmental effects (Dorst 2004). With shippers forced by economics to carry the maximum amount of cargo and consequently to load their ships to the deepest draft possible, it is essential that marine charts be routinely and continually updated. The importance of marine charting is recognized by the International Maritime Organization (IMO), the organization responsible for the safety of international navigation. Its Safety of Life at Sea (SOLAS) Convention requires that all ships carry charts and certain complementary publications. In addition, in 2002 it required all its signatories, who include most maritime nations, maintain hydrographic services (Ehlers 2002).

Work on formal specifications for paper charts began in 1972 and chart specifications were adopted in 1982 (Newson 1984). With the development of digital charts, standards for the transfer and presentation of digital chart data became necessary. The two specific standards in use at the beginning of the twenty-first century were IHO Publication S-52, *Specifications for Chart Content and Display Aspects of ECDIS*, and S-57, *IHO Transfer Standard for Digital Hydrographic Data*. In addition to developing these standards the IHO has formed the International Chart Committee, an organization to encourage the worldwide adoption of common standards for paper charts. This committee has also developed a worldwide chart scheme. For digital charts the IHO formed the WEND (Worldwide Electronic Navigational Chart Data Base), to encourage the development and distribution of official electronic charts (Wainwright and McPherson 2000).

The economics of marine charting, at least in relation to navigation, have been much discussed since the development of the electronic chart. With economics of government services becoming increasingly important in the last years of the twentieth century, an overriding issue has been whether countries should offer their work in marine charting as a service to the international community or whether they are expected by their governments to cover the costs of their products by their sale. It is clear in this argument that hydrographic offices believe that the safety of ships requires that they have a monopoly on the information available. The balance between government agencies and private agencies producing charts has varied greatly over the years (Fisher 2001). The governments argue that their products are without error, while the private firms argue that they are more efficient in production. The advent of the electronic chart has only refocused this discussion, not ended it. IMO requires inter alia that only a digital chart produced under the authority of a government agency can be accepted to replace the paper charts that are required under the SOLAS Convention (Hecht et al. 2006, 243–45). On the other hand, commercial charting organizations, which have obtained permission to use data from hydrographic offices, claim that they have digital charts available with global coverage whereas the hydrographic offices do not.

Nautical charts are legal documents and have an important role to play in the provision of evidence in courts of law (Shaw 2000; Troop 1985). These legal documents, both when used for navigation and in support of work in interpreting the United Nations Convention on the Law of the Sea, in particular in determining maritime boundaries, must be accurate and up-to-date. Although hydrographic offices always ensure that when charts are printed the information they contain is completely up to date, traditionally these hydrographic offices have produced *Notices to Mariners* at frequent intervals, usually weekly. These booklets provide information on all changes that have taken place to charted information. It has then been the responsibility of the owner of the chart to keep his charts up-to-date by amending the information. The availability of digital information and new methods of communication, such as the Internet, have altered this procedure. Another development that took place during the last decade of the twentieth century was print on demand (POD) technology, which sought to minimize print runs and ensure that charts were kept up to date to the moment of sale (Holroyd 2000).

During the twentieth century there were three major conferences dealing with the Law of the Sea and each resulted in relevant international conventions released in 1958, 1961, and 1982. Marine charting has provided a significant background for each of these events and is referred to in numerous articles of these conventions. Charts have a particular role in maritime boundary delimitation, and they are specifically referenced in defining maritime zones, such as the territorial sea, and the limits of the juridical continental shelf (Cook and Carleton 2000). While the nautical charts themselves are referenced in the convention and may be used as a basis for the legal and political discussions, special maps or charts are also drawn to illustrate how maritime boundaries are described geographically.

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SEE ALSO: Coastal Mapping; General Bathymetric Chart of the Oceans (GEBCO); Geographic Names: Gazetteer; Hydrographic Techniques; International Hydrographic Organization (Monaco); Law of the Sea; Marine Chart

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Marine Charting by Canada. Canada entered the twentieth century with what would prove to be the longest coastline in the world, once the ice-infested and then largely unknown waterways of the Arctic Archipelago were mapped and Newfoundland joined the Confederation. In addition to saltwater shorelines touching three oceans, the country's freshwater shoreline includes the Great Lakes, the St. Lawrence River, and various smaller features. However, because the number of people dedicated to marine charting has never been large, Canada has had perhaps the poorest ratio of marine cartographers to length of shoreline of any maritime nation. Considering the hostile climate and remoteness of much of that shoreline, the size of the area charted is truly impressive.

The twentieth century began with a small number of Canadian hydrographers taking over charting, including surveys, cartography, updating, and distribution, from the British Admiralty. The Canadian Hydrographic Service (CHS) produced the first all-Canadian chart (of Lake Winnipeg) in 1903. Until the 1950s CHS charts were generally indistinguishable from their Admiralty forebears, in accord with the objectives of the International Hydrographic Organization for standardization for the sake of safety. Moreover, the country's size dictated that energy be focused on extending coverage into the enormous uncharted areas, and not on improving symbols or content. The order in which areas were charted reflected demands of the day; for example, the inside passage between Vancouver Island and the mainland was charted in response to the Klondike gold rush. Other pressing needs included new charts to serve the man-made St. Lawrence Seaway and the far-flung stations of the Cold War's Distant Early Warning system. In the late 1970s, after Canada claimed an Exclusive Economic Zone (EEZ), which extended its jurisdiction 200 nautical miles offshore, special charts were constructed to show fishing limits and help litigate disputes with France and the United States over boundaries of the EEZ.

Requirements unrelated to expanding geographic coverage made inroads on the small cartographic staff and consumed most of the resources available. Programs responsible for this diversion include the addition of French text in response to the Quiet Revolution (which emphasized the bilingual nature of Canada) of the 1960s, the conversion from imperial to metric units in the 1970s, the need to reconstruct charts on new horizontal and vertical datums, the addition of lattice overlays for the Loran and Decca electronic positioning systems, and the introduction of a completely new system of buoys in the 1980s.

Even so, the CHS pursued a variety of cartographic innovations. During World War II, for example, chartlets (small-scale charts) showing water temperature helped mariners avoid U-boats, which could be hidden from sonar by temperature gradients. In 1964, the CHS began to produce charts for the amateur boater. In the 1960s, the agency realized that data painstakingly collected at sea for traditional navigational hydrography could have a wider role within marine science. Reinterpreting the same field data led to the production of bathymetric maps, specifically, a series of more than five hundred 1:250,000 bathymetric maps, designed to extend topographic coverage out to the edge of the continental shelf. Another way to create more information from the same data was to examine echo sounder records and partition the seafloor into areas that returned a similar signal. After bottom sampling confirmed that acoustically similar areas were also geologically similar, extensive areas off eastern Canada were mapped this way. Experimental combinations of maps showing bathymetry and the surficial geology of the seafloor were made for the commercial fishing industry. Hydrographic survey ships were equipped with gravimeters and magnetometers, and the data collected were presented to the public as additional versions of the bathymetric maps.

Computers were introduced into chart production in the 1960s. Because software suitable for marine charting was in short supply, the CHS began to develop its own in-house system in 1968. Software development was eventually transferred (through the University of New Brunswick) to a small company in Fredericton that grew to become CARIS (Computer Aided Resource Information System), the producer of hydrographic software recognized as the de facto worldwide standard. This initial period of computer-assisted cartography was aimed at increased efficiency in the production of paper charts, but as computer usage increased, CHS officials began to explore the replacement of paper charts. In 1983 the agency proposed what later become known as the Electronic Chart. Early papers and mock-ups suggested the eventual emergence of a totally new form of cartography—the shopping list included three-dimensional views, radar integration, queryable aids, depths that adjusted with tide in real time, night maps and night-viewing screens, and views from the crow's nest—but progress toward these innovations was slowed by the enormous demands of standards development and data storage.

Tasks left for the twenty-first century included a substantial reduction in uncharted areas as well as an integration of navigation and sensing instruments (echo sounder, lidar, remote sensing), improved underwater and seafloor visualization, more reliable methods for depicting uncertainty and coping with rising seas, a thorough charting of deeper waters and, ultimately, a seamless map with fine resolution covering the entire surface of the earth, both subaerial and subaqueous.

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SEE ALSO: Coastal Mapping; Geographic Names: Gazetteer; Hydrographic Techniques; Marine Chart

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Marine Charting by the United States. The history of marine charting by the United States in the twentieth century is a complex and multilayered story, one of multiple government agencies, each with roots firmly set in the nineteenth century, sometimes at odds with each other (often in territorial disputes), at others in close cooperation (as during the world wars), working toward a common goal of promoting safe navigation through nautical charts. It opens with an ascendant United States, invigorated from victory in the Spanish-American War, and closes with the United States as a global partner in a maritime marketplace where ships of previously unimagined size ply the waterways of the world.

As the twentieth century opened, there were three agencies responsible for charting in the United States, each, in theory, with its own unique mission and sphere of responsibility. First among these was the Coast and Geodetic Survey (USC&GS), a civilian agency under the Department of Treasury (after 1903 under the Department of Commerce), which harked back to President Thomas Jefferson's Coast Survey of 1807. In addition, there was the Hydrographic Office of the Navy Department, whose origins date back to the Depot of Charts and Instruments established in 1830, and the newly revived Lake Survey, under the War Department's Army Corps of Engineers, which had begun surveying the Great Lakes in 1841 but had closed its doors upon fulfilling its stated mission in 1882.

By century's end, only two of these agencies—the USC&GS and the Hydrographic Office—would remain, with new names and changes in mission. A fourth agency, the Defense Mapping Agency (DMA), would come into being in 1972 (National Research Council, Panel 1981, 46–51). The agency that did not survive the century, the Lake Survey, finally closed its doors in 1976.

In January 1901, after a hiatus of nearly twenty years, the U.S. Lake Survey renewed its operations on the Great Lakes. The engineers of the Lake Survey believed they had completed their mission of surveying and charting the Great Lakes, only to discover that the business of making charts was never ending. Not only had the user base changed as the age of sail gave way to the age of steam, but the continual increase in vessel size coupled with the fact that hydrography is ever changing combined to make the charts sold by the Lake Survey obsolete. The Lake Survey had made an effort to keep the mariner informed of changes by publishing the *Great Lakes Bulletin*, an annual publication of maritime information with monthly supplements published during navigation season (May–December), which sometimes included small maps that contained critical data. This information proved insufficient, and the Lake Survey embarked on a new age of Great Lakes charting (Woodford 1991, 85–87).

The Lake Survey immediately encountered a turf war since the Hydrographic Office had established a presence on the Great Lakes. The two were at odds until 1909, when a firm line was established between Lake Survey and Hydrographic Office areas of operation. The Hydrographic Office would cease publication of Great Lake charts in U.S waters and concentrate solely on charts in Canadian waters. In addition, the Hydrographic Office released its collection of Great Lakes charts in U.S. waters to the Lake Survey. This brought a suite of Mercator charts into the Lake Survey's otherwise polyconic projection fold. Sold alongside the polyconic charts, the Mercator charts were eventually discontinued in 1925 when sales data showed that mariners preferred polyconic charts (Woodford 1991, 102).

In 1914, the Lake Survey's area of responsibility was extended to include the boundary waters between the Lake of the Woods and Lake Superior. At its greatest extent, Lake Survey chart coverage ran from the New York State Barge Canal in the east to the Lake of the Woods in the Midwest (Woodford 1991, 104–5).

Most lake traffic followed established routes, but in 1907 the Lake Survey decided to attempt the challenging task of obtaining expanded bottom coverage. There were some who, given the traffic patterns, thought this unnecessary, but the number of pinnacles and shoals found proved them wrong. By 1922 the Lake Survey had produced 123 different charts. Their mission was hampered by the economic downturn in the early 1920s, but was injured even more by the Great Depression, when traffic on the lakes saw a dramatic decline. However, they completed the resurvey plan in 1936, a period of almost thirty years. It would take nearly thirty more years before adequate deepwater sounding data for each of the lakes were collected (Woodford 1991, esp. 95–97, 113–14, 130–31).

During World War I the Lake Survey contributed to the war effort by increasing its chart production and by printing such things as recruiting posters for the U.S. War Department. World War II ushered in a new era of shipbuilding and commerce on the Great Lakes. Not only did the number of charts printed increase exponentially, but the Lake Survey created a special *Submarine Training Chart of Upper Lake Michigan* for the Navy (Woodford 1991, 137).

In 1957, anticipating the opening of the Saint Lawrence Seaway, cartographers at the Lake Survey created three provisional charts, which when put into use once the seaway was flooded, proved to be very accurate. Another innovation, not technological but sales oriented, was the recreational or book chart. First published in 1962, the recreational chart was a spiral bound booklet measuring 14 × 17 inches. Sales of these small-format charts were aimed at the increasing pleasure boating community (Woodford 1991, 159, 174–75).

The Lake Survey ended its years of service under the Corps of Engineers in July 1970, when it was transferred to the newly created National Oceanic and Atmospheric Administration (NOAA), as the Lake Survey Center, under NOAA's National Ocean Survey (NOS). The

Lake Survey Center continued making charts for four years until July 1974, when all charting functions were transferred to the NOS facilities in Rockville, Maryland (Woodford 1991, 186–89).

The U.S. Naval Hydrographic Office, formed from the Navy Department's Depot of Charts and Instruments in 1866, was the U.S. agency traditionally responsible for charting foreign oceans and waters. Their charts were often recompilations of charts from other nations, but they also compiled charts from their own data (Weber 1926). Early in their existence, contractors printed the Hydrographic Office's suite of charts, but by the twentieth century they were fully versed in the printing of charts and contributed to the field with technical innovations such as the pantograver and Gray's lettering device (Pinsel 1982, 51, 61).

In the early twentieth century the Hydrographic Office had surveyed across the globe—off the coasts of Africa, as far north as Alaska and south to Argentina, far to the east in China, and in the deep Pacific at Samoa. By 1925 their chart suite consisted of about 2,700 general-purpose charts and about 200 classified charts. Most were reproductions of foreign, Coast Survey, or Lake Survey charts, but 345 were compiled from original Hydrographic Office surveys (Weber 1926, 54).

During World War II the Hydrographic Office did unparalleled work. At the height of production their offices were manned twenty-four hours a day, printing over forty million charts in the final year of the war (Pinsel 1982, 59). Some survey ships were equipped with presses that could print 2,000 sheets per hour (Bates 2005, 287).

President John F. Kennedy, an advocate of oceanography, renamed the office the Naval Oceanographic Office in 1962. However, its duties remained the same. In 1972 its charting functions were transferred to the newly created DMA (National Research Council, Panel 1981). It retained its surveying functions into the twenty-first century (Bates 2005).

The DMA, renamed the National Imagery and Mapping Agency (NIMA) in 1996, continues to produce charts of foreign waters, albeit as the National Geospatial-Intelligence Agency (NGA) from 2004 onward. In addition to paper charts, the NGA has produced digital versions of their suite of over 5,000 charts in their copyrighted, International Maritime Organization (IMO) Electronic Chart Display and Information System (ECDIS) compliant, Digital Nautical Charts (Bates 2005, 232).

Among the federal organizations responsible for providing nautical charts in the United States, only the USC&GS, later known as the Office of Coast Survey (OCS), continued operations uninterrupted through the entire twentieth century. At the beginning of the twentieth century, the USC&GS was in a situation similar to that of the Lake Survey, as it was embroiled in a turf war with the Hydrographic Office. The war developed in the nineteenth century when two special commissions (the Allison Joint Commission of 1884–86 followed by the Dockery Joint Commission of 1893–95) recommended that the duties of the USC&GS be transferred to the Hydrographic Office. Political infighting and the Spanish-American War forestalled any such action on the part of Congress. The wording in the Sundry Civil Act of 1899, which allowed the USC&GS to survey territory brought under the U.S. sphere of influence following victory in the Spanish-American War, further exacerbated the situation. The state of affairs became serious enough to attract the attention of the U.S. Congress, which held a series of hearings into the matter in 1900 (National Research Council, Panel 1981, 66–68).

The Hydrographic Office's stance was that the USC&GS should integrate into the Navy. They reasoned that the officers of the Navy, trained mariners and navigators, were more suited to conduct surveys and make charts than USC&GS scientists and that, unlike the USC&GS scientists, the Navy would stick to the task of surveying and not become sidetracked with other endeavors. The USC&GS countered with the argument that ships of the Navy were subject to changes in orders, often called away to duty, and therefore unable to complete surveys. The argument went further; the USC&GS suggested that there was little similarity between officers of a deepwater navy and merchant mariners engaged in a coastwise trade (Manning 1988, 137–38). Upon weighing testimony from both camps, Congress decided to maintain the status quo (National Research Council, Panel 1981, 67–68). This allowed the USC&GS to go forward with its survey plans for the Philippines and other new territories beyond the continental United States (Manning 1988, 148–49) while continuing in its scientific duties, printing charts, and issuing reports of hazards in notices to mariners (a task it would eventually transfer to the Lighthouse Bureau, but would continue to provide data for throughout the century).

From an organizational point of view, the USC&GS was divided into two broad groups—the field and the office. The field comprised the personnel whose duties were to do the measuring—surveyors, engineers, ship's crew, and so on. The office was responsible for providing support to the field, for receiving the raw data from the field, and for transforming data into a format useable by cartographers. The office also employed a staff of copperplate engravers and printers (USC&GS 1925, 2–3).

Within the office there were two divisions involved with hands-on chart production: the Chart Construction Division (renamed from the Drawing and Engrav-

FIG. 505. DETAIL FROM 1900 EDITION OF *APPROACHES TO BALTIMORE HARBOR*, 1:40,000. U.S. Coast and Geodetic Survey, chart 549. Note the number of projection graticule lines in use and the amount of detail shown on land as well as the lack of color.
Size of the entire original: 83.8 × 99 cm; size of detail: 30.3 × 26.3 cm. Image courtesy of NOAA's Historical Map & Chart Collection.

ing Division in 1911) and the Chart Division. The Chart Construction Division housed the cartographers who made new charts and revised existing charts from data received from the field. Those who worked in the actual printing process—copperplate engravers, printers, photographers and so on—were also in the Chart Construction Division (USC&GS 1913, 92–94).

The Chart Division was responsible for hand correcting printed charts prior to sale to the public (from the information printed in the notices to mariners), hand coloring buoys and lights, sales and distribution, and general chart correspondence (USC&GS 1913, 94–95). By 1915, with an eye toward gaining efficiency, reorganization brought these two together as the Chart Division, with separate drafting, engraving, printing and photography sections (USC&GS 1915). The Drafting Section of the Chart Division survives as the OCS Marine Chart Division.

The charts (slightly over 500 at the beginning of the century, numbering more than 1,000 by century's end) were compiled from a wide variety of source documents. Data were supplied by USC&GS survey teams, the Corps of Engineers, the Light House Bureau (later the Coast Guard), and the Navy as well as by other public and private organizations. The types of charts produced in 1900—sailing charts, general charts, coastal charts, and harbor charts (fig. 505) (USC&GS 1925, 88–89)—continued into the twenty-first century for both paper and electronic charts. Charts were first drawn on the polyconic projection, which the Navy complained about for years until a board of experts was assembled in 1910 and recommended a change to the Mercator projection, a process that took two decades to complete (Monmonier 2008, 75).

World War I spurred innovation and new technologies, such as the use of airplanes for aerial photography (Ehrenberg 1983, 369–70). The USC&GS conducted its first aerial shoreline feasibility tests in 1919 (Smith 1979, 10), finding that aerial photography allowed a wealth of coastal detail to be captured quickly and cheaply using

FIG. 506. DETAIL FROM 1931 EDITION OF *APPROACHES TO BALTIMORE HARBOR*, 1:40,000. U.S. Coast and Geodetic Survey, chart 549. Land is now shown in a buff tint, and larger-scale chart coverage is mentioned as a parenthetical "(chart 545)" in red. Red buoy hulls are also colored. Curves are made to stand out through "sanding," i.e., use of a stipple pattern. Also of note is the area just above the center labeled "AIRPORT *being filled*."
Size of the entire original: 88.9 × 101.6 cm; size of detail: 30.3 × 26.3 cm. Image courtesy of NOAA's Historical Map & Chart Collection.

FIG. 507. DETAIL FROM 1945 EDITION OF *APPROACHES TO BALTIMORE HARBOR*, 1:40,000. U.S. Coast and Geodetic Survey, chart 549. Blue tint has been added to this edition, allowing marsh areas to now be shown in green. The airport has been completed. Much of the landward detail has been removed.
Size of the entire original: 88.9 × 111.8 cm; size of detail: 30.3 × 26.3 cm. Image courtesy of NOAA's Historical Map & Chart Collection.

photogrammetric techniques (fig. 506). In the 1930s, data collection was assisted by the invention of a nine-lens large-format aerial camera that could image an 11 × 11 mile area on nine film negatives that were subsequently merged into a single air photo using a special "transforming printer" (Monmonier 2008, 61–62). By the 1940s, aerial photogrammetry had replaced plane table surveying as the principal coastal data collection technique.

During World War II, as in World War I, USC&GS survey ships were transferred to the Navy. However, the most important contribution to the war effort was charts, with over four million copies printed in 1945 alone. Hydrographic survey data and charts of the Philippines, constructed at the USC&GS Manila office in the years prior to the war, and transferred for archival purposes to Washington, were indispensible to operations in the Pacific due to the amphibious nature of the Philippines Campaign (USC&GS 1945).

The increase in marine traffic that followed in the wake of the postwar prosperity gave rise to an increase in chart sales. As the number of pleasure boaters increased, the USC&GS sought ways to meet their needs (fig. 507). In 1959 the first small-craft chart (a folding chart of the Potomac River) was printed (USC&GS 1959). That number grew to more than fifty toward the end of the century, though sales declined through the 1980s and 1990s (National Research Council, Committee 1994, 46–48).

By the 1970s (fig. 508) and into the 1980s, USC&GS cartographers were working with computerized charting techniques, but these efforts were hampered by limits of processing speed and available memory. A chart of Pascagoula Harbor was printed in 1973 using computerized methods, but a fully automated system was still

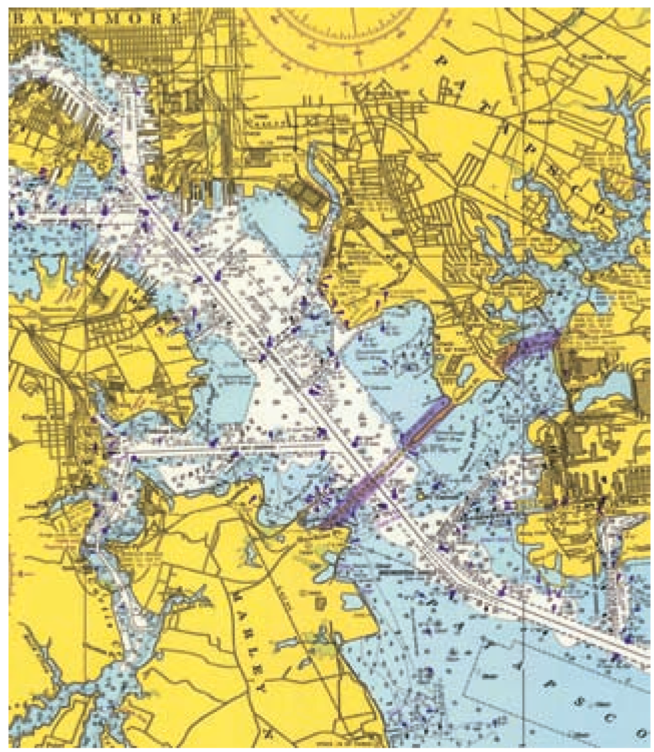

FIG. 508. DETAIL FROM 1974 EDITION OF *APPROACHES TO BALTIMORE HARBOR*, 1:40,000. National Ocean Survey, NOAA chart 549. As the jet age made Baltimore's aging airport obsolete, a new airport was built to the south of the city. The old airport became a marine terminal. Note the magenta screen showing the Francis Scott Key Bridge under construction, which is the southern extension of Interstate 695. Also note the growth of the Bethlehem Steel plant at Sparrows Point, which led to the disappearance of Humphrey Creek.
Size of the entire original: 93.1 × 115.8 cm; size of detail: 30.3 × 26.3 cm. Image courtesy of NOAA's Historical Map & Chart Collection.

FIG. 509. DETAIL FROM 2000 EDITION OF *APPROACHES TO BALTIMORE HARBOR*, 1:40,000. Coast Survey, National Ocean Service, NOAA chart 549 was renumbered to 12278 in the 1970s. Much of the interior road detail has been removed in favor of an urban tint. Detail in the water area to the north of the Key Bridge has been removed, and a note "(use chart 12281)" added.
Size of the entire original: 94 × 119.4 cm; size of detail: 30.3 × 26.3 cm. Image courtesy of NOAA's Historical Map & Chart Collection.

decades off (USC&GS 1973). It took the computer revolution of the 1990s to pave the way to a digital system for making paper charts. By the late 1990s this system completely replaced the ink-on-mylar used in chart compilation since 1956 (fig. 509).

As the century closed and into the first decade of the twenty-first century, the USC&GS was producing electronic nautical charts in an International Hydrographic Organization format, a suite of slightly more than 1,000 traditional paper charts and raster versions of the paper charts. Newly acquired topographic detail for the charts came from traditional aerial photography and newer satellite imagery, with bathymetry obtained by sonar soundings and newer technology such as bathymetric lidar. At the end of the century, lidar held the promise of providing superior shallow water survey data and more precise definition of shorelines.

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SEE ALSO: Coastal Mapping; Geographic Names: Gazetteer; Hydrographic Techniques; Marine Chart

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Marine Charting by Argentina. Coastal hazards and a long coastline flanked by numerous islands and indented by navigable waterways gave the Argentine Republic a strong incentive for nautical cartography. An independent nation since 1816, the country did not chart its waters systematically until the late nineteenth century. The Río de la Plata (José Murature), the Río Negro, the Río Santa Cruz, and the Isla de los Estados (Luis Piedra Buena) were the first features to be surveyed, although not as a national endeavor. The Oficina Central de Hidrografia was established in 1879, but at that time the only charts available were those produced by the English, the Spanish, and the French.

A modernization movement that included weather observations, lighthouses, and coastal beacons inspired completion of Argentina's first nautical chart (the Bahía de San Blas sheet), published in 1883. The country published its first chart of Antarctica in 1904, and the fraction of main ports charted increased from one-third in 1917 to three-quarters in 1932. Twenty-five years later charting was complete for the entire coast as well as for navigation routes to Argentina's Antarctic territory and the Islas del Atlántico Sur (Malvinas, Georgias del Sur, and Sandwich del Sur). Other advances included *Notices to Mariners*, initiated in 1918 to supplement printed charts with the latest information about hazards, and tide tables, published annually since 1920.

Early mapping of Argentina was based on the Bessel ellipsoid of 1841 (Mugnier 1999). The International ellipsoid (also called the Hayford ellipsoid), developed by John Fillmore Hayford in 1909–10 and adopted by the International Union of Geodesy and Geophysics in 1924, provided a geodetic framework for later charts. It was replaced in the late twentieth century by the World Geodetic System 1984 (WGS84) datum.

Lack of standardized hydrographic methods and internationally accepted charting symbols was addressed in 1921 by the founding of the International Hydrographic Organization (IHO). Argentina was one of the original nineteen member states and has been actively involved in IHO efforts to create worldwide charting standards.

As technological advances made nautical cartography more precise, Argentina launched an oceanographic program in 1938 and began to use photogrammetry for acquiring onshore topographic data in 1948. The Centro Argentino de Cartografía, founded in 1955, promoted a fuller sharing of national data among cartographers in government and academia. The Escuela de Cartógrafos Buenos Aires, founded in 1962 and later known as the Escuela de Ciencias del Mar, addressed a shortage of trained personnel in cartographic science.

Following completion of its nationwide series of charts in 1957, Argentina initiated a new cartographic plan in 1969. In accord with IHO guidelines, the new plan standardized the representation of objects and the use of geodetic systems, called for a uniform treatment of bathymetry (in meters), and standardized paper sizes and compilation scales. To differentiate them from previous series, these new charts were given the prefix "H." Shortly afterward the 1972 Ley Hidrográfica defined the scope and objectives of nautical cartography as well as the duties of the Servicio de Hidrografía Naval.

The final decades of the century witnessed a fuller use of electronic technology. In 1987 the Instituto Geográfico Militar (IGM) introduced the *Carta de Imagen Satelitaria*, which signaled the growing importance of remote sensing and digital methods. In 1996, Argentina released its first nautical chart produced using digital technology (Chart H-116, *Río de la Plata Medio y Superior*). In 2001, the technical publication *Producción de Cartas Náuticas Digitales*, a new manual developed as a teaching aid, focused on the production of digital nautical charts. The increased importance of river ports led to a new series of forty charts covering 240 nautical miles of the Paraná River, and in 2006 the first electronic navigational chart was published in accord with the *IHO Transfer Standard for Digital Hydrographic Data* (S-57).

Despite these advances, electronic cartography posed several challenges for Argentine maritime cartographers at the beginning of the twenty-first century. In addition to developing an electronic chart database based on the S-57 standard and more effectively integrating hydrographic data with the National Spatial Data Infrastructure, Argentina needed to integrate mapping prepared for the United Nations Commission on the Limits of the Continental Shelf with its overall plan for maritime charting.

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SEE ALSO: Coastal Mapping; Geographic Names: Gazetteer; Hydrographic Techniques; Marine Chart

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Marine Charting by Great Britain. The United Kingdom's Royal Naval Hydrographic Office was founded in 1795 to provide navigational information for the fleet. Since then, the sale of charts and other publications to commercial shipping has brought a responsibility to consider its requirements, but the Hydrographic Service remains part of the Ministry of Defence, and the needs of the fleet are its primary responsibility.

The first official hydrographer was a civilian, Alexander Dalrymple. He was succeeded in 1808 by Captain Thomas Hurd, the first of a line of Royal Naval officers who continued until 2001. After the end of the Napoleonic Wars, with a surplus of ships and men, the Royal Navy began to survey and chart worldwide, wherever British shipping sailed. In 1819 Hurd obtained permission to sell copies of the Admiralty charts to private users. He also established a corps of seamen specializing in surveying who officered his ships.

Hurd's greatest successor was Francis Beaufort, hydrographer from 1829 to 1855. In the Crimean War (1854–56), he attached surveyors to the Baltic and Black Sea fleets who proved their worth to their commanders-in-chief. In 1856 the printing of Admiralty charts, until then done by the hydrographer's staff, was contracted out. There was cordial cooperation with civilian scientists, and most foreign-going surveying ships carried them. HMS *Challenger*'s world voyage (1872–76) gathered data that greatly boosted the science of oceanography.

By 1900 the method of production of charts had been standardized. A compilation drawing (a shorthand depiction of the final chart) would be redrawn by a "production draughtsman" as it would appear in print. This would be engraved on a copperplate from which printing plates, either stone or zinc, would be made for printing on flatbed presses. Each stage would be checked, and a final proof was seen by the hydrographer himself and passed for publication. The published charts were corrected between new editions by *Notices to Mariners*.

In 1901 the Admiralty Chart Series consisted of 3,089 charts. Volumes of *Sailing Directions, Lists of Lights, Tide Tables*, and other publications were also produced (U.K. Hydrographic Office 1901). The astronomer royal came under the hydrographer and published *The Nautical Almanac*.

Surveying overseas was carried out from a rag-bag of obsolete sloops and gunboats. In home waters there were two specially built small paddle steamers, HMS *Triton* and HMS *Research*. Private firms continued to publish charts throughout the century, though increasingly they catered only to special interests, fishing, and yachting (Fisher 2001).

As Anglo-German rivalry increased toward 1914, surveying and charting in the shifting banks in the southern North Sea and the shallow waters of the Dogger Bank took priority. For surveying overseas a new ship, HMS *Endeavour*, was fitted out with printing equipment to produce operational charts in theater, and during the war *Endeavour* served in the Mediterranean (fig. 510).

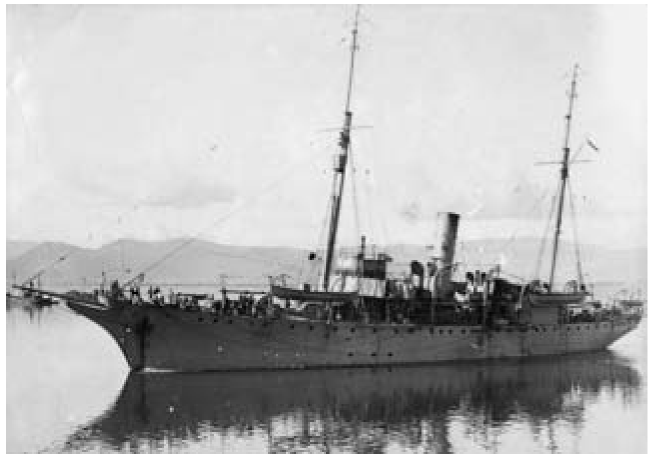

FIG. 510. HMS *ENDEAVOUR*, 1915. The ship, purpose-built for surveying in 1912, is shown here in 1915 in Mudros during the Dardanelles operations, where the printing machinery carried on board was invaluable for the timely production of operational charts.
Image courtesy of the U.K. Hydrographic Office, Taunton.

In wartime the promulgation of navigational information had to be controlled so that details of minefields, buoyage, lights, wrecks, etc., were made available to Allied shipping, and denied to the enemy. Fleet Notices were instituted to promulgate classified information to official chart users, and Fleet Charts in a range of security classifications were issued as required for operations. Unclassified *Notices to Mariners* reduced from 2,030 in 1913 to 1,345 in 1915, while Fleet Notices increased from 43 in 1913 to 855 in 1918 (Day 1967).

During World War I all vessels under the control of the Ministry of Shipping were supplied with charts and publications by the hydrographer. In 1919 the scheme was modified to allow charts to be sold to shipowners directly from the Admiralty. Protests from chart agents soon stopped this, and commercial users were supplied through agents again.

Dissatisfaction with the contract printers of charts had been growing before the war, but no action was taken until after the armistice. In 1922, printing was brought back in-house and an Admiralty Chart Establishment set up at Cricklewood in north London.

After the war new ships replaced the old converted sloops. Four minesweepers were provided for surveys in home waters and four fleet sloops for overseas surveys. One of the home ships, HMS *Kellett*, was fitted in 1921 with an early echo sounder. After teething troubles had been overcome echo soundings were accepted as standard in 1927.

The staff of the Hydrographic Office had been cut after the war from 367 in 1918 to 118 in 1923. In 1924 the cartographic staff was moved out of the Admiralty building across the Thames to Cornwall House. The new location provided, for the first time, the space and light lacking in the attics of Whitehall.

Chart printing was by direct impression from copper or lithographic plates on flatbed presses. This was precise but slow. The rotary offset process, printing from a zinc plate copied from the original copper, allowed copies to be printed much more quickly and reduced wear on the copper original. After successful trials in 1938 a crash program converting all chart plates to zinc was completed before World War II began in September 1939.

All charting operations were under the hydrographer's control, but they were scattered across London. Concentrating them in London would be prohibitively expensive, and with the threat of aerial bombing looming, the government wanted to move nonessential departments away from the capital. A move to Taunton was approved. This location had good road and rail links with the south coast naval bases, Portsmouth and Plymouth, and was not threatened by bombing. Work on the new buildings began in 1940, and chart production and distribution moved there in June 1941.

When war broke out the department had moved to Bath, into commandeered buildings. The move was completed by the end of October 1939 without interrupting the supply of charts to ships. With World War II so much more fluid than World War I the demand for charts was much greater, and it could not have been met without the offset rotary printing process (fig. 511). There was the same problem of making navigational information available to allied shipping while denying it to the enemy. Many of the staff from the earlier war resurrected the same organization of classified *Notices* and Radio Navigational Warnings.

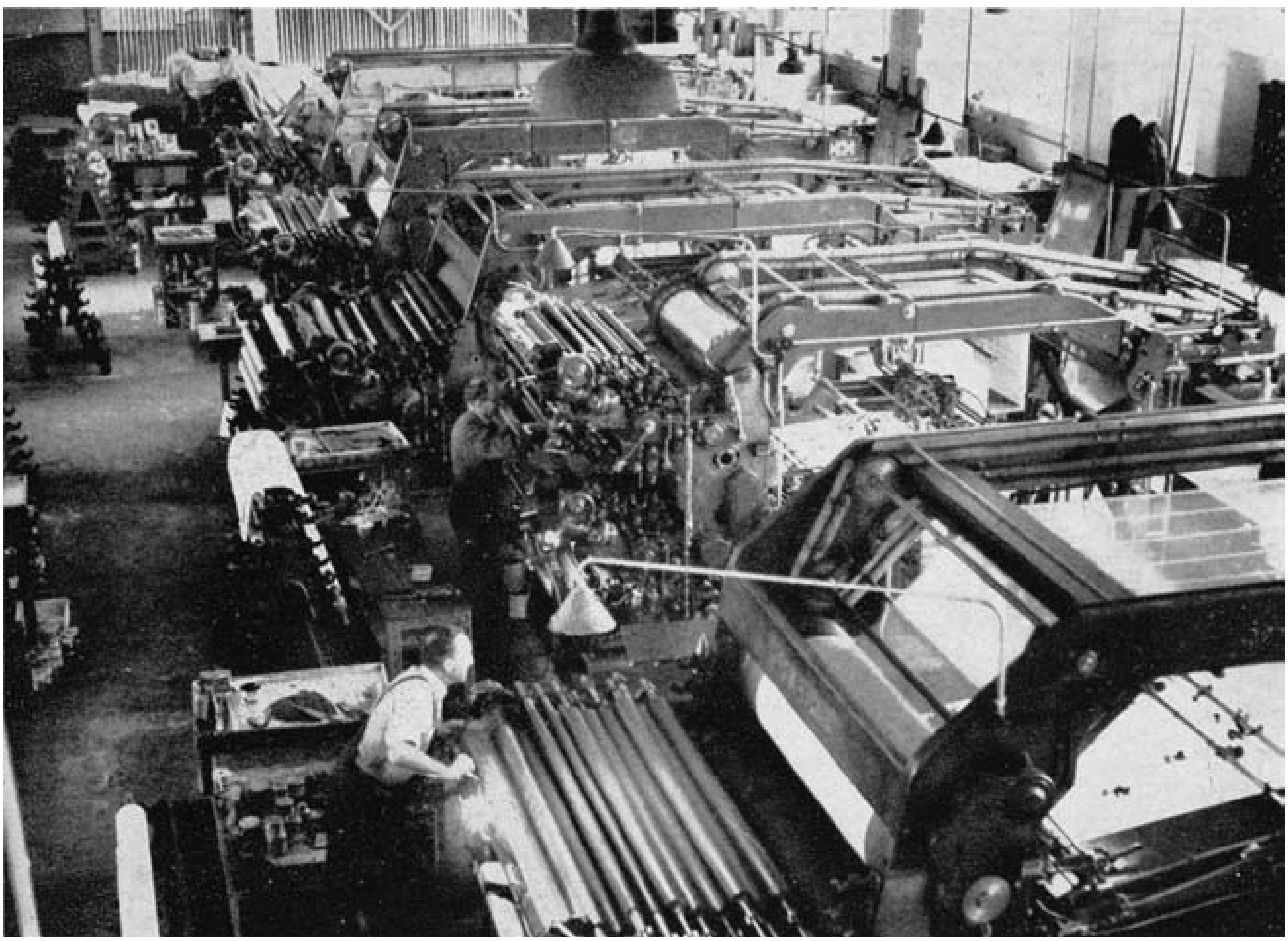

FIG. 511. THE PRINT ROOM AT THE HYDROGRAPHIC SUPPLIES ESTABLISHMENT AT TAUNTON, CA. 1960, SHOWING ROTARY OFFSET PRINTING MACHINES. From the hydrographer's annual report for 1960.

Image courtesy of the U.K. Hydrographic Office, Taunton.

The work of the Hydrographic Service, both ashore and afloat, in support of the invasion of Europe in 1944 was immense. Security was a constant worry, and the Staff Charts office in the Admiralty had to limit the issuing of charts of the Bay of the Seine, and make issues of other areas, to disguise the invasion site. Clandestine check surveys were carried out from small craft at night off the invasion beaches. In the final run-up to D-Day the Hydrographic Department supplied over 30,000 packets of documents to over 6,000 ships, craft, and authorities, and all classified at least "Secret."

After World War II the Hydrographic Office, except for the printing and issues departments, was concentrated at Cricklewood. The charting staff was kept fully occupied in charting the devastated ports of Europe, the Mediterranean, and the Far East and assisting in clearing minefields or charting safe passages through those that were not cleared immediately.

The introduction of radar and electronic navigation systems allowed ships' positions to be fixed in all weather. Charts overprinted with the systems' lattices were produced. Satellite navigation's advent in the 1960s completed the change from visual fixing in sight of land in daylight and in good visibility to the ability to fix ships' positions anywhere in the world at any time of the day or night in any weather.

The constant shuttling of proofs between Cricklewood and Taunton was very inefficient, and in 1963 approval was given to expand the buildings at Taunton and to move the Cricklewood staff and operations there. Work on the new building started in 1964, and the staff moved in April 1968.

The introduction of inertial navigation led to a need for information on the variations in the earth's gravity. The first sea gravity meter was fitted in HMS *Owen* in 1961, and these instruments became standard fit in the ocean-going surveying ships of the *Hecla* class. Complicated calculations were necessary to reduce the observations, so automatic data logging and plotting equipment was fitted both in the ships and ashore.

In the late 1950s plastic drawing materials were introduced. These were more dimensionally stable than paper and better suited for use with automatic plotters. When plastic sheets began to be used for the master bases for printed charts, with printing "plates" reproduced from them by precise photography, it became easier to use color on the published charts. In 1948 color washes in shallow water were introduced to make dangers more conspicuous—the first of an increasing variety of colored features. More of the data on the bases for the published charts came to be drawn automatically, until by the 1990s the whole printing base was generated digitally, and the reproduction draughtsmen became extinct.

By the 1960s charts in the Admiralty Chart Series varied widely, dating from as early as the 1830s to fully modern in style and content. In 1966 the government of Prime Minister Harold Wilson committed the United Kingdom to convert to metric units. The opportunity was taken to modernize the whole series. It was reschemed and the style of the charts changed so that their units would be seen at a glance. Land was tinted in buff, much more use made of shallow water blue washes, and lettering styles were simplified and clarified (figs. 512 and 513). Four-color rotary offset printing presses were introduced to print the new style charts. It had been planned to complete the whole changeover within ten years, and additional staff were recruited for the task. Even with them, only half of the series had been converted by 1989.

By the 1970s the needs of military and commercial shipping were diverging. With the advent of the VLCC (very large crude carrier), warships were no longer the biggest vessels afloat. The needs of deep-diving nuclear submarines had no commercial relevance. With cuts in the size of the Navy the surveying fleet was pressed to take its share of the pain, yet the demands on the Hydrographic Office were growing, not shrinking. After much wrangling, an annual subvention from the Department of Trade was agreed and a program for surveys that took into account the needs of commercial shipping drawn up.

The increased use of automated systems on the bridges of ships led in the 1970s to a demand for charts in digital format. A struggle arose between the ideal of a fully authoritative system that could apply the data (for instance, select a depth contour and keep the ship outside it) and simpler data sets that only allowed the ship's position to be plotted electronically on a digital image of a paper chart. Standards for fully manipulable data have been produced by the International Hydrographic Organization, but by century's end full world chart coverage was not available in this format. In the interim the Admiralty Raster Chart Series, a digitized reproduction of the Admiralty Chart Series, was inaugurated in 1998 (U.K. Hydrographic Office 1999).

In the 1990s the ships of the surveying flotilla were removed from the hydrographer's direct authority and incorporated in the Royal Navy's surface fleet. This removed the rationale behind the hydrographer being a serving flag officer. In 2001 came the appointment of a civilian hydrographer. So, 205 years from the office's foundation, the chief executive of the Hydrographic Office was a civilian again, responsible only for the production of charts, and not for surveying.

ROGER MORRIS

SEE ALSO: Coastal Mapping; Geographic Names: Gazetteer; Hydrographic Techniques; Marine Chart

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FIG. 512. DETAIL FROM FEET AND FATHOMS CHART, 1860. *Sound of Iona*, 1:24,000, Admiralty Chart 2617. Compare figure 513.

Size of the entire original: 96.4 × 64.9 cm; size of detail: 34.9 × 34 cm. Image courtesy of the National Library of Scotland, Edinburgh.

Fisher, Susanna. 2001. *The Makers of the Blueback Charts: A History of Imray Laurie Norie & Wilson Ltd*. St Ives: Imray Laurie Norie & Wilson.

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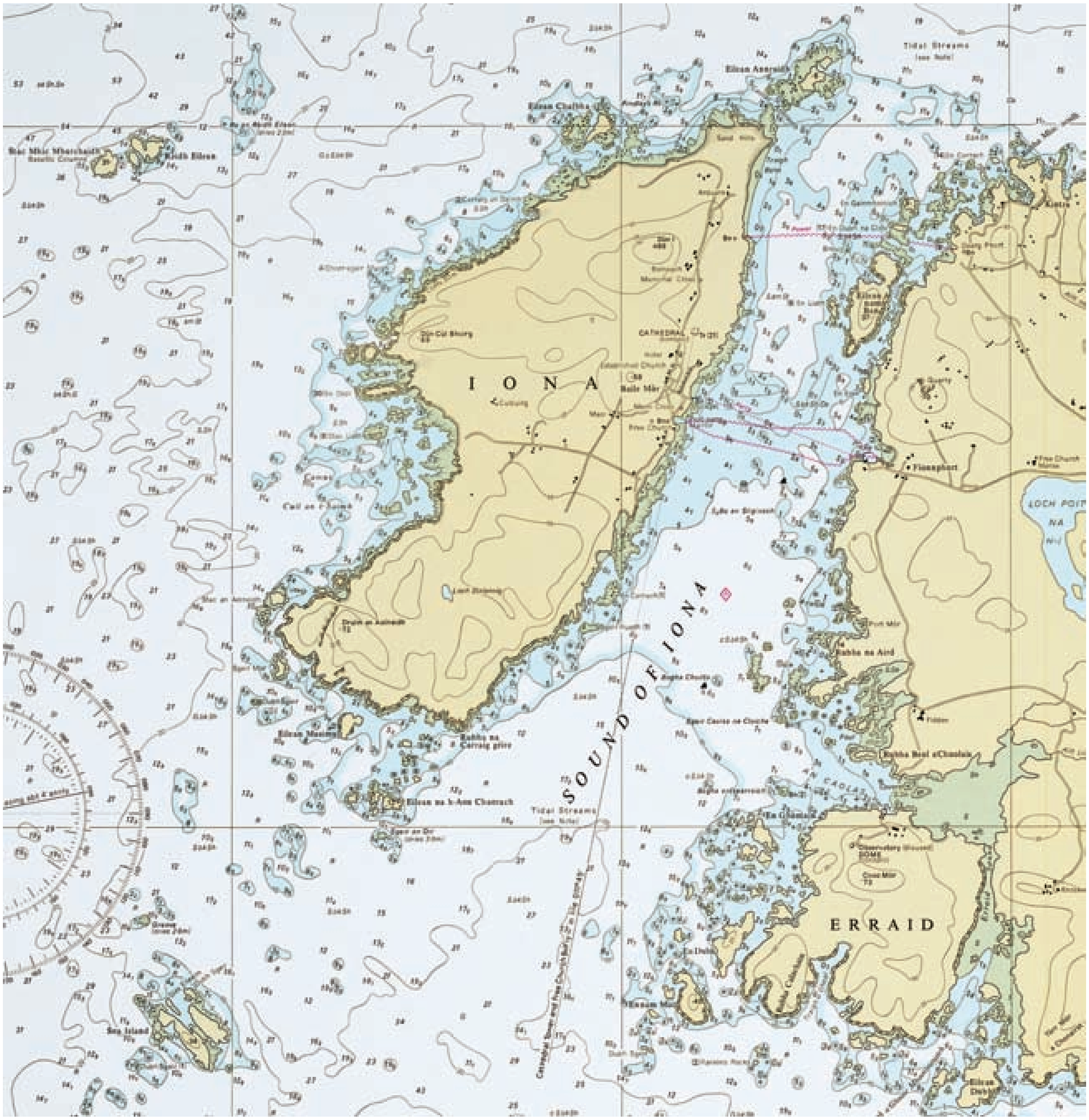

FIG. 513. DETAIL FROM METRIC CHART, 1977. *Sound of Iona*, 1:25,000, BA 2617. The same area of the Sound of Iona on the west coast of Scotland is shown on a feet and fathoms chart (fig. 512) and this metric chart. This colorful later chart is immediately distinguishable as in metric units from the monochrome Victorian version. Size of the entire original: 68.9 × 86.5 cm; size of detail: 35.1 × 34.2 cm. Permission courtesy of the U.K. Hydrographic Office, Taunton.

Marine Charting by France. The French nautical chart portfolio reached its apex in 1880, two centuries after the first edition of the *Neptune françois* and one century after Joseph-Antoine-Raymond Bruny d'Entrecasteaux's expedition during which Charles-François Beautemps-Beaupré designed modern surveying methods. With 3,000 charts, including 1,200 original ones, the effort was not as large as that of the British, but ambitious enough to allow French war and merchant ships to ply the world seas safely. The need resulted from the vast expanse of the French colonial empire. Surveys undertaken along with colonization continued at a steady pace until the demise of the French Union (1948–58), except during the two World Wars.

Systematic surveys to create original nautical charts were conducted in Madagascar, Indochina, Algeria, Tunisia, West Africa, and Morocco. After 1965, the work continued first in New Caledonia (mining industry development), French Polynesia (initially for the benefit of the nuclear experiment center), and in the West Indies, the Indian Ocean, and French Guiana. More limited charting took place in the French Southern and Antarctic Territories, in support of scientific activities, and in Saint-Pierre et Miquelon. The Service hydrographique et océanographique de la Marine (SHOM) did not undertake new surveys in West Africa until 2002.

The charting of the home waters of France required systematic resurveys as early as 1864. The development of steam power introduced new charting requirements while facilitating the capability to follow sounding lines during surveys. A succession of developments during the next century, namely radiopositioning, vertical echo sounders, sidescan sonars, and multibeam echo sounders, made all surveys previous to 1970 obsolete and required almost continuous new charting along both the Atlantic and Mediterranean coasts for military and civilian needs as well as oceanic surveys to meet the demands of military submarine navigation. Simultaneously, the evolution of weapon systems entailed the studying and charting of the many environmental factors that impact their performance. The creation of the strategic submarine force deeply affected the activities of the French hydrographic office (renamed Service hydrographique et océanographique de la Marine in 1971). When the Cold War ended, military requirements extended into shallower waters, for example, the deployment areas of the aircraft carrier group and mine warfare units in the Indian Ocean, which became the subject of annual hydrographic and oceanographic surveys beginning in 2000.

The maintenance of a worldwide set of charts became more and more arduous under budgetary constraints due to the exponential increase in the volume of information and documents to process. The French hydrographic office strove to overcome this difficulty, aggravated by the steady decline of the French merchant fleet, by three means: the evolution of display methods (replacement of copperplates after 1950, development of digital techniques beginning in 1974, emergence of electronic charts in 1988), the active promotion of international standards (facilitated by the International Hydrographic Bureau created in 1921), and the progressive reduction in the number of charts. Worldwide coverage was abandoned in 1983 and an additional cut reduced the total number of sheets to 1,100 (including 630 original charts) in 1997.

During the twentieth century the distribution system for charts, adopted in the nineteenth century, was retained with one navy system for distribution for warships and a network of private dealers for other users. Since 1850, the charts have been updated between successive editions through periodic *Notices to Mariners* that became weekly in 1920; an electronic version was begun in 2000.

During the twentieth century, additional actors concerned with charts for scientific work and applications other than the safety of navigation became active. France was an active contributor to the General Bathymetric Chart of the Oceans from the first edition launched in 1903 by Prince Albert I of Monaco. The combination of open sea fishing requirements, progress in marine geophysics, and marine mineral resource exploitation led to the publication from 1962 onward of bathymorphological and geological maps of the Manche, the Atlantic, the Mediterranean, and the Indian Ocean by the Institut de physique du globe de Paris, the Bureau de recherches géologiques et minières, the Institut scientifique et technique des pêches maritimes, and the Centre national d'exploitation des océans. The last two merged into the Institut français de recherche pour l'exploitation de la mer in 1984. In 1992, SHOM created a series of sedimentology charts (G-charts), remote heirs to the sole chart of the nature of the bottom of the Brest Channel, *Iroise et entrée de Brest: Nature des fonds*, published in 1897.

The explosion of leisure craft created a market for maps derived from official charts by private firms. SHOM itself has published special leisure charts since 1983 (P charts and later S charts).

GILLES BESSERO

SEE ALSO: Coastal Mapping; Geographic Names: Gazetteer; Hydrographic Techniques; Marine Chart

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Marine Charting by European Nations. With the formation of the International Hydrographic Bureau (IHB) in 1921 (Ritchie 1983) marine charting became a truly international pursuit, and cartographic procedures became increasingly similar both in Europe and across the world as the century progressed. A major objective of the IHB, enshrined in the Convention of the International Hydrographic Organization (IHO), is to bring about the greatest possible uniformity in nautical charts (IHO 2007, article II). As many European countries were active in the establishment of the IHB, it was natural that they worked together to establish uniformity in their marine charting. Some cultural difficulties existed, such as the use of the metric system on the European mainland. The United Kingdom Hydrographic Office (UKHO) was originally unwilling to convert its charts to the metric system but in the middle of the century did make the move. The United States remained intransigent and continued to produce charts in imperial units throughout the twentieth century. However, the need to provide products in support of safe navigation has gradually forced a truly common system of units. The need for standardization went far beyond the choice of units, and specifications were developed for every cartographic detail of the nautical chart. This included everything from symbol design to colors used (Newson 1984).

Hydrography and marine cartography are truly international endeavors, and the introduction of new data collection and presentation technology during the twentieth century did as much to advance cartography in Europe as elsewhere in the world. Depth measurement had been determined primarily by the use of sounding lead and measured line, but during the period 1915 to 1930 acoustic methods were developed (Shipman and Laughton 2000). Acoustic methods made it possible to measure continuous depth profiles rather than the spot depths that were only possible previously. Depth profiles provided cartographers much denser data sets from which to make interpretations of seabed topography. However, there were still large areas left to interpret between the profiles. In the second half of the century the availability of computer technology greatly enhanced the cartographer's ability to manipulate the depth data and display underwater topography (Murt and Brown 1981). Nevertheless, hydrographers and cartographers remained concerned that they were still interpreting between measured profiles and about the likelihood that shallow areas could exist between profiles, endangering ships. The invention of sidescan sonar helped to overcome this problem, and at the very end of the century the United States developed, primarily for military purposes, multibeam echo sounders capable of providing total depth coverage of the seafloor (Hughes Clarke 2000).

The measurement of geographic position at sea saw significant advances during the twentieth century. These advancements were worldwide, although the United States played the greatest role. The needs of war provided the impetus for some of the developments, but after World War II the technology was tailored to civilian interest in safe navigation. The first advances were in electronic positioning systems requiring ground-based transmitters. Systems such as Gee, Decca, and Loran (Blanchard 1997) were developed to provide nighttime and all-weather navigation. The importance to marine charting was a much-improved accuracy in positioning.

The next development was satellite positioning in the 1970s. The first generation Transit satellites were positioned relative to a small number of globally spaced terrestrial monitoring stations. Early in the 1970s, a twenty-four-satellite constellation formed the second-generation Global Positioning System (GPS) (Hill, Moore, and Ashkenazi 2000). Later, other systems working on similar principles, such as GLONASS (Global'naya Navigatsionnaya Sputnikovaya Sistema) in the Soviet Union and Compass in China were developed. Europe began to develop its own satellite-based system, Galileo, in the 1990s. Like depth measurement, these advances in positioning technology have had major effects on both marine charting technology and chart users. Again, advances were international and were adopted by European marine cartographers to the same extent as those working in other parts of the world.

While the technological developments discussed so far have focused on improvements in data gathering, significant advances in data management have also had a large impact on marine cartography. During the second half of the twentieth century applications of computer technology increased exponentially. Computers were initially used by marine cartographers for computational tasks but the later availability of graphic devices, such as plotters, scanners, and digitizers, were to have a very major impact (Murt and Brown 1981) initially on both sides of the Atlantic and later in Asia. A prerequisite for these devices to operate is that all data must be in digital form, and the cautious hydrographer was initially skeptical of digital depths that had previously been presented in analog form. Nevertheless, by the end of the century the development of the digital or electronic chart was to have a great effect on marine charting. In about 1980, groups in Europe and the United States were beginning to develop digital charts that could be displayed on a computer monitor, as opposed to being printed on paper. The North Sea Hydrographic Commission (Bermejo

2005, 52–54), a group made up of all north European hydrographic offices (HOs), was concerned about the uncontrolled development and use of this technology. This group advised the IHO, which in turn advised the International Maritime Organization (IMO) that it was necessary to develop comprehensive standards for this new form of nautical chart. From the 1980s into the twenty-first century various IHO committees and working groups have been established and chart specifications prepared (Hecht et al. 2011)

Having described technological changes that were affecting marine cartography both globally and in Europe, we can delve more deeply into cartographic practices and some of the changes that were taking place in the twentieth century. It has already been stressed that marine cartography is truly international and that the differences between charts made in one country and those produced in another country are quite subtle. So far we have not distinguished the different types of marine cartography or their particular clients. The need for marine cartography in the form of nautical charts has been predominately driven over several hundred years by the marine navigator. However, there has been an increasing demand by marine scientists for some form of graphic on which to assemble and display their data. The prime example is the General Bathymetric Chart of the Oceans (GEBCO), a global ocean mapping project first printed in 1905 (Scott 2003b). This was initially very much a European project. A group of European scientists, inspired largely by Prince Albert I of Monaco and Professor Julien Thoulet of France, produced the first edition of GEBCO largely based on listings prepared by the French and British Hydrographic Offices. Later it became a much more international effort when its administration was transferred to the IHB, which collected data from all its member states. In 1965 the French Institut géographique national (IGN) became responsible for production of the fourth edition. Later it became jointly administered by the IHO and the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO). During this period, contributions of data and specialist interpretations of bathymetry came from many countries. A major change took place when the production of its fifth edition moved to Canada, where it was published in 1982. At that time its appearance had changed greatly with much greater attention given to scientific interpretation and data display (Scott 2003a). Magnificent as it was, the time had come for a major change to digital production and presentation and its administration moved back to Europe. As of the beginning of the twenty-first century, it has been available as the *GEBCO Digital Atlas* (Jones 2003). Although GEBCO has bathymetry as its main data topic, it has also been used as the base map for presenting various other kinds of marine geophysical data, and sets of regional maps have been produced showing magnetism, gravity, and other data.

Producing nautical charts for navigators had changed little over hundreds of years. The famous portolan charts had given way to charts gridded in latitude and longitude and using the Mercator projection. The symbols used and general design was insignificantly different from a chart produced in the era of Captain James Cook in the 1770s and those available in the middle of the 1950s. Two things changed in the years after World War II. One was the much-improved mapping technology that became available; the other was a determined drive by the IHO and its member states to develop international specifications that would lead to achieving the greatest possible uniformity in nautical charts and documents (IHO 1996). With respect to technological change, the driving force was the development of computers and their peripheral devices in conjunction with the development of a multitude of hardware and software. Data conversion into digital form was a basic requirement, and once this had been achieved data could be manipulated and displayed in many forms. This led during the 1980s to the display of charts on computer monitors and the electronic or digital chart was born (Kerr, Eaton, and Anderson 1986). Once again this technology owed no geographic allegiance and was being developed across the world, but it was the North Sea Hydrographic Commission that identified possible problems associated with commercial development of digital chart systems (Bermejo 2005, 52–54). Recommendations made to the IHO and in turn to the International Maritime Organization (IMO) subsequently led to the drafting of performance standards and other specifications governing the design and use of systems now called ECDIS (Electronic Chart Display and Information Systems).

The IHO goal to develop chart specifications was first directed at paper charts and the UKHO, a major producer of charts on a worldwide basis, led the way. In 1967 the International Hydrographic Conference of the IHO established a study that led to two series of international (INT) charts being developed. INT charts are tightly specified charts that can be produced by any HO and are designed according to an internationally agreed chart scheme (fig. 514). The IHO established two bodies, the North Sea International Chart Commission and the Chart Specifications (later Standardization) Committee (Newson 1984). These actions had a major impact on achieving uniformity between charts produced by different HOs. No sooner was paper chart production being tightly specified than the need to standardize the exchange of digital hydrographic data came into

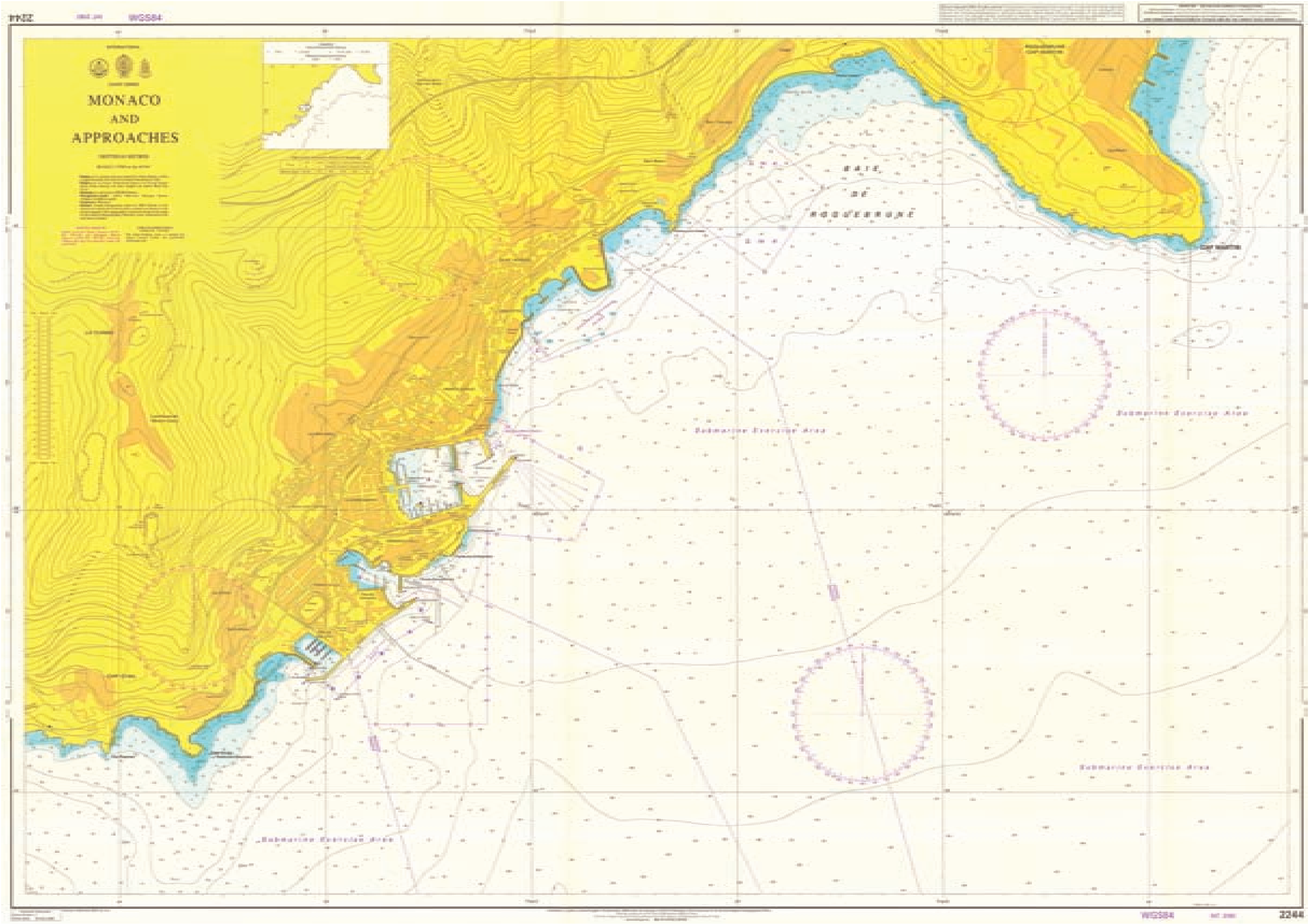

FIG. 514. *MONACO AND APPROACHES*, 2006. Chart 2244, INT 3190, International Chart Series, 1:7,500, with depth in meters. Size of the original: 79.7 × 112.9 cm. Permission courtesy of the U.K. Hydrographic Office, Taunton.

focus. There was initially a need to transfer data sets as part of the process of producing paper charts, but with the introduction of digital charts the matter became critical. Several international bodies were formed, and these gave rise to an international standard known as S-57 (IHO 1996) that was developed as the approved data exchange format. This was later upgraded to a new standard known as S-100 (Alexander et al. 2007). Some earlier difficulties in interpreting these standards have been overcome and the official charts, termed electronic navigational charts (ENCs), are truly international. The IMO has now agreed on mandatory carriage of ECDIS and their accompanying ENCs for certain classes of vessels; as of the early twenty-first century, these tightly specified charts were available over all European waters, and steady progress was under way over the rest of the globe (IHO 2010).

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SEE ALSO: Coastal Mapping; Geographic Names: Gazetteer; Hydrographic Techniques; Marine Chart

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Marine Charting by Russia and the Soviet Union. The inventory of Russian sea charts listed 557 items at the beginning of 1917 (Kovalev 1977b, 85), including numerous sketchy and outdated maps. A thirty-year nationwide program of hydrographic surveying started in 1910 was interrupted by World War I. During the war and the following revolutionary period, the Allied intervention, and the Civil War (1917–23), marine charting was stimulated by the activities of the navy and the necessities of military activities in maritime regions. Innovations in sea warfare led in 1919 to the establishment of a committee for the development of special maps for use on board submarines.

The main stock of Russian printed and manuscript charts dating from the eighteenth to the early twentieth centuries survived this troubled period in the Russian state navy archive, Rossiyskiy gosudarstvennyy arkhiv voyenno-morskogo flota, although some valuable prerevolution hydrographic data and materials, including copperplates for more than 212 charts, had been lost. The Kartograficheskiye masterskiye (cartographic workshops) in Petrograd, the core production facility of the main hydrographic directorate (Glavnoye gidrograficheskoye upravleniye), suffered no damage, but many specialists had left, the number of employees had been reduced, and equipment had been shattered. Very few new maps were produced. A lack of printing paper meant that corrections had to be made on previously printed maps that remained in stock instead of making new editions. These difficulties caused delays in the transition to the officially adopted metric system and the implementation of the new Russian orthography on sea charts.

The first Soviet five-year hydrographic survey program started in 1925. These restricted hydrographic surveys were further expanded within the framework of the countrywide five-year development programs. The first Soviet shipbuilding program led to the reemergence of a military naval presence in the Pacific (1932) and in the Arctic (1933). Major efforts were undertaken to make the Northern Sea Route navigable along the Arctic coastline of the Soviet Union. To this end a special administration of the Northern Sea Route was established in 1932. Expanded investments and increased needs resulted in a gradual growth in Soviet marine charting. By 1932 the inventory of sea charts had reached the level of 1917, and the total number of map sheets printed exceeded half a million copies per year. However, even for the Baltic Sea, the most important sea theater, 75 percent of existing charts were still based on measurements made during the second half of the nineteenth century.

Between 1933 and 1936, 208 new charts were published, including the first Soviet sea charts of foreign waters in 1934 (Kovalev 1977b, 125). By 1936 Soviet 1:200,000 navigational charts covered the Baltic Sea, the eastern coastline of Scotland, and the Norwegian coast. Navigational charts at 1:500,000 to 1:600,000 were produced for the coastline of Japan, and the Yellow and East China Seas. New special experimental sea charts were developed for joint operations of the navy and the army (1929) as well as roll-maps for use on torpedo boats (1931).

The technical facilities of the main navy chart printing workshops were modernized and expanded. Machinery for offset printing was purchased abroad, allowing the creation of multicolor charts in six to eight colors. A specially designed Soviet paper of improved quality has been used for chart printing since 1933.

Over time the production process became more specialized. Chart production editors were in charge of data collection, source analysis, and technical assignments. Computations connected with multiple coordinate frames and grids were made by cartographic engineers, the earliest of whom were mostly graduates of mathematical or geographical faculties of the Leningrad State University. Later such specialists were trained in the Leningradskoye voyenno-morskoye uchilishche svyazi named after G. K. Ordzhonikidze and some special hydrographic departments of other navy colleges as well as Moskovskiy institut inzhenerov geodezii, aerofotos" yëmki i kartografii (MIIGAiK). In 1936 the Kartograficheskiye masterskiye organized a special two-year course for marine chart compilers, and its first graduates started work in 1938. The inflow of new personnel, among them many women, with different areas of expertise was crucial not only because of the rapid expansion of charting production but also because of the political repressions of 1937–38, which affected many qualified specialists.

New equipment made the chart compilation process easier, faster, and more efficient. Computations were made using mechanical calculators, and photographic methods were used to transform different cartographic materials to the same scale. Since 1938 all chart compilations have been made on paper attached to a hard aluminum base to avoid deformation of the compilers' originals. A technique for the permanent correction of navigational charts was implemented in 1939, and a new procedure made it possible to print any of these maps within ten days.

Progress in marine charting made cartographic support possible for special projects of the Soviet navy, such as the movement of squadrons from the Baltic Sea to the Pacific (1936) and the Arctic (1938). Between 1938 and 1940, 484 new sea charts were compiled using recent hydrographic measurements made on an accurate geodetic basis. In less than ten years the inventory of sea charts had almost doubled, and by 1941 listed 1,118 items (Kovalev 1977b, 131).

The necessity for sea charts for military operations increased drastically with the outbreak of the war between the Soviet Union and Germany. However, the rapid advance of the German army toward Leningrad led the Navy High Command to order an almost complete evacuation of the central marine charting facilities from Leningrad to Siberia. The first charts were printed there by November 1941. The evacuation was carried out under very difficult conditions, partly while Leningrad was already besieged. A quarter of the personnel and a considerable part of the equipment remained in the city. This became the core of the Northwestern center of marine charting production, Severo-zapadnoye kartograficheskо-izdatel'skoye proizvodstvo (SZKIP). During the war two more such centers, the Southern Yuzhnoye kartografichesko-izdatel'skoye proizvodstvo (YuKIP) and Eastern Vostochnoye kartografichesko-izdatel'skoye proizvodstvo (VostKIP), were organized close to the main sea theaters.

Between June 1941 and May 1945 about 900 sea charts were made, as well as many special operation plans and twenty river atlases (Kovalev 1977b, 149). High priority was given to providing the navy with marine navigational-artillery charts. The concept of these charts had been developed before the war, although at that time only a few trial charts were produced. In addition to the usual navigational symbols, navigational-artillery charts provided detailed inland information and a kilometer grid, making it possible for ships to use them in support of ground forces.

After the end of the World War II a new organization was established in the navy (Voyenno-morskoy flot), the Marine Cartographic Institute, Morskoy kartograficheskiy institut (MKI VMF). Between 1946 and 1953 most of its efforts were directed to the creation of navigational charts for foreign waters of the Northern Hemisphere.

Areas of mine danger and waterways cleared of mines were added for navigational safety on postwar sea charts. Small corrections to navigational charts started to be printed as special insets for use on board by pilots.

This method proved to be efficient and since 1962 has become a regular procedure. In 1953 the first Soviet sea charts were published with azimuth and hyperbolic grids necessary for radio navigation. Systematic hydrographic surveys of Soviet seas were renewed after the war, and most were completed by the mid-1950s.

In 1954 the MKI was combined with the Izdatel'stvo gidrograficheskogo upravleniya VMF (the publishing house of the hydrographic directorate) and renamed the Tsentral'noye kartograficheskoye proizvodstvo VMF (the central cartographic production department of the navy). By 1955 Soviet navigational charts covered the entire Northern Hemisphere. Between 1956 and 1960 work was begun on the creation of navigational charts for the Southern Hemisphere. This interest in distant waters was primarily driven by the needs of the modernized Soviet navy, which became deepwater and nuclear. The merchant and fishing fleets of the Soviet Union had also increased, and investigation of the world's oceans was being carried out not only by navy hydrographers, but also by different research institutes of the Soviet Akademiya nauk, the Gidrometeorologicheskaya sluzhba, the Ministry of Fishery, and others. After 1957 the Soviet Union took an active part in international oceanographic programs.

The development of new technologies as well as the design of new special types of charts—not only for use by the navy but also for other applications such as fishing, whaling, and marine geological exploration—was stimulated by increased investigation of the world's oceans together with the enormous inflow of hydrographic, geophysical, meteorological, and aerological data. By the end of the 1960s wide use of sonar and other types of underwater echolocation had significantly improved the representation of the deep seabed. In 1963 the first electronic computer was introduced for the preparation of sea charts and the first group of cartographers was trained as programmers (Kovalev 1977a, 203).

In 1972 the Gidrograficheskoye upravleniye VMF (the hydrographic directorate of the navy) was reorganized into the Glavnoye upravleniye navigatsii i okeanografii Ministerstva oborony SSSR (GUNiO MO; the head department of navigation and oceanography of the ministry of defense). The Soviet collection of sea charts became worldwide in the middle of 1970s, allowing the Soviet Union to rely completely on its own resources in any part of the world's oceans. Most of this collection consisted of detailed sea shelf zone and coastal charts. Open and deep water charts were more general; however, the emergence of new methods of data gathering, based on satellite measurements, increased the number of Soviet oceanographic expeditions, and research vessels facilitated further improvement of these charts. Constant efforts are made to keep this collection updated.

The main navy chart printing workshop, the Kartograficheskaya fabrika, underwent major renewal and modernization of its polygraph equipment between 1959 and 1963. Plastic transparent films started to be used for chart preparation, and new photo technologies for reproduction were adopted. In 1973 the Kartograficheskaya fabrika moved to a new building specially constructed for it. Another building was erected next to the Kartograficheskaya fabrika for the Tsentral'noye kartograficheskoye proizvodstvo VMF, which moved there in 1976. This proximity made possible further collaboration between two closely related organizations.

The *Morskoy atlas* has played an important role in the history of Soviet marine charting. The project started in 1939 but was delayed by World War II. The first volume, navigational-hydrographical, was published in 1950 (see fig. 497); the second, physical-geographical, in 1953. Two parts of the third volume, military-historical, were completed in 1958 and 1964.

In 1964 preparation started for a new national cartographic project—an atlas of the oceans, which was supposed to replace the already out-of-date first two volumes of the *Morskoy atlas*. More than thirty research institutions contributed to the creation of this fundamental scientific work, the *Atlas okeanov*. Three volumes were published: Pacific Ocean, Atlantic and Indian Oceans, and Arctic Ocean (Gorshkov 1974, 1977, 1980). Each one of these volumes contained seven sections: the history of exploration, the ocean bed, climate, hydrology, hydrochemistry, biogeography, and navigational-geographical charts. The *Atlas okeanov* was rapidly translated into English and republished for international use. In 1993 an additional volume covering the straits of the world ocean appeared.

The high quality of Soviet marine charting has been internationally acknowledged. The cartography and publication of the *International Bathymetric Chart of the Mediterranean* was handled by GUNiO MO, under the auspices of the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization. The first edition was printed in 1981 at a scale of 1:1,000,000 in ten sheets. Soviet marine charting methods, standards, and expertise have influenced marine charting production in many other socialist countries, among them East Germany, Bulgaria, Poland, Romania, Yugoslavia, and Cuba. After the disintegration of the Soviet Union in 1991, its marine charting legacy became a starting point of marine charting for several independent states (Ukraine, Lithuania, Latvia, and Estonia). However, most of this legacy, as well as almost all the facilities, were inherited by the Russian Federation. In 2003 the inventory of Russian sea charts listed close to 6,500 items (table 34).

MITIA FRUMIN

SEE ALSO: Coastal Mapping; Geographic Names: Gazetteer; Hydrographic Techniques; Marine Chart

TABLE 34. Russian sea charts, 2001–3. Numbers are from the Map Centre online shop of navigational charts produced by the Glavnoye upravleniye navigatsii i okeanografii (GUNiO). The year listed for each ocean is the year of the GUNiO catalog used.

	General charts 1:1,000,000 (or smaller)	Route charts 1:500,000	Particular charts 1:200,000 (or larger)	Total
Atlantic Ocean (2002)	100	350	2,253	2,703
Indian Ocean (2001)	66	132	344	542
Arctic Ocean (2003)	14	91	890	995
Pacific Ocean (2003)	137	561	1,465	2,163
Inland Waters	–	–	95	95

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Marine Charting by Japan. Modern nautical charting in Japan was begun by graduates who learned surveying techniques from the Dutch navy at Nagasaki kaigun denshusho 長崎海軍伝習所 (Nagasaki naval training center) between 1855 and 1859. In 1871 the Japanese hydrographic organization was established by Rear Admiral Yanagi Narayoshi 柳楢悦, who graduated from the training center. For most of the twentieth century, the organization was called the Nihon suirobu 水路部 (Japan Hydrographic Department; JHD). After reorganization in April 2002, the name became Kaijō hoanchō, kaiyō jōhōbu 海上保安庁海洋情報部 (Japan Hydrographic and Oceanographic Department; JHOD).

The United Kingdom Hydrographic Office (UKHO) carried out hydrographic surveys of the Japanese coast from the end of the Edo era until 1882. During that period, charting technology was actively transferred to Japan through practical experience. Thanks to this training, staff of the JHD acquired the skills to prepare nautical charts independently. The JHD adopted the British imperial system of measurement; therefore nautical charts used the fathom as the unit of depth and the foot as the unit of height and consistently used a system in which the length of one nautical mile scaled to one inch on charts until the modernization of charts began in 1922.

In 1887 a clear copper-engraved chart was printed, following the method of foreign hydrographic offices, which updated original charts on copperplates. However, the JHD printed the first copper-engraved chart in 1872. Until then engraved copperplates needed etching before printing. The JHD purchased an Ourdan engraving machine from the United States in 1901 with the aim of engraving numerals for soundings and around compass roses. In 1906, an engraver was dispatched to the UKHO for a year of study, and the most recent technology from Britain was introduced to Japan. As a result, Japanese engravers were able to create products comparable to foreign nautical charts (fig. 515). When a large number of printings of a chart were to be produced, prints were made by photographic transfer of the copperplate chart to a lithographic stone (since 1899), but when rapid printing was required, charts were sometimes drawn directly on a lithographic stone. Lithographic printing remained in use until an offset printing machine was introduced in 1921.

In October 1902, the JHD decided to add geographical names in the Roman alphabet to nautical charts to show the pronunciations. The synonyms used on Admiralty charts were added for places significant for navigation. Early in 1901, nautical charts were classified as either secret or public (for the improvement of public services), and a financial scheme for responding to civilian needs was also instituted. Charts for secret use were marked as "Gunki" 軍機 (military secret) in red. In 1903 the *Nautical Chart Symbols, Abbreviations and Terms* was revised and became available to the general public for the first time.

The classification of nautical charts by navigational purpose was regulated in 1915 (table 35). The standardized classification by scale and year of publication in the *Catalogue of Charts and Publications* was implemented in anticipation of the regulations of 1915 and remained in use at the end of the century. With the exception of coastal charts (which were made available at a larger scale), the scales were almost the same throughout the century.

To modernize nautical charts and eliminate comparatively unimportant items, the explanation in the title

FIG. 515. DETAIL FROM CHART NO. 66, YOKOHAMA AND APPROACHES, 1898. Major corrections, October 1909, scale 1:18,201. JHD soundings in fathoms outside the breakwater. Soundings inside the breakwater are in feet and were engraved by the Ourdan engraving machine.

Image courtesy of the Archives of the Japan Hydrographic and Oceanographic Department, Tokyo.

TABLE 35. Classification of Japanese Nautical Charts, 1915

Category name	Length of 1 nautical mile	Standard scale	Current standard scale
General chart	Smaller scale than sailing chart		
Sailing chart	0.03 inch	1:2,400,000	1:2,500,000
General chart of coast	Approximately 0.16 inch	1:450,000	1:500,000
Coastal chart	Approximately 0.50–1.00 inch	1:145,000–1:73,000	1:200,000–1:100,000
Harbor plan	Approximately 1.00–8.00 inch	1:73,000–1:9,000	Larger than 1:50,000

block and notes outside the margins were simplified in 1915. In 1918, Gothic letters were adopted for water depth and other items were simplified or omitted. Weekly issue on Saturday of *Notices to Mariners* began in 1918.

Twenty-two countries, including Japan, unanimously adopted the metric system for nautical charts at the first International Hydrographic Conference (IHC), held in London in 1919. Since the creation of the International Hydrographic Bureau (IHB) in 1921, the unified use of the metric system for nautical charts was a long-running issue for the IHB and its successor, the International Hydrographic Organization (IHO). In 1921, the Japanese Law of Weights and Measures (1891) was amended to adopt the metric system, and the JHD selected two harbor plans to be converted to the metric system as a trial without affecting other ports in the same region. In 1922, a seven-year plan was adopted to successively apply the

FIG. 516. DETAIL FROM CHART NO. 66, YOKOHAMA AND APPROACHES, AUGUST 1924. Minor corrections 1928/no. 382, scale 1:11,000. Soundings in meters. JHD urgently surveyed in 1924 after the huge earthquake.

Image courtesy of the Archives of the Japan Hydrographic and Oceanographic Department, Tokyo.

metric system to adjacent areas. In 1921 and 1922, the metric system was first applied to the Nanpou Shoto Islands, Kurile Islands, and areas without large ports.

The first-order triangulation network of Japan was established by the Japanese Imperial Land Survey (JILS; Dai Nippon teikoku rikuchi sokuryōbu 大日本帝国陸地測量部). The 1:50,000 topographic map series began in 1888 and was completed for the home islands by 1925. Hydrographic survey, which was based on astronomical observation of each surveyed area, suffered from the discontinuity of land maps. In 1922, with the adoption of the metric system, longitudes and latitudes on nautical charts were made to match the national geodetic system based on the triangulation network.

Implementation of the metrication project, including other chart-modernizing items, was delayed by various circumstances, but in 1940, almost twenty years after the plan was begun, nearly all the nautical charts of coastal waters had been converted to the metric system. At that time, in order to make nautical charts with fathoms clearly distinguishable, metric charts added a color tint for land areas (instead of fine dot shading), and the margin was also stamped with a vermilion seal reading, "Soundings and heights in meters." Vertical datum in land areas was changed from the high water level to mean sea level in accord with the agreement at the IHC. The geodetic datum of Japan was linked to Greenwich by the JHD geodetic survey and connected with Guam and Vladivostok (differences in longitude determined in 1915 and 1916). Consequently, longitude of nautical charts was shifted by 11″ (about 330 m). In addition, characters were written horizontally from left to right to match Western lettering style (fig. 516), and the romanization was changed from the Hepburn system, which harmonizes with English pronunciation, to a Japanese domestic system.

The beginning of World War I made it impossible for Japanese mariners to purchase British Admiralty charts through sales agents. The JHD started reproducing British Admiralty charts in 1914 to create external nautical charts and began to distribute them to those who applied and were granted permission to use such materials. During the period in which the sale of British Admiralty charts through agents was suspended, 1,417 external charts were published. Only 814 published nautical charts were recorded in the *Catalogue of Charts and Publications* in 1913, but the total reached 2,404 in 1920 (Hamasaki and Kambayashi 1993). Having finished the first stage of domestic nautical charting, the JHD began charting foreign waters, and the experience of publishing external charts proved valuable in the publication of overseas nautical charts. Publication of the external charts began to be phased out in 1922 and was abolished in 1924.

The increase in the Japanese shipping fleet during the war led to an increase in demand for charts, from 60,000 charts sold to civilian entities by the JHD in 1914, to 380,000 charts at the peak in 1918. The department had hitherto focused on publishing charts of the northwest Pacific Ocean, but in 1916 it began to publish nautical charts of the entire Pacific Ocean, as well as of the Indian Ocean. Charts of particularly important international shipping routes—European shipping routes (thirty-seven charts) and North and South American routes (fifty-five charts)—were completed by 1921.

Due to the limited demand, only a few copies of nautical charts were printed at one time. However, revisions were constantly being made to ensure the safety of navigation. At that time, copperplates were regarded as superior to lithographic stones or zinc plates for original charts and for maintaining the latest information. In 1919 the JHD introduced the Vandyke process to create zinc printing plates directly from transparent manuscript charts, and an offset printing press was purchased in 1921. Compilation methods were changing to new styles as cartographers drew their compilations on tracing paper. And the copperplates and printing press of the JHD were completely destroyed in the Great Kanto Earthquake on 1 September 1923, making a complete change to zinc plates unavoidable, even though the JHD still preferred and wished to re-create the copperplate charts.

During the recovery following the great earthquake, various IHB member states sent many charts and publications to Japan (IHB members regularly exchanged their nautical charts and publications). The JHD selected 1,000 urgently needed charts and publications and reproduced these using zinc plates. In 1926, the JHD decided to make charts of Japanese coastal waters using copper-engraved originals. But by 1930, the use of zinc deep-etched lithography had replaced the use of copperplates, and the plan to create copperplates was revised. Creation of zinc master plates, which were transferred to zinc printing plates, was also stopped in the same year to save on expense, and deep-etched zinc plates were used for original chart plates. The use of the new zinc plates made printing easier, and color printing of land areas and lighthouse signs was begun in 1931. The main drawback of the new methods was the labor required to maintain them.

Corrections to nautical charts continued to increase year after year. Finally the maintenance problems of the deep-etched zinc plates, which were susceptible to abrasion, came to a head. In 1940, to eliminate the difficulties of making changes with deficient deep-etched zinc plates and because the workforce was insufficient, normal zinc plates were again used for printing all new editions.

The JHD withdrew from the IHB in 1940 and became internationally isolated. Under the wartime system there was a large increase in the number of personnel as nautical chart production expanded massively to support military operations. Very little scientific research has been carried out on Japanese military mapping, so it is not possible to go into detail on the work of that period. However, it has been observed that the war "set the conditions of the navy back several decades and stopped advances in hydrographic services for approximately ten years" (Ōkawa 1951, 196).

The JHD introduced the use of film with printed characters and symbols (stick-up method) in 1954 with the goal of modernizing nautical charts. This method was introduced by the U.S. Hydrographic Office at the sixth IHC (1952) soon after Japan rejoined the IHB in 1950. Further advances in drafting included mylar (plastic base sheet) introduced in 1959 for the elimination of expansion and shrinkage.

Lith film was adopted for chart originals in 1958, replacing zinc plates and solving the problem of zinc plate abrasion that plagued the JHD for nearly thirty years since the two-chart plate system was abolished in 1930. At first, a photo-film positive was used as the chart original and minor corrections were made on the positive film. From around 1975, the correction process was improved by making corrections on the negative film, which was used as the original chart.

As the Japanese economy experienced a postwar boom, the development of industrial areas along the coast was changing. Ship mooring facilities serving these areas required deeper water to accommodate the increased size of ships, with depths reaching ten to sixteen meters. Shipping routes and mooring areas were maintained by port authorities. Precise surveying of the main harbors with multisonar echo sounders began in 1963.

Before that, precise surveying of the tracks and routes of large ships had been done only to a depth of ten meters. The indication of water depth expressed in decimeters (dm) to fifteen meters was revised in 1965 to twenty-one meters. For six years beginning in 1962 precise surveying of thirty routes was carried out by echo sounding to a depth of twenty-five meters to ensure routes for large ships. The surveyed areas on ten nautical charts were shown with green hatching for the safe navigation of a deep-draft ship. Precise surveying with echo sounders was continued from 1965 based on a ten-year plan. As Japan was the only country to use hatching to indicate the precisely surveyed area, the domestic symbols were changed to an international style according to the IHO *Repertory of Technical Resolutions* for indications of dredged areas, adopted in 1971.

The JHD published a new edition of the symbols and abbreviations for nautical charts in 1966 to bring it in line with the IHB *Standard List of Symbols and Abbreviations Used on Nautical Charts* (1965), an appendix to the *Technical Resolutions*. In 1968, expression of mountain shapes was changed from form lines to contour lines transferred from land maps to reduce the amount of drawing work.

Further progress was made in the uniformity of nautical charts at the ninth IHC (1967) with a proposal to prepare an international set of charts covering the world's main ocean areas. The following year, six countries with comparatively large numbers of nautical charts and publications formed the International (INT) Chart Committee. As a result, Japan started to publish small-scale INT charts (at scales of 1:10,000,000 and 1:3,500,000) in 1974.

The JHD published the first nautical chart drawn by a computer-assisted compilation system in 1986 (Hanzawa, Ueda, and Kikuchi 1986). Use of a scribe style of plotting restricted the drawing of complicated symbols and characters, so a partially automated system of plotting was introduced. Lettering for the title block and symbols was added using computer phototypesetting. After the IHO revised the style of symbols suitable for automated plotting in 1987, the partially automated system was used for all new editions. Consequently distortion caused by manual drafting was eliminated.

An electronic navigational chart (ENC) project provided an opportunity to improve automated chart compilation. Laser plotters with resolution of 4,000 dots per inch (dpi) were introduced. As the publication of ENCs was given priority, the automation of drafting was delayed, but in 1996 a nautical chart from a completely automated process was produced: *Ōshima itaru Torishima* 大島至鳥島 (Ohshima to Torishima). The previous year, *Tōkyō Wan itaru Ashizuri Misaki* 東京湾至足摺岬 (Tokyo Wan to Ashizurimisaki) was published in March 1995 based on *IHO Transfer Standard for Digital Hydrographic Data* (S-57 ed. 2) and was the first of its kind in the world. It was followed by small-scale ENC covering the entire country. As S-57 ed. 2 recognized the use of local geodetic reference systems, the ENCs were created using the Tokyo Datum.

The standard was revised in 1996 (to S-57 ed. 3) based on World Geodetic System 1984 (WGS84). At that time, because many countries had not adopted the WGS for paper charts, a description of the amount of shift from the local geodetic system to WGS84 was appended to the standard. In addition, because there was no standard profile for updating ENC information in S-57 ed. 2, publication of large-scale nautical charts with frequent changes in the entries was difficult. However, this became possible with S-57 ed. 3. As a result, the large-scale ENC *Tōkyō Wan* was published in March 1998. In September of the same year, the JHD started to issue *Electronic Notices to Mariners* for ENC updating.

The JHD's Basic Maps of the Sea Project published a general map series of the oceans, the continental shelf areas, and the coastal waters of Japan. The project began in 1967 to map the sea at 1:200,000. It was a uniform survey running parallel survey lines two nautical miles apart (1.8 cm on the map). Soundings were collected from bathymetric survey records at regular intervals, as well as peaks, valleys, and points of gradient change sufficient to draw contour lines. Acoustic explorations done at the same time provided important data for understanding submarine topography. Surveys done during the project covered the entire topographical continental shelves by 1976. High-quality 1:200,000 maps could be prepared representing submarine topography in three dimensions (fig. 517). The coastal waters subseries began in the 1970s and was handled in exactly the same way as the 1:200,000 series except the maps were at a scale of 1:50,000 with survey line intervals of 900 meters (1.8 cm on the map).

The JHD introduced the first narrow multibeam echo sounder in 1983 to equip the S/V *Takuyo*. These first multibeam survey devices could sound in a band to 80 percent water depth, demonstrating their effectiveness for survey in deep seas. The dense data from multibeam surveys provides such high volumes of information that it cannot be represented by contour lines on bathymetric charts. The map of undersea images from these investigations uses GMT (Generic Mapping Tools) software, and the color scheme of blue for the ocean floor, blue to yellow for the continental slope, and brown for the continental shelf make the maps easy to read (fig. 518).

SHINICHI KIKUCHI

SEE ALSO: Coastal Mapping; Geographic Names: Gazetteer; Hydrographic Techniques; Marine Chart

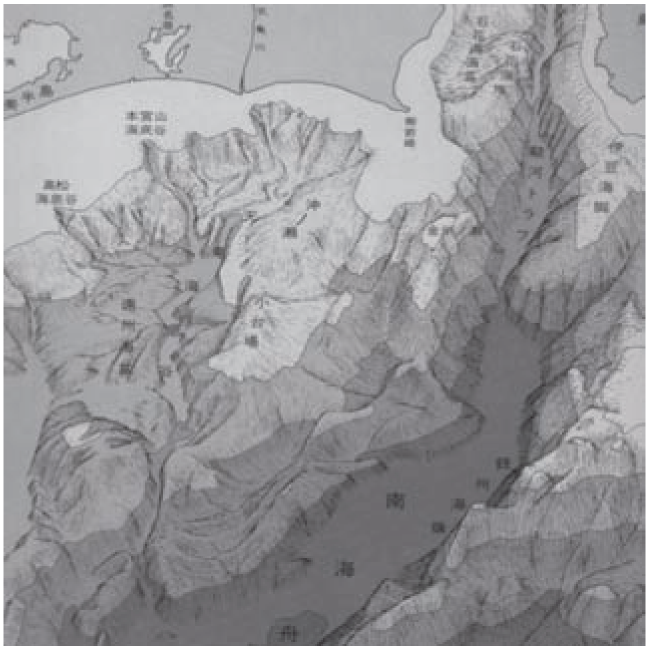

FIG. 517. DETAIL OF SUBMARINE PERSPECTIVE VIEW OF KUMANO-NADA. Hand-drawn physiographic diagram. From Mogi Akio 茂木昭夫, *Nihon kinkai kaitei chikeishi: kaiteifukanzushū* 日本近海海底地形誌: 海底俯瞰図集 (An atlas of the seafloor around Japan: Aspects of submarine geomorphology) ([Tokyo:] Tōkyō Daigaku Shuppankai, 1977), 30 (the book was published in English in 1979). Image courtesy of Shinichi Kikuchi. Permission courtesy of the Tōkyō Daigaku Shuppankai.

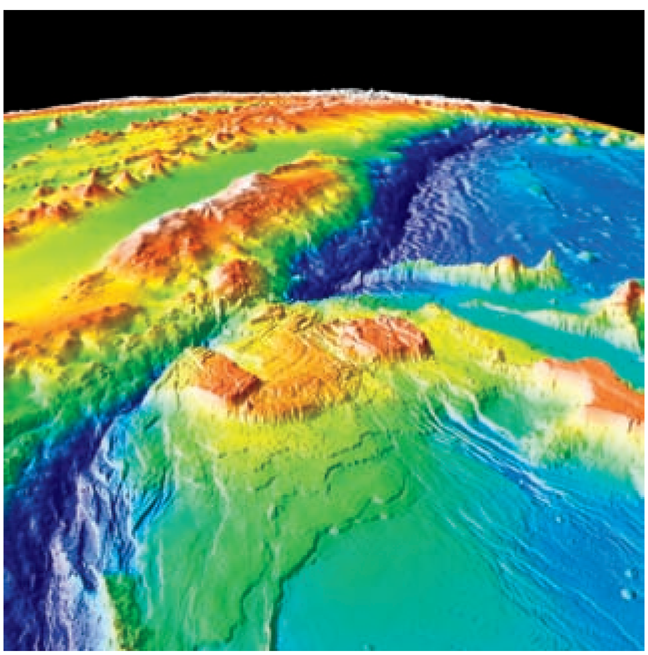

FIG. 518. THREE-DIMENSIONAL MAP, CENTRAL PERSPECTIVE PROJECTION OF OGASAWARA KIDAI CREATED FROM SURVEY DATA OF THE JHOD. Manuscript drawn by Takashi Yoshida in 2006.
Image courtesy of Shinichi Kikuchi.

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Marine Charting by Australia. Cost sharing by the colonial governments and the Admiralty for marine surveys in Australian waters ceased with the formation of the federation in 1901, but the Australian Commonwealth Government paid half the survey costs from 1908 onward. World War I delayed further surveys. Awareness of deficiencies and lack of Admiralty support led to the formation of the Royal Australian Navy Hydrographic Service (RANHS) in 1920, which undertook surveys of Torres Strait, Endeavour Strait, and the southeastern approaches to the Prince of Wales channel, but only isolated anchorages were completed (Myres 1988, 567–69, 632–33). Aerial photographs were used in 1923, and commercial shipping and strategic reasons prompted the 1925 survey of the Cumberland Channel within the Great Barrier Reef. Sounding technology advanced from lead and line to acoustic and recording equipment, echo sounders, and sonar between 1926 and 1932. The surveying service was disbanded around 1930, and the chart depot moved from Melbourne to Sydney.

Strategic needs took priority for surveying ports and adjacent coasts of Australia and Tasmania in the late 1930s, and units outside the Admiralty surveyed the Great North East Channel, Great Barrier Reef openings, Blanche Bay, and Rabaul Harbor. Limited hydrographic knowledge of the Solomons, New Guinea, and northern Australia was recognized, and the New Guinea survey commenced in July–August 1942. RANHS was designated the charting authority for Allied Naval Forces in the South Pacific in 1943, surveys of Seeadler Harbour were undertaken in 1944, and surveys of the Timor and Arafura Seas, Leyte Gulf, and Guiuan were completed in 1945, with the charts based on old U.S. Coast and Geodetic Survey mapping.

Wartime experience revealed the need for faster methods of surveying. In 1946, a new agreement with the Admiralty continued RANHS as the national charting agency and a new series of modern Australian charts was undertaken, using radar adapted for survey work. Further progress was delayed until 1952, when shipping and the economy again became the driving force.

The first five-year hydrographic plan was formulated in 1960. Surveys were undertaken for new deep draft shipping routes and approaches to new mineral ports as well as the Great Barrier Reef and Torres Strait. Satellites were used to position survey vessels in the 1960s, imagery was used for reconnaissance in the 1970s, and the transition to modern standards was complete by 1974. Reconnaissance surveys were undertaken in the Antarctic in 1985. Annual survey work was undertaken by the Hydrographic Office Detached Survey Unit (HODSU), responsible for surveys in the Solomon Islands, Vanuatu, and Samoa. New survey ships for northern Australian waters were commissioned in 1989 and 1990, and a Laser Airborne Depth Sounder (LADS) system (Hudson and Johnson 1991), operational by 1993, was used for Torres Strait, the Great Barrier Reef, Sahul Banks, and Spencer Gulf. In 1994, the survey office moved to Wollongong, forty miles south of Sydney.

By the century's end, 630 charts covered the Australian charting area, but accurate hydrographic surveys of the north and northwest coasts were incomplete. Some 400 charts had been published, with the Army Topographic Support Establishment in Victoria in charge of printing, and digital charts were available for use on land or at sea, including electronic navigation systems (Roberts et al. 1993) using satellite navigation and Global Positioning Systems (GPS).

DAVID R. GREEN

SEE ALSO: Coastal Mapping; Geographic Names: Gazetteer; Hydrographic Techniques; Marine Chart

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Marketing Cartographic and Spatial Data. Marketing is a twentieth-century term that has defied a singular definition. William J. Stanton and Montrose S. Sommers (1973, 3–4) offered the following: "*Marketing* is a total system of interacting business activities designed to plan, price, promote, and distribute want-satisfying products and services to present and potential customers." Not mentioned in their definition are market analysis and market research, which underlie the planning of proposed products and services.

Cartographic data are the expression by symbols of selected geographic phenomena having varying degrees of abstraction and may be accompanied by text. Such data have been represented on hard-copy maps throughout the twentieth century. Since the earliest experiments in the mid-1960s, digital cartographic data have been stored as points, line segments, and polygons and structured in layers or, more recently, in topological format. Spatial or geographic data consist of a set of spatial locations together with properties or attributes that characterize those locations and a relation or relations that are defined. Indications may be given of the time at which the data were captured or revised, the quality or fitness for use of the data, the data structure, and any dynamic features.

The first decade of the century was a period of discovery that led to the recognition of marketing, assisted in part by the development of relevant university courses that began in 1905 (Bartels 1976, 21–30). The second decade saw concepts of marketing developed, followed by principles and the integration of prevailing knowledge during the 1930s. Marketing cartographic data became the preserve of the private sector from about 1920 to the mid-1960s, spurred by the growing popularity of atlases and the adoption of the automobile as a business and leisure product. Some cartographic organizations in the public sector were encouraged to adopt marketing principles and practices through increasing external pressures exerted by their parent governments. This began with an isolated case in the mid-1960s, reinforced in 1973 and 1979; spread to other organizations in the 1980s; and was adopted more widely in the last decade of the century. It was not until the 1980s that academic attention was turned to the theoretical and practical aspects of marketing cartographic products and spatial data.

The contexts for marketing cartographic products, and later spatial data, in the private and public sectors differed significantly. A consistent theme for the private sector was the production of "private goods," which, when purchased, would meet the costs of production, distribution, and investment, and return a profit. After depressed economic circumstances during the 1930s, postwar reconstruction and subsequent economic expansion brought encouragement to private-sector cartography. Natural resource exploration and development, particularly in oil and gas, minerals, and forestry, provided many opportunities for surveying and mapping companies to sell their services and products. Large infrastructure projects such as the construction of dams, power generation, and pipelines also contributed to the growth of the private sector. Although social circumstances changed somewhat between the two world wars, recovery from World War II had much greater and longer-lasting effects. During the world wars, millions of people experienced parts of the world far from their homes, and their interests in these areas continued. Increasing disposable income led to mass ownership of automobiles in Western and later in newly industrialized countries. Reduced hours of employment meant greater leisure time and allowed enhanced mobility. Travel-related associations such as the American Automobile Association became influential publishers of cartographic products and navigational services for the traveling public. Access to secondary and postsecondary education was broadened, and improved knowledge of geography and history, together with mass travel by air from 1970 onward, was reflected in greatly increased demand for geographical atlases, guides, and road maps. Thus there were strong incentives for private-sector map producers and publishers to be well attuned and responsive to their markets and to apply marketing techniques as they evolved. With the constellation of Global Positioning System (GPS) satellites complete in 1994, and with rapid expansion and growing sophistication of wireless communication, private-sector firms became essential catalysts in increasing the visibility and use of spatial data in car and marine navigational and tracking systems and location-capable cellular phones.

Throughout the first half of the century the context for public mapping was dominated by the needs of departments of defense in many countries. Production was usually undertaken by a public-sector civil mapping organization. In France and the United Kingdom (U.K.) the defense department also played an influential role in the mapping of colonial possessions. That emphasis in the U.K. was changed significantly in 1946. After the war, civil requirements for national mapping increased substantially due to postwar reconstruction in Europe followed by broad and sustained economic expansion and enhanced investment in the development of colonial possessions. Nevertheless, civil map specifications continued to be influenced by national defense departments until the 1960s or later. During this period national mapping was financed by central governments from general tax revenues. Such mapping was generally considered to be in the public interest and to be a type of public good, which, in its purest form, is (1) available to everybody, (2) open even to free riders, and (3) free of cost to all users. The last element was not applied strictly to national mapping, as the maps were sold at nominal cost to the general public. In almost all countries, the published maps were covered by national copyright law. However, security restrictions in several countries excluded the release of large- and medium-scale maps to the general public. In these circumstances there was little need for market research within public-sector civil mapping organizations. Ordnance Survey Great Britain made one of the first attempts to investigate and understand the market for its map products in 1970 (Drewitt 1975).

Although the distribution of official maps relied to a large extent on the private sector for many years, the 1970s saw a small number of governments introduce competition into the production of "public goods" by national mapping organizations. Some aspects of production were contracted to private-sector companies on competitive terms, particularly photogrammetric compilation and cartographic preparation. Contracting these services continued to grow throughout the last two decades. Several other important changes occurred during this period that encouraged national mapping organizations to introduce, refine, and expand marketing techniques. One was the greatly increased involvement of provincial and state governments, together with those of large municipalities, in producing large-scale topographic mapping and later digital data or in contracting the private sector to produce them.

As spatial information became recognized in the 1980s as a commodity that could be traded, governments saw the potential to recover a greater proportion of the costs of capital investment, particularly in hardware, software, and training, and the costs of data collection, processing, and distribution. Thus governments imposed on national mapping organizations requirements to recover gradually increasing proportions of the costs of producing printed maps and spatial data. For example, in 1973 Ordnance Survey Great Britain was instructed to maximize revenue on all products. By 1991–92 it had to recover a minimum of 70 percent of its costs from sales of goods and services (Rhind 1992, 15). In 1999 it became a Trading Fund, which permitted more commercial flexibility but carried a commitment to making a profit (Lawrence 2004, 119). Finally, as the volume of national digital data grew, and the range of potential applications multiplied, national mapping organizations developed new products and assumed new roles in spatial data assessment, management, and quality assurance.

Taken together, private- and public-sector cartographic producers in the United States were recognized as the "cartographic enterprise" in which the private sector consisted of Type A and Type B organizations (Petchenik 1991, 296). The former produced end products for sale and was exemplified by large and small cartographic publishers. The latter produced maps and supporting graphics, usually in small quantities, for clients to use as tools in specific applications. The photogrammetric companies fell into this subgroup. The last thirty years have seen significant changes in the cartographic enterprise. Illustrations additional to those mentioned previously are joint publishing ventures by public and Type A private-sector organizations; conversion of analog to digital map production in both sectors; widespread utilization of remote sensing, geographic information systems (GIS) and land information systems (LIS); and Type B organizations adding value to digital data collected by the public sector for sale to the public. A broad

TABLE 36. A view of the cartographic enterprise at the end of the century (after McGrath 2002)

	Type A For sale as end products	*Type B* For use as tools
Public sector governments		
Central/federal	Positional and elevation data, aerial photos, remote sensing images/data, orthophotos, topo maps/data, aeronautical and hydrographic charts (analogue and digital), pilots, national and road atlases, recreational and thematic maps, gazetteers, metadata, digital spatial data, digital elevation models (DEMs)	Positional and elevation data, aerial photos, remote sensing images/data, orthophotos, topo maps, aeronautical and hydrographic charts, pilots, atlases, recreational and thematic maps, gazetteers, metadata, digital spatial data, DEMs
State/provincial	Positional and elevation data, aerial photos, remote sensing images/data, orthophotos, topo maps/data, cadastral maps/data, state/provincial atlases, recreational and thematic maps, metadata, DEMs	Positional and elevation data, aerial photos, remote sensing images/data, orthophotos, topo maps/data, cadastral maps/data, thematic maps, metadata, DEMs, GIS and LIS data
Municipal		Topo maps/data, cadastral maps/data, thematic maps, GIS and LIS data
Private sector firms		
Surveying	Cadastral plans/maps	Positional and elevation data, cadastral and engineering surveys (for public and private sector clients), large-scale plans/data, subdivisional plans, volumetric data, GIS and LIS data
Photogrammetry	Aerial photos, photo mosaics, orthophotos	Positional and elevation data, topo maps/data (for public and private sector clients), DEMs, cadastral maps/data, engineering plans, volumetric data, GIS and LIS data
Cartography	Aeronautical and hydrographic charts (including electronic charts), general, national and road atlases, guides, route maps, recreation and thematic maps, small-scale digital data (including electronic charts, car navigation systems), some topo maps	Aeronautical and hydrographic charts, thematic maps, small-scale digital data
Remote sensing	Data, images, image maps, thematic maps	Data, images, image maps, thematic maps, GIS applications
GIS/LIS		Data, thematic maps, GIS and LIS data

view of the enterprise at the end of the century is given in table 36.

The focus of market analysis is upon the macro and micro environments. The former covers the demographic, economic, technological, and legislative circumstances in which private- and public-sector cartographic organizations operate. Published data and information on most aspects of the macro environment were available to varying degrees from government departments and, where they existed, trade associations. The micro environment concentrates on the consumer and producer markets and is concerned with market size and segmentation, competition, and market share. Gerald McGrath (1990) reported on several examples of the scarce published literature on these subjects and noted that the commercial sensitivity of market data helped to explain this situation. The annual reports of some public-sector organizations contained aggregated data on sales of products, and in the first decade of the twenty-first several companies specializing in market intelligence published statements of the current market for spatial data and market projections.

Market research is focused upon current and prospective products, customers, competitors, and risk. It requires problem definition, a statement of research objectives and design, fieldwork to collect appropriate data, and data analysis. Private-sector cartographic houses undertook market research as an essential contribution to market relevance, competitiveness, and profitability. Most public-sector mapping organizations had little incentive to do so until after 1980. Published literature on market research in cartography and spatial data was modest. University researchers provided some papers and open reports on studies and surveys, most of which dealt with the users of public-sector products. However, there were occasions when governments published in-house research or the results of contracted work, such as the Ontario Ministry of Natural Resources in 1975 and the Ordnance Survey Great Britain in 1983 and 1984. There were also occasional published reports by government mapping organizations on the results of user trials of new products. The most frequently encountered literature on market research dealt with consultation by a small number of public-sector mapping organizations with users of their products. The reasons for such consultation were described by McGrath (1980), together with the principal mechanisms and the specific initiatives of the Ordnance Survey since 1946. The mechanisms included published proceedings of user conferences (for example, the U.S. Federal Map Users' Conferences held in 1964, 1967, 1972, and 1981) and journal reports of regular map user consultations and meetings of advisory and standing consultative committees (for example, by Balchin and Coleman 1966).

The *marketing mix* consists of a set of variables that can be controlled by an organization in order to influence customer response to a product or service. Though the number of variables involved in a marketing decision may differ by sector, four basic variables are applicable to cartography and spatial data. The first is *product*. The range of products, or the product matrix, of many public-sector organizations was increased significantly from the 1950s arising from reconstruction and development and responding to an expanded and more diversified market for maps, charts, and derived products such as tourist maps and atlases. The matrix was expanded further in the 1980s with a variety of spatial data products. However, some organizations were affected by government decisions to fund from general revenues only those specified core services and products that were required by government to perform its statutory functions or deemed to be in the public interest. Walter Smith (1979) and David Rhind (1991) provided guidance on this matter. The continuation of "other" products necessitated increased revenue from a greater volume of sales to nongovernment users, perhaps entailing higher selling prices, and certainly improved marketing. A typical public-sector product matrix in 2000 consisted of standard analog products, standard digital products, value-added digital, custom digital, and one-off products produced for specific customers. Private-sector firms also increased their product mix after 1945, particularly in leisure- and education-related products. They added spatial data products in the 1980s and, as they developed capacity to capture digital data, became significantly less dependent on topographic data collected by public-sector organizations to whom royalties had to be paid. The adding of value to standard digital products produced by the public sector became increasingly important to private-sector firms. Throughout these transformations the need remained to identify market segments whose requirements are not being met; to design, implement, and test-market possible products with appropriate packaging; to select an appropriate brand name; and to create a marketing strategy for the new product.

Price is the second variable. The theory and practices of pricing were examined intensively in the general literature on marketing, but the cartographic literature did not reflect this until after 1980 (McGrath 1984). Pricing land information and related subjects received close attention in publications of the Australia New Zealand Land Information Council, one of which addressed charging for land information (ALIC 1990). The International Cartographic Association Working Group on the Marketing of Spatial Data surveyed current policies and practices in pricing digital spatial data together with other aspects of marketing (Cartwright and Deakin 1991). Rhind (1992) then focused attention on issues of pricing a broader range of spatial data. The context for growing public-sector interest in a new policy for pricing products and services was shaped by several factors: redefining the role of government, the national interest, and public goods; spatial data collected by government becoming viewed as a tradable commodity to which copyright was applied by almost all public-sector mapping and cadastral organizations, and royalties or fees charged for the use of the data; financing these organizations in a more stringent financial environment to which accrual accounting was applied; and the commercialization of selected government production functions.

The cost-based pricing models of the public sector that had prevailed for more than fifty years, and were designed to recover the average or marginal costs of reproduction, largely disappeared during the 1990s. These factors collectively, and several well-publicized errors of judgment in setting prices for specific products, encouraged public-sector producers to seek a more relevant pricing objective from the choices available (McGrath 2002). Two solutions were examined: cost-based pricing aimed at partial or full cost recovery and market-based pricing. The latter was the solution used most consistently by the private sector, the principal exception being a new product priced at or below cost to achieve early market penetration. A further change in approach to pricing was prompted by the adoption of the Internet as a means of delivering spatial data. The two-part tariff was one example of pricing innovation in response to this dynamic environment. This might have suited frequent customers who purchased data in bulk, but as David J. Coleman and Douglas D. Nebert (1998) noted, existing pricing objectives and models might be inadequate for customers who browse and select.

The third variable is *promotion* of the product or service, which received scant attention in the cartographic literature. The print media were the dominant form of paid promotional advertising of maps and atlases throughout the century, the vehicles being newspapers and their supplements, magazines, and the Yellow Pages of telephone directories. Collectively this was classed as general advertising in that it was not directed to specific groups of potential customers. Advertising in professional journals and in magazines dealing with outdoor leisure activities was defined as directed advertising. By far the largest volume of general advertising comprised printed map indexes and catalogs produced and circulated by public- and private-sector map publishers. Public response to these forms of advertising was indirect and difficult to measure. Direct mailing of information on products was facilitated by the introduction of bulk rates for mailing as early as 1928 in the United States, and the creation of appropriate lists of past or potential customers. Promoting cartographic products and spatial data utilized radio, and later television, to a very limited extent due to their inability to reach targeted audiences, high cost, very short lifespan and, in the case of radio, lack of a visual dimension.

Starting in the 1970s, mailing lists came to depend on computer technology, databases, and database management systems. Direct mailing was judged to be effective by at least one national mapping organization (McDermott 1984). Of far greater significance was electronic mail, an innovation of the early 1970s that was not available generally until 1990, and the Internet. The latter became a vehicle for all map publishers to promote maps of many types in both hard-copy and electronic forms. Despite the rapid technological developments in the last decade, point-of-sale promotion was a significant mechanism used by private-sector publishers throughout the second half of the century that utilized specially designed stands and decals. Public-sector organizations were late but earnest in adopting this mechanism. Some used public service announcements, a form of unpaid promotion in which press releases, space in printed media, and presentations on radio and television announced new products and services. And many public-sector organizations were present at professional, trade, leisure, and travel shows to advertise, educate, and sell directly to consumers. Finally, the private-sector mass publishers of maps and atlases sold selected products to manufacturers of food and consumer goods as premiums that were packaged with the item or good as an inducement to purchase.

The final variable is *place*. The essential steps that preceded the sale of hard-copy cartographic products were finishing, packaging, storing inventory in warehouses at an acceptable cost and with the necessary records and controls, and distributing inventory by appropriate channels. The last included direct mail to purchasers—a network of outlets owned by the organization or by wholesale and retail dealers, government offices or state-owned enterprises holding stocks of public-sector products, and libraries. Associated with dealer networks were policy issues such as dealer discounts, sales staff, and practical matters of ordering, stocking, replenishment, and return of unsold stock. Computerized inventory control and order systems were introduced by map publishers during the late 1970s. They were refined gradually to include picking, packing, labeling, and revenue accounting as custom-designed software systems were implemented (McArthur and McGrath 1991). The availability of digital cartographic data to government and commercial customers in the mid-1980s changed the dynamics of delivery. Selections could be made from digital data sets that were packaged electronically for direct shipment to customers. In the late 1980s online access was granted to approved law firms to read-only textual land registration databases (e.g., in Western Australia) and subsequently to the first generation of digital cadastral map databases. Online access to topographic databases was also developed for government and commercial users. However, the major transformation occurred with the adoption of the World Wide Web as an electronic mechanism by which a member of the public could determine the availability of, and then download, selected spatial and attribute data. A notable achievement was the launch of the MapQuest website for maps and navigational instructions in 1996. Public-sector mapping organizations with rapidly growing topographic databases were quick to recognize the potential of the Internet for spatial data infrastructures and cultivating a potentially larger market for spatial data (Coleman and Nebert 1998). Numerous issues arose that required resolution. They included software compatibility; licensing of large customers; mechanisms for online ordering, secure payments, and delivery; control of public access to a database, data piracy, and protective devices; offering inducements to potential customers; the potential for litigation due to errors and uncertainty in spatial data; and the need for liability insurance.

Although the preparation of a marketing plan in 1980 was a relatively new development, by the end of the century it was common practice in both public- and private-sector mapping organizations. An organization's short mission or vision statement designed for public consumption provided context for a marketing plan. Expansion of the mission statement occurred in the business plan. In the private sector this was commercially sensitive and used externally when investment was sought. In the public sector the business plan was circulated within government. The plan was developed for the organization as a whole and/or for component business units. Examples of its contents were the business objectives, the present and future market, products and services, competition, and strategies for growth and risks. A public-sector organization that had agreed with its government minister on the provision of core products and services might also include the criteria by which the organization's performance was evaluated. The marketing plan might be a component of the business plan or be separate. It focused in greater detail on marketing objectives, segmentation of the market, specific products and services, customers, suppliers, promotion, pricing, distribution, and marketing costs. Finally, marketing and educational programs became interwoven in public-sector organizations after 1960. They covered the nature, construction, and applications of hardcopy maps and utilized workshops, site visits, displays, and events to promote map awareness. The addition of digital products in the 1980s increased the need for such programs and eventually led to the Internet being used for the wider dissemination of information.

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SEE ALSO: Electronic Cartography: Data Capture and Data Conversion; Intellectual Property; Marketing of Maps, Mass; Public Access to Cartographic Information; Remote Sensing: Remote Sensing as a Cartographic Enterprise

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Marketing of Maps, Mass. Under the leadership of Western cartography, the map trade underwent remarkable changes worldwide in the twentieth century—changes that reflected dramatic currents in the broader social context of which maps were a component. The production, distribution, and sale of mass-market maps became a significant element of the information revolution, particularly with the rapid development of computer technology in the years after World War II. Cartography emerged as part of the evolving cultural symbiosis between science and technology on the one hand and the forces of modernization, democratization, and globalization on the other. Map publishing became a key ingredient in the popular adjustment to these changes.

Between 1891 and 1913, international agreement was reached on a standard International Map of the World, or Millionth Map, that would be drawn on a scale of 1:1,000,000 (1 cm = 10 km; 1 in = 15.78 mi) and based on the Greenwich prime meridian. In the realm of map reproduction, direct photographic exposure of sensitized zinc and aluminum lithographic plates and the development of the offset press radically transformed map printing during the first quarter of the twentieth century. The two world wars significantly spurred the production of maps and a corresponding increase in map users, especially in the United States. Despite these successes, mechanization, synthetic drafting films unfriendly to pen-and-ink drawing, and the introduction of aerial photogrammetry all contributed to a decline in the quality of cartographic reproduction between the wars.

After World War II, an era of cartographic modernization and experimentation ensued that not only remedied the qualitative deficiencies of the interwar years but also sought to satisfy a growing public hunger for geographical information. In magazine and newspaper maps, polar (northern) projections became popular, reflecting interest in a more global outlook. Somewhat relatedly, perspective maps, including three-dimensional views with southern continents distorted by an azimuthally equidistant projection adopted from the military, stressed proximity and immediacy. In the last quarter of the century, the use of space-age remote sensing and computer technologies also greatly enhanced the possibilities and potential of modern cartography, especially in the mass market, while once again giving rise to criticisms of a decline in quality, creativity, and exceptionality.

The public's newfound cartographic appetite was fed by the abundance of more affordable atlases and atlas-related maps and globes. These were produced for classrooms and the general public not only by corporate map publishing houses, large and small, but also by elite newspapers, such as the *Times* of London and the *New York Times*, and by learned organizations, such as the venerable British Royal Geographic Society (RGS) and America's more dynamic National Geographic Society (NGS). On occasion the RGS included colorful pull-out maps, some based on satellite imagery, with its popular *Geographical Magazine* while the NGS included similar maps much more regularly and in a more standardized format with its widely circulated magazine, *National Geographic*. In the 1960s, the NGS introduced a greater uniformity of size, color, and scale into these loose maps so that subscribers around the world could better collect and preserve them, perhaps in binders, envelopes, or file folders, or even place them side by side to form larger maps of various parts of the earth. Even so, these highly popular NGS maps were criticized frequently for their excessive detail, cluttered appearance, and bland presentation.

Schoolrooms at all levels witnessed an increased availability and use of geographical, thematic, and historical atlases, wall maps, and globes. These showed the various parts and features of the earth, often in relief, as well as countries and their histories. In the lower grades, print and eventually electronic publications like *Weekly Reader* and similar youth-oriented periodicals produced by the NGS had increasing cartographic content to support current stories on global events as well as more localized developments and environmental issues. In the wake of the United States' manned Project Mercury (1958–63) and unmanned Landsat (1972–) programs, public enthusiasm for space exploration created a demand for satellite imagery and maps and globes based on the moon, Mars, the moons of Jupiter and Saturn, and other heavenly bodies.

The transportation revolution of the twentieth century brought a heightened interest in travel and tourism and with it an enormous demand for maps. The rise of the automobile spurred a growing market for road maps, which oil companies used to promote and advertise their products. As major sponsors of road maps, gasoline producers in the United States began to distribute free maps in 1919 and continued the practice through the late 1970s, when cost cuts forced its elimination. Since then, the production and free distribution of highway maps has been sustained to a lesser degree by state and local governments eager to promote tourism and commerce. City maps have attained a similar popularity, and large American private map companies as well as a growing number of smaller regional firms publish them for sale through bookstores and other retailers at several dollars a copy. Because of their massive numbers and cheap cost, paper road maps became nearly ubiquitous, undervalued, underappreciated, and even ephemeral. By the end of the century, though, printed way-finding maps were gradually being replaced by narrated electronic versions for the growing number of automobiles equipped with a Global Positioning System (GPS) unit and by customized Internet maps, available free with detailed directions from MapQuest or Google Earth and easily printed out on personal computers whenever road journeys were planned or undertaken.

Similar trends affected the production of sea and aeronautical charts for commercial and private use, and GPS is now used more extensively in sea and air navigation than on land. With the dramatic increase in air travel, commercial airlines have been providing a mixture of often excellent route maps, usually in their in-flight magazines, for the diversion of their patrons as well as to publicize networks and services. On occasion these maps have also been somewhat political. For example, Egyptian Airlines for years did not show Israel on its in-flight maps, while American Airlines omitted Cuba. In-flight magazines also provide handy airport maps, showing gates, baggage collection areas, and access to ground transportation.

Modernization and the general rise in standards of living and material culture in the developed world, including increased leisure time and greater individual mobility, fostered increased interest in recreation during the twentieth century. A distinct cartography has resulted. Serviceable maps—typically thematic, often colorful, and less commonly informational—have become essential to the fuller enjoyment of recreational pursuits such as cycling, hiking, skiing, golfing, camping, and tourism. Intentionally less scientific, recreational maps are more engaging and easier to use than conventional maps and are frequently created by accomplished design artists rather than professional cartographers, although artists sometimes collaborate with mapmakers. While many recreational maps are clearly ephemeral, some of them are designed for sustained use, even on media other than paper so as to be more flexible, easily refolded, waterproof, or erasable. And, as appropriate to the pastime, these maps might be based on digital geographic data, integrated with GPS technology, or distributed electronically as print-on-demand publications. As exemplified by the *New Mexico State Highway and Transportation Department Bicycle Guideline Map* (2002), some recreational maps are commissioned by governmental authorities or commercial enterprises to promote related activities under the aegis of tourism. Good recreational maps are typically, and almost symbiotically, available at low cost or even free of charge to enthusiastic users.

With the era of the traditionally drawn and published map all but over at the end of the twentieth century, almost all new mass market maps were produced digitally. The mounting demand for low-cost, advanced, and ever-current cartographic products by governments, business interests, and especially the general public seems unlikely to abate in the twenty-first century.

DENNIS REINHARTZ

SEE ALSO: Advertising, Maps as; Globe: Manufacture of Globes; Intellectual Property; Marketing Cartographic and Spatial Data; Public Access to Cartographic Information; Reproduction of Maps

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Marschner, Francis Joseph. Francis Joseph Marschner was born in Austria in June 1882. He acquired his professional education during five years at a cartographic institute in Berlin and held cartographic positions in Geneva, Rome, Düsseldorf, and London before immigrating to the United States in 1915. His first American job was at the U.S. Department of Agriculture (USDA). Once Marschner acquired citizenship, he was offered a permanent appointment in the former Bureau of Agricultural Economics (BAE) (Anderson 1967).

Marschner worked on a wide range of projects throughout his long and celebrated career as a cartographer with the BAE and later with the USDA's Economic Research Service (ERS) and Agricultural Research Service (ARS). In the 1920s and 1930s he devoted himself to constructing land use maps of the United States, which required the painstaking mining of diverse sources. Relying on survey field notes, aerial photographs, and statistical analyses, he pioneered an interdisciplinary approach to land use research (Anonymous 2003). Marschner is credited with creating the first authoritative medium-scale U.S. land use map in 1950 (fig. 519) (Anderson 1967; Anonymous 2003). When the Bureau of the Census used automated cartography to produce hundreds of dot maps for the Graphic Summary (1973) of the *1969 Census of Agriculture*, a digital version of Marschner's map was used to guide dot placement (Monmonier 1985, 106–7, 210n40). Marschner's other major works, all for the USDA, include *Rural Population Density in the Southern Appalachians* (1940) and *Land Use and Its Patterns in the United States* (1959), which was published after his official retirement.

As these titles suggest, Marschner was concerned with understanding the relationship between human settlement and the environment. As one reviewer noted, Marschner's 1959 *Land Use and Its Patterns* constitutes a "precisely integrated and smoothly flowing analysis of the salient aspects of 'man's taking-up of the land' in the continental United States" (Glendinning 1960, 610). Referring to his 1940 *Rural Population Density*, another reviewer opined, "This is one of the best bulletins dealing with the relation of population to natural resources and use of the land, which the Federal Government has ever issued" (Baker 1941, 106).

Marschner served as vice president of the Association of American Geographers in 1944, and received the USDA's Superior Accomplishment Award in 1947 for his service during World War II. In 1963 he was elected a fellow in the American Association for the Advancement of Science (Anderson 1967, 636).

Marschner retired from the BAE in 1952 but continued to work for the USDA under an unpaid joint appointment in the ERS and the ARS (Anonymous 2003; Anderson 1967, 636). A full twelve years after his official retirement, Marschner still regularly walked the seven miles to his office. His body was found on the Mall in Washington, D.C., on 31 January 1966. Despite deep snow and blizzard conditions, he had set out to

FIG. 519. FRANCIS JOSEPH MARSCHNER, *MAJOR LAND USES IN THE UNITED STATES*, 1950, 1:5,000,000. Marschner's acclaimed map of U.S. land use made for the U.S. Department of Agriculture, Bureau of Agricultural Economics, Washington, D.C. Size of the original: 63.6 × 99 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

walk to work as usual. His death was attributed to a heart attack. He was 83.

Marschner never married and had no relatives in the United States. He was a devoted civil servant and a revered scholar. His work contributed massively to understanding the trends and patterns of land use in the United Sates.

EFFIE DAVIDSON SCOTT

SEE ALSO: Biogeography and Cartography; Land Use Map; Photogrammetric Mapping: Air Photos and Geographic Analysis; *National Atlas of the United States of America, The*; Planning, Urban and Regional; Soils Map

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Martin, Lawrence. One of the most influential members of the first generation of professional geographers in the United States, Lawrence Martin also contributed substantially to the use of maps in the public arena during a military and government career that spanned three decades. Colonel Martin, as he preferred to be known, was born in Stockbridge, Massachusetts, on 14 February 1880, and died in Washington, D.C., on 12 February 1955 (Thwaites and Bertrand 1956; Williams 1956; Wright and Field 1955).

Martin studied physical geography with Ralph S. Tarr at Cornell University (AB degree, 1904; PhD, 1913) and William Morris Davis at Harvard (AM degree, 1906). From 1906 to 1917, he taught physiography and glacial geology at the University of Wisconsin, and conducted field surveys in Alaska, Wisconsin, and the Lake Superior region that culminated in two works now considered classics: *Alaskan Glacier Studies* (1914, coauthored with Tarr) and *The Physical Geography of Wisconsin* (1916).

As an army officer during World War I, Martin taught the fundamentals of cartography and map interpretation, and then served as chief of the Geographical Section, General Staff's Military Intelligence Division, a position that involved collecting, evaluating, and disseminating geographic and cartographic information. Following the armistice, he conducted fieldwork and map studies in Central Europe with the American Commission to Negotiate Peace, which led to a life-long interest in boundary issues. Martin retired from active military duty in 1920, but remained in the Officers Reserve Corps with the rank of lieutenant colonel.

Martin was geographer at the U.S. Department of State from 1920 to 1924, and chief of the Library of Congress Map Division from 1924 to 1946. Concurrently, he served on two federal government bodies responsible for establishing and maintaining national mapping standards: the U.S. Board on Geographic Names and the U.S. Board of Surveys and Maps. During World War II, he was on special assignment to the Map Division of the Office of Strategic Services.

Martin was one of the first government officials to actively promote the use of historical and current maps in the conduct of official business and public affairs. He made the State Department's map collection and the Library of Congress Map Division focal points for government officials, legislators, military leaders, and diplomats seeking geographical and cartographic information. An internationally recognized authority on maps and boundaries, Martin appeared as an expert witness on numerous occasions before federal courts and international arbitrators in relation to boundary disputes. His testimony in the Michigan-Wisconsin boundary case of 1923–26 formed the basis of his Association of American Geographers presidential address (Martin 1930). Detailed studies by Martin of several early American maps associated with national boundary issues became standard reference works.

Martin was also recognized for informing and educating a wider public audience through facsimile reproductions of significant maps in American history, including an atlas commemorating George Washington on the bicentennial of his birth and another devoted to maps of the original thirteen states prepared for the U.S. Constitution Sesquicentennial Commission.

RALPH E. EHRENBERG

SEE ALSO: Histories of Cartography; Libraries and Map Collections, National

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Martonne, Emmanuel de. Emmanuel de Martonne was a major figure in classical French geography. Born in 1873 in Chabris, France, he attended the lycée de Laval before entering the École normale supérieure in 1892 where he studied under Paul Vidal de la Blache. After obtaining an *agrégation* (teaching certificate) in history and geography in 1895, he defended a Docteur ès Lettres thesis in 1902 and a Docteur ès Sciences thesis in 1907.

De Martonne privileged the role of the map in his university teaching, ensuring its place in the institutionalization of French geography. For him, a geographer's training was incomplete without an introduction to interpretation and construction of maps. He held that maps encouraged geographical thinking about shapes and distributions of phenomena, relationships among them, and explanations for them. De Martonne oversaw the development of map collections at the geography laboratories he founded, first in Rennes in 1902 and later at the Sorbonne after 1909. He added cartography to the university curriculum, creating a specialized certificate equivalent to a four-year degree and founding l'École de cartographie at the Université de Paris in 1934. Because he regarded written interpretation of topographic maps as the most basic educational exercise, he made it a requirement for the *licence* (bachelor's degree) and the *agrégation* in geography created at his initiative in 1943. The exercise emphasized physical geography, particularly explanation of relief, more than human geography.

Maps were also indispensable research tools for de Martonne when, as a young teacher, he studied the Upper Nile basin in 1895. The resulting article (de Martonne 1896–97) was based almost entirely upon comparison of three maps: physical geography, ways of life, and ethnicity. De Martonne employed a determinist approach in that early study. He also mastered various cartographic techniques useful for his scientific studies, notably topographic surveying, which he learned from military officers. De Martonne's doctoral research during 1899–1900 involved mapping the Paringu and Soarbele massifs (southern Carpathians, Romania) at 1:10,000 in order to locate traces of ancient glaciers and identify factors underlying their distribution.

Later he concentrated on synthesizing original data for small-scale thematic cartography. His maps showed facts that could be studied in their own right or, following his

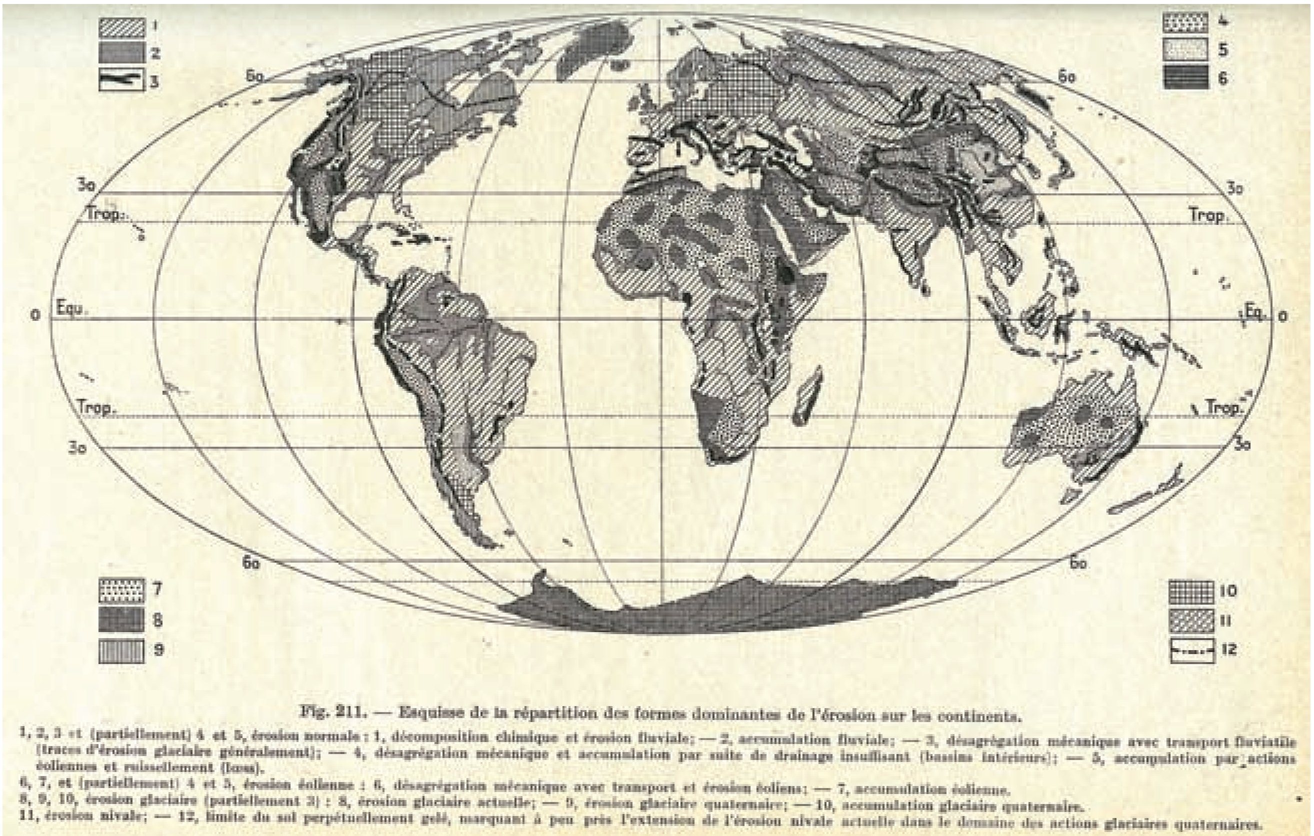

FIG. 520. EMMANUEL DE MARTONNE, WORLD DISTRIBUTION OF DOMINANT TYPES OF EROSION. This is a typical small-scale thematic map illustrating de Martonne's three-volume treatise on physical geography. Size of the original: 13.2 × 20.3 cm. From Emmanuel de Martonne, *Traité de géographie physique*, 4th ed., 3 vols. (Paris: Armand Colin, 1925–27), 2:541 (fig. 211).

inductive approach, could provide a starting point for comparisons of physical phenomena and research into their causes and consequences. Examples of his thematic cartography include a world map of physical regions with interior drainage, begun in 1904 and constructed from observations made in Mexico, the United States, North Africa, and Egypt. The 1:50,000,000-scale map, *Map of Interior Basin Drainage*, was published in 1927 and presented at the International Geographical Conference at Cambridge in 1928. De Martonne's analysis of causal relationships often fostered other innovations. Thus, his observations on interior drainage led him to create an aridity index that was portrayed on world maps published in 1926 and 1941. Many other physical maps illustrated the various editions of his *Traité de géographie physique* (fig. 520).

In 1931, de Martonne became secretary of the International Geographical Union (IGU) and created a working committee to standardize symbols used in morphological cartography. The committee presented its results at the IGU conferences in Warsaw in 1934 and Amsterdam in 1938. De Martonne followed that project with several morphological maps of France, published between 1937 and 1941, and a world map of structural geology in 1946.

Although de Martonne was first and foremost a physical geographer, he ventured into the cartography of human phenomena on two occasions. For his 1902 thesis comparing methods of population cartography, he produced an original map of Walachia showing population density by natural region. In 1917, he became secretary of the Comité d'études, a group of experts who advised French politicians and diplomats on the post–World War I peace settlement. The group prepared syntheses of territorial questions and related maps that were used during the deliberations leading to the Treaty of Versailles. Some of those maps were included in the 1919 atlas of the Service géographique de l'armée. De Martonne personally drew the ethnographic map of Romania, for which he used three shades of color to represent the population density of each nationality (fig. 521).

During his career de Martonne gained recognition as a researcher in physical geography and a pioneer in geomorphology. He also played a vital role in giving

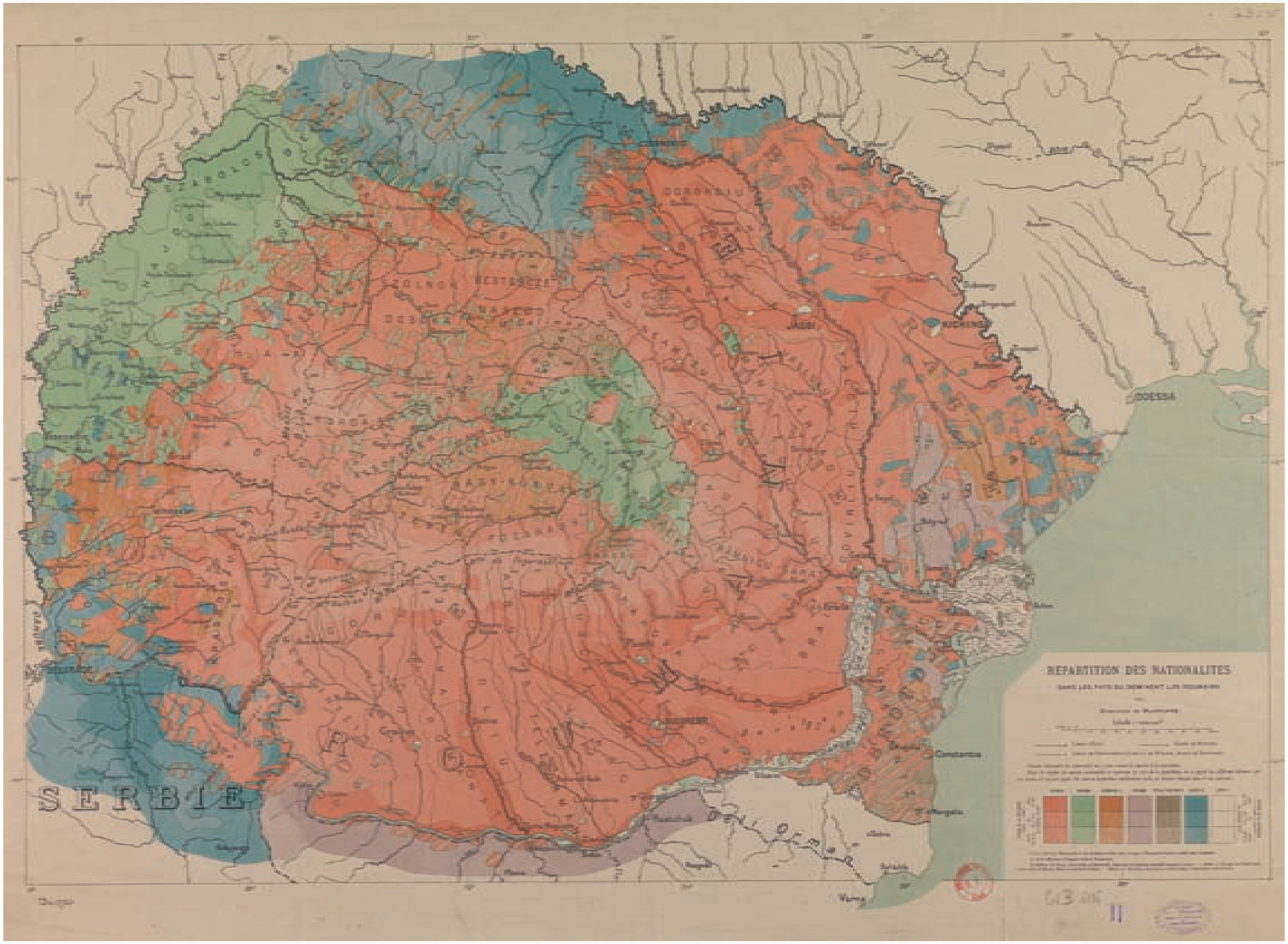

FIG. 521. EMANNUEL DE MARTONNE, *RÉPARTITION DES NATIONALITÉS DANS LES PAYS OÙ DOMINENT LES ROUMAINS*, 1919, 1:1,000,000. In addition to representing the population density of the seven nationalities in Romania by seven hues, each graded into three steps from light to dark, de Martonne also varied the width of interfingered stripes of these colors to indicate the proportion of minorities in northwestern Romania.
Size of the original: 65 × 92 cm. Image courtesy of the Bibliothèque nationale de France, Paris (Cartes et plans, Ge B 6135). Permission courtesy of the Cartothèque, Institut géographique national.

cartography institutional roots in the study of geography in French universities. Furthermore, he tried to promote cartography as a geographical methodology for supporting scientific research. He sought not just to locate but also to clarify the relationships between human and physical phenomena.

GILLES PALSKY

SEE ALSO: Ethnographic Map; Paris Peace Conference (1919)

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Marxist Perspectives in Cartography. See Social Theory and Cartography

Mathematics and Cartography. The interaction between mathematics and cartography during the twentieth century was more profound than in any earlier period. Branches of mathematics previously ignored were applied in parallel with the development of computers and satellites. In adopting these technological innovations, cartographers not only adapted more complex and abstract forms of mathematics to cartographic display and spatial analysis but also invented new analytical applications for maps. Because of the sharp conceptual and methodological changes that resulted, it is convenient to divide the century into two fifty-year periods.

Advances during the first half of the century consisted largely of traditional applications of differential geometry and related theory to developing new projections, improving map accuracy, and reducing distortion. The most innovative of these traditional applications expanded the use of conformal projections. For example, the Riemann mapping theorem, which proves that any region enclosed by a curve of any shape can be conformally mapped to a circular region using the geometry of complex numbers, inspired mapmakers to expand the number of conformal map projections from a few known examples to an infinite family of unique projections. When combined with the Cauchy-Riemann equations, the theorem provided the mathematical formalism for creating a new projection from any existing conformal projection. Unlike earlier projections, this newly created family of projections could be customized to reduce map distortion within any particular geographic region, large or small. Applying pure mathematics in this way not only led to important theoretical breakthroughs in mathematical cartography but also created computational difficulties not resolved until the advent of high-speed digital computers.

Many of the mathematical innovations applied to cartography during the early part of the century focused on reducing the complexity of calculations and developing accurate projection tables. An example of this practical utilization of abstract mathematics can be found in the attempts to construct numerical methods for solving conformal transformations. One method, discovered by French engineers Ludovic Driencourt and Jean Laborde (1932), was based on the use of complex analysis, and like the Riemann mapping theorem, utilized imaginary numbers. The reasoning behind their method was derived from earlier work on the convergence of trigonometric series by mathematicians Augustin-Louis Cauchy, Karl Weierstrass, Bernhard Riemann, and Georg Cantor.

This borrowing was quite common early in the century, an exciting time in mathematics. From 1900 to around 1935 the foundations of the field of analysis, a more formalized version of the calculus, were developed, and the new non-Euclidean and hyperbolic geometries found real-world physical applications. Formalizations of theorems and their corresponding axiomatic systems led to mathematical insights and deep philosophical debates within the mathematics community, and mathematically inclined cartographers took notice (Hessler forthcoming; Gray 2008). Some cartographers experimented with new mathematics simply as exercises. Oscar S. Adams, a calculator (his job title) at the U.S. Coast and Geodetic Survey, was probably the most prolific in this regard, deriving original projections from a host of untried equations, including Jacobian and Dixon elliptic functions and Abelian equations (Adams 1925).

The mathematics applied in cartography in the early part of the twentieth century was mostly inferential, chosen simply to represent the empirical phenomenon of interest rather than derived directly from it (Bueno and Colyvan 2011). Inferential applications of mathematics at century's end still shared certain structural properties with the phenomenon but tended to be only ad hoc models useful for calculation.

The use of mathematics in the second half of the twentieth century was quite different, marking a radical break with traditional applications and a move toward increasing levels of abstraction in mapmaking. Theorems and algorithms were taken from areas of mathematics never before used in cartography, most notably set theory, topology, algebraic geometry, complex analysis, graph theory, number theory, symbolic logic, and newly discovered fields like fractal geometry, all of which were employed in original and groundbreaking ways. Through the advent of computers, these newly applied forms of mathematics not only improved maps in the traditional sense and expanded their uses but also influenced the designer's concept of the maps. Many cartographers and geographers of the post-1950 period thought of maps not just as graphic versions of the surface of the earth useful for measuring distance and direction but as tools for solving complex spatial and geographic problems (Nystuen 1968).

The idea that a map could be used in geography as an analysis tool can be found either explicitly or implicitly in the writings of most of the early practitioners of computer mapmaking. Geographers like Waldo R. Tobler and William Bunge expanded the conception of maps as planar visual representations to true analysis tools by recognizing their essential mathematical form (Hessler forthcoming). Bunge, writing in *Theoretical Cartography* (1962), argued that maps are essentially mathematical because their core structural concepts can be expressed most simply in the mathematical frameworks of set theory and geometry. Geographer William Warntz imagined maps as logic diagrams and geographical mapping as merely a special case of the mapping of convex sets (Warntz 1968).

One of the most unexpected avenues for using maps as tools in spatial analysis came from attempts to create algorithmic solutions to existence theorems. An example of this can be found in the cartographic algorithms created for the Sandwich and Borsuk-Ulam theorems (Matoušek 2003), both of which come from algebraic topology.

The Sandwich theorem states that "given any three sets in space, each of finite outer Lebesgue measure, there exists a plane which bisects all three sets, in the sense that the part of each set which lies on one side of the plane has the same outer measure as the part of the same set which lies on the other side of the plane" (Warntz et al. 1971, i–ii). Because the theorem proves the existence of various equipartitions of a hyperplane, Warntz and his colleagues thought it to be of "paramount importance" (ii) to theoretical geography. They assumed the earth to be a solid sphere with an infinite number of planes bisecting its volume. After presenting this straightforward set of bisecting planes, they discussed more abstract types of partitioning and bisection that employed less physically imaginable variables. One possibility was a small circle that would divide the earth's surface into two parts, each with half the world's cathedrals, half the world's synagogues, and half the world's mosques.

The idea of partitioning geographic and social variables based on some statistical distribution and then mapping the result on the surface of the earth has always been one of the mainstays of thematic cartography, and the above theorem, though highly abstract, asserts that these complex partitions actually exist. The theorem is a member of the group of mathematical proofs called existence theorems, and begins with the statement, "given any three sets in space . . . there exists a plane," which is a statement of existential quantification. It goes on to show that such a plane must exist in the real world. The problem with this and many other existence theorems is that they provide no way to actually calculate the mathematical object that the theorem claims existence for (Hessler forthcoming). In pure mathematics this is not an issue, but for actual applications to cartography, one needs to find and map the partition purported to exist, perhaps using a graphical or numerical approximation method. The various parts of the Sandwich theorem paper reflect this hope and take up numerical and cartographic solutions to the problem culminating with a map of the United States that shows the joint partitioning of geographical area, population, and income.

In order to produce the map, the researchers faced the problem of making the abstract notions described in the theorem calculable on the available computers of the time. The question of whether this was even possible was still to be answered, as general applications of existence theorems in cartography were exceedingly rare. In order to find an algorithmic solution to the Sandwich theorem, Carlos Ernesto S. Lindgren, one of Warntz's coauthors, took a geometric approach to the problem, which can be seen as a case study in how cartographers worked with existence theorems in the early years of computer cartography. Instead of tackling the complexities of the mathematics directly, researchers would look for graphical solutions reducing the theorems to their most basic topological components. Such reduction was not always simple or successful even though computer mapping, perhaps with human manipulation at one or more steps, offered a plausible strategy for approximate solutions (Selkowitz 1968).

Much of the motivation for use of existence theorems came from investigations into the properties of surfaces. During the 1950s and 1960s cartographers like Arthur H. Robinson, George F. Jenks, and John Clinton Sherman published studies on the nature of surfaces and their applications in thematic cartography (Hessler forthcoming). The properties of surfaces and their use in spatial analysis naturally led to investigations of their topological properties. Topology is an area of mathematics that is principally concerned with how spatial properties of objects of any dimension are preserved under transformation. The topological properties of surfaces differ from their geometric properties and are concerned with questions of connectedness, continuity, and convergence, rather than with size and distance. Some of the most interesting and powerful results that emerged from twentieth-century mathematics came from topology and the new formalizations of the structure of space developed out of axiomatic set theory.

The surface-oriented approach to the creation and analysis of maps influenced many early computer programmers and led to the development of the topological data structures that lie at the foundation of modern geographical information systems (GIS). Like most of the mathematics used by cartographers in the late twentieth century, the investigations of the topological properties of surfaces was new and led to a rethinking of the very nature of maps. According to Nicholas R. Chrisman (1978), an associate of Warntz at the Harvard Laboratory for Computer Graphics and Spatial Analysis, cartographic data structures, as a model of geographic knowledge, provided an alternative theory of space based on newer topological concepts rather than older geometric ideas.

Topology would change the basic structure and the underlying ontology of the objects that made up maps. Using abstract topology instead of metric geometry, cartographers reduced the elements on a map to three basic shapes—the point, the line, and the polygon—that could be manipulated algebraically. These three shapes and the logical connections between them were not only sufficiently general to represent anything found on a normal map but easily stored in a computer's memory. The topological property of the three basic shapes most important to the construction of these databases was their dimension. Because each of these objects is of a different dimension (point = 0, line = 1, polygon = 2), they could not logically interact with one another without an object of lesser dimension coming between them (Corbett 1979). In this way maps could be made from these three objects that had clear overlaying boundaries, well defined regions, networks of roads, and point features like cities and towns. The application of these different topological objects signaled the introduction into cartography of very abstract mathematical spaces. Chrisman (1978), in describing the nonintuitive nature of these topological spaces compared with the usual image of a map, noted that topological constructs are not only abstract, relative, and nonmetric but have little in common with traditional spatial theories of the real world.

The question of dimensionality would prove important not only for the topological data structures used in GIS but also for the new science of fractal geometry, which offered promising solutions to problems in map projection and cartographic generalization. In 1967 the mathematician Benoit B. Mandelbrot published a paper that would change how cartographers and geographers looked at the question of scale and distance by showing that the concepts of boundary and coastline were not as simple as previously thought. He called these lines "geographical curves" and showed that many of them are "so involved in their detail that their lengths are often infinite or, rather, undefinable" (636). Mandelbrot concentrated on the shapes of seacoasts, finding them to be highly involved curves, parts of which, in a statistical sense, can be considered reduced-scale images of the whole. Mandelbrot called these shapes fractal sets (Mandelbrot 1977, 294).

Although fractals, like existence theorems, might appear to have little to do with cartography, the mathematical physicist Mitchell Jay Feigenbaum exploited their self-similarity in the development of a new type of projection for the *Hammond Atlas of the World* (1992). Feigenbaum (1983) discovered a group of equations known as "scaling functions" that precisely describe the evolution of a self-similar object under scaling transformations. He applied these scaling functions in the *Hammond Atlas* and developed a method that allowed computers to draw maps of varying scales from one single high-resolution image. This technique, resulting in a projection called the optimal conformal, was used in the atlas to map regions of various scales and produced maps with less distortion than any other previously known projection.

In the latter part of the century several other investigators made important contributions to the field of projections either by applying new mathematics or inventing new computational techniques. For example, Tobler (1977) broke new ground in both areas by proposing the use of computers and numerical techniques to design hybrid projections that did not fit any of the common projection categories but balanced the various kinds of distortion to serve a specific application.

By the end of the twentieth century mathematics and computers had changed cartography radically. Geographer Peter Gould (1999, 95), made this point succinctly when he wrote, "The use of mathematics as a 'language,' as a means of geographic expression, constitutes a marked departure from the writings of twenty years ago." At the century's end, many other mathematical methods and forms of analysis would be used in cartography as the field truly became a scientific enterprise. Remotely sensed imagery and image analysis became active areas of mathematical innovation and engineering research (Gao 2009). GIS, the Internet, and desktop mathematical programs like Mathematica and Maple put the tools of advanced mathematics, spatial analysis, and cartography in the hands of anyone interested studying spatial phenomenon and brought the interplay of mathematics and cartography deep into both the physical and the social sciences.

JOHN W. HESSLER

SEE ALSO: Cartogram; Fractal Representation; Geodesy: Geodetic Computations; Geographic Information System (GIS): Computational Geography as a New Modality; Hotine, Martin; Lunar and Planetary Mapping; Statistics and Cartography; Tissot's Indicatrix

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Memory. See Perception and Cognition of Maps: Perceiving, Understanding, and Remembering

Mental Map. See Cognition and Cartography; Community Mapping; Map: Sense of Place and the Map; Perception and Cognition of Maps: Perceiving, Understanding, and Remembering; Travel, Tourism, and Place Marketing

Mercator Projection. Devised in the sixteenth century as a navigation tool, the Mercator projection was prominent throughout the twentieth century because of its diverse uses and misuses. Developed by projecting the globe onto a cylinder tangent at the equator, it is a special case of the rectangular projection, so called because straight-line meridians perpendicular to straight-line parallels partition the planet into rectangles. Named after Gerardus Mercator, who introduced it in 1569 as the geometric framework of his famous multisheet world map, the Mercator projection is valuable to mariners because any straight line describes a loxodrome (or rhumb line), a line of constant geographic direction. In principle, a navigator who connects a course's origin and destination with a straight line can then determine the bearing with a protractor. With the additional property of conformality, the projection also preserves angular relationships at all points. Another prominent trait is the increased separation poleward of its parallels, which notoriously inflates the size of Greenland, Siberia, and other northern lands. Helpful to Mercator because it allowed a greater density of detail in Northern Europe than in more tropical lands, areal exaggeration made the projection especially useful to organizations eager to dramatize the threat of the Soviet Union during the Cold War.

Mariners had little use for the Mercator projection as a navigation tool until the late eighteenth century, when all other requirements for efficient "Mercator sailing" were in place: sextant, marine chronometer, nautical almanac, and charts showing magnetic declination. Matthew Fontaine Maury adopted the projection for his "Track Charts" (issued 1848 through 1861) describing winds, currents, and favorable sea lanes across the Atlantic, Indian, and Pacific oceans as well as for his seminal textbook on oceanography, *The Physical Geography of the Sea* (1855) (Monmonier 2004, 84–85). Prominent adoptions by earth scientists in the twentieth century included an endorsement in 1937 by the International Meteorological Organization, which recommended the Mercator projection for whole-world weather maps and maps focused on the tropics. Like the conformal projections the commission endorsed for polar and midlatitude regions, the Mercator projection accurately portrays angles between isobars and wind vectors.

Not all hydrographic organizations accepted the Mercator projection. A notable holdout was the U.S. Coast and Geodetic Survey, which adopted the polyconic projection for its coastal and harbor charts, typically published at scales between 1:10,000 and 1:80,000. Ferdinand Rudolph Hassler, the agency's first superintendent, favored the polyconic framework, which the agency promoted by publishing tables and instructions. In 1910, after persistent lobbying by the U.S. Navy Hydrographic Office, which had adopted the Mercator projection, the Coast and Geodetic Survey began the slow, costly process of conversion, not complete until 1930. The agency's annual report for 1915 accounted for this resistance by noting "no practical difference except in high latitudes between the Mercator projection and the Polyconic projection, in so far as charts on a scale of 1:80,000 or larger are concerned" (Monmonier 2004, 91).

The conformal cylindrical projection gained further converts during World War I, when military mapmakers adopted the transverse Mercator projection, centered on a regional meridian rather than the equator, for large-scale maps. Grid coordinates reliably estimated with a conformal map were especially useful for calculating azimuth and elevation for field guns with a range of five miles or more. A secant version of the transverse Mercator projection provides the geometric framework of the Universal Transverse Mercator (UTM) grid, introduced in the late 1940s (Snyder 1993, 160) and adopted by NATO (North Atlantic Treaty Organization) countries for military and some civilian mapping.

Although conformality was a logical requirement for aviation cartography, the Mercator map was not the only option. The U.S. Coast and Geodetic Survey, which initiated a national series of 1:500,000 sectional aeronautical charts in 1930, selected the Lambert conformal conic projection, instead of the Mercator projection, which more severely distorts great circles, particularly relevant to pilots guided by radio beacons. Despite early adoption of the Mercator projection by the Royal Air Force and the International Aeronautical Conference, which endorsed it for general aviation and route maps in 1919 (Bryan 1942), American aviation officials chose the Lambert conformal conic framework for the 1:1,000,000 World Aeronautical Chart because of its smaller scale error. Although satellite navigation systems later undermined the value of the Mercator projection for marine navigation, it continued to frame most hydrographic charts.

By the mid-nineteenth century the Mercator projection was widely used by publishers of reference atlases, wall maps, and school textbooks. In a sample of thirteen atlases published in Britain, France, Germany, and the United States between 1820 and 1897, John Parr Snyder (1993, 105) found nine atlases with whole-world reference maps, all on a Mercator projection. Among the eleven atlases with a separate map of Oceania, nine employed a Mercator framework. Arthur Hinks (1912, 69) examined ten general reference atlases published in Britain, France, and Germany between 1894 and 1912, and reported that "nearly all" included Mercator world maps as well as others framed on the globular and Mollweide projections. However appreciative of the Mercator projection's value as a navigation tool, Hinks objected vehemently to "the great distortion in the north and south [that] makes [it] altogether unsuitable for a land map" (29). A textbook issued by the U.S. Coast and Geodetic Survey held the Mercator projection "responsible for many false impressions of the relative size of countries differing in latitude" (Deetz and Adams 1921, 146). Erwin Raisz registered a similar objection to the projection's "unmerited popularity," which he attributed to mapmakers' eagerness to "represent the small countries of Europe on a world map." Despite this advantage, he complained, "the Mercator projection conduces to such erroneous impressions of areas and distances in high latitudes that its use should be restricted" (Raisz 1938, 87).World War II triggered further attacks on the Mercator world map, which not only exaggerated the isolation of the United States from Europe but also portrayed the Pacific Ocean as a formidable barrier against Japanese expansion (Schulten 2001, 228). Particularly powerful were an August 1942 *Life* magazine essay that condemned the projection as a "mental hazard" and a February 1943 *New York Times* editorial that called for "discard[ing] it for something that represents continents and directions less deceptively" (Monmonier 2004, 126). The impact of these criticisms is apparent in a survey of thirty-eight world atlases published in the United States between 1940 and 1960: although most atlases from the 1940s included a Mercator world map, only one publisher, C. S. Hammond & Company, used it after 1951 (Wong 1965, 68–71). An informal survey in 2002 indicated that the whole-world Mercator map never regained the respect of atlas publishers, despite frequent use for wall maps, on which its distortions were arguably irrelevant to viewers focusing on a small portion of the world (Monmonier 2004, 121–23, 127–28).

Decline of the Mercator projection accompanied an increased appreciation of other frameworks, such as Goode's homolosine projection, an equal-area projection constructed as a composite of six lobes, each divided into two zones with their own regionally centered pseudocylindrical projection. Until the mid 1940s, though, the Mercator map provided a powerful "master image" (Vujakovic 2002, 190–91), which the originators of alternative frameworks like the Miller cylindrical and Van der Grinten projections sought to emulate. Although the Mercator worldview was widely considered inappropriate for small-scale reference maps, advocates of the Peters projection vigorously condemned it throughout the 1980s and 1990s and ignored other map projections in touting the Peters and Mercator frameworks as the only

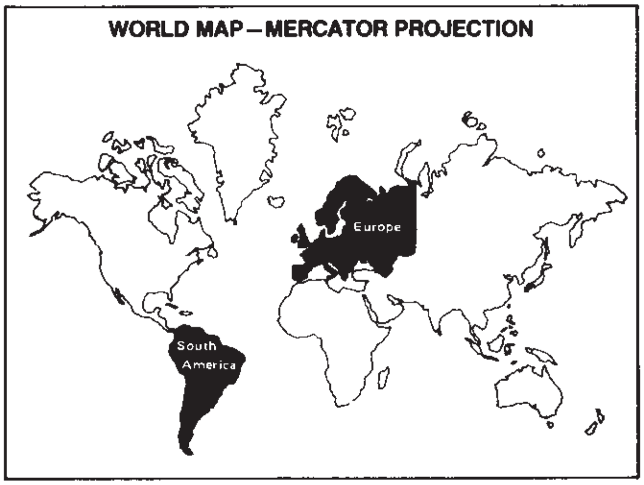

FIG. 522. WORLD MAP—MERCATOR PROJECTION. Mercator maps centered on the equator must be truncated because scale is indefinitely large at the poles. Cropped to include all of Greenland and none of Antarctica, this rendering supports the argument that the projection is "Eurocentric." The caption in *Christianity Today* underscores the projection's dysfunctional areal exaggeration, "The Mercator map . . . makes Europe appear larger than South America. It is actually smaller."
Size of the original: 4 × 5.4 cm. From "A New View of the World," *Christianity Today* 28 (17 February 1984):39–40, map on 39.

choices for a whole-world map. In making their argument, Peters proponents often portrayed the Mercator map as "Eurocentric," a view conveniently enhanced by cropping it asymmetrically to exclude all of Antarctica while showing all of Greenland (fig. 522).

MARK MONMONIER

SEE ALSO: Conformality; Coordinate Systems; Eurocentric Bias; Goode, J(ohn) Paul; Marine Chart; Miller, O(sborn) M(aitland); Peters Projection; Projections

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Meteorology and Cartography. Meteorology is an inherently geographic discipline that has been immersed in maps since it emerged as an applied science in the nineteenth century. Isopleths on maps are key to visualizing the current atmospheric patterns of synoptic-scale relationships (with a horizontal extent of one thousand kilometers or more) and mesoscale features (ranging from a few kilometers to about one thousand kilometers across) for weather variables such as temperature (isotherms) and pressure (isobars). Other observational tools, such as satellite and radar imagery, are also inherently cartographic. As a critical component of meteorology, essential for both basic understanding and advanced forecasting, maps have shaped the growth and development of the discipline in the twentieth century.

The earliest weather-related maps were not depictions of weather, which is the instantaneous state of the atmosphere, but of climate, which is the long-term average state of weather conditions and their variations (Monmonier 1999, 19). Creation of the U.S. Signal Service, predecessor of the National Weather Service (NWS), in 1870 and the hiring of astronomer Cleveland Abbe the following year stimulated the creation of weather maps because meteorologists now had a reliable federally subsidized network for regular and systematic observations (Willis and Hooke 2006). Abbe supervised the creation of thrice-daily weather maps from the central office in Washington, a natural outgrowth from his earlier work to create weather maps at a private observatory in Cincinnati (Monmonier 1999, 49–50). Maps of this era included modern conventions such as isobars and station plots but lacked fronts and other features common in the latter half of the twentieth century.

Operations became less centralized in 1891, when the weather service was transferred from military to civilian control and renamed the Weather Bureau. By the start of the twentieth century around one hundred local weather stations were issuing their own daily weather maps, which were often posted in public places (Monmonier 1999, 53). In addition to exploiting electric telegraphy—Samuel Finley Breese Morse had sent his first message by wire in 1844—the weather service benefited politically from a concentration of population in the east, where forecasts were comparatively accurate, because weather systems moved generally from west to east, and the integrated coast-to-coast network covered a huge area.

To accurately forecast the weather, meteorologists also needed to map air patterns above the surface of the earth. Experimentation with kite observations began in the 1890s, but a formal program was not launched until 1898 (Whitnah 1961, 101). Frank H. Bigelow was in charge of turning these observations into weather maps, which he began doing on a daily basis in 1903 (Monmonier 1999, 69–74). Eventually, less troublesome

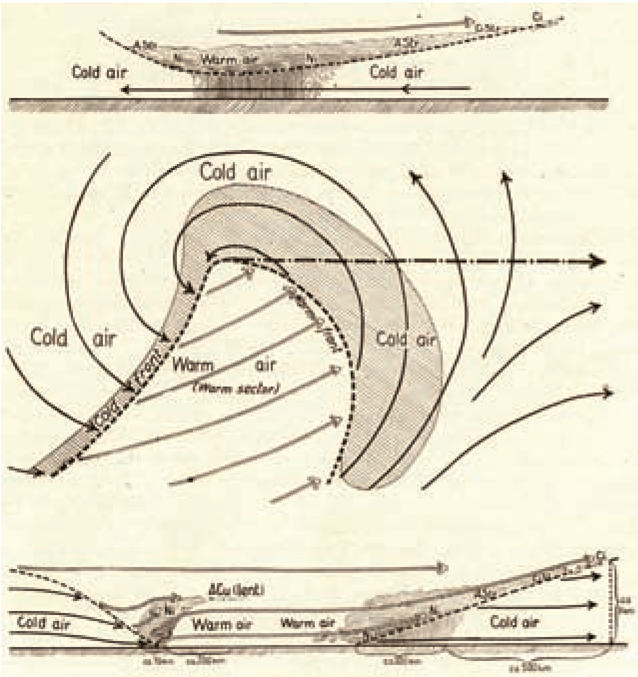

FIG. 523. TWO CROSS-SECTIONS AND A PLAN VIEW OF CLOUDS, PRECIPITATION, WINDS, AND FRONTS ASSOCIATED WITH AN IDEALIZED CYCLONE.
Size of the original: 13.4 × 12.6 cm. From Bjerknes and Solberg 1922, 3 (fig. 1).

weather balloon and aviation observations replaced kite observations. These tools also provided information from much higher levels of the atmosphere, something not possible with kites.

Beginning in the late 1910s, and continuing through the 1920s, weather maps were used as tools to advocate for or against air mass theory. A group of Norwegian meteorologists (the Bergen School) led by Vilhelm Bjerknes sought a conceptual framework to overcome the limitations of observing the weather at only a six- or twelve-hour interval, the common practice at the time. Members of the Bergen School argued that weather was shaped by discrete air masses (large regions of high pressure with relatively uniform weather conditions) and that fronts (the boundaries between air masses) served as the basis for cyclones and storms. This viewpoint differed sharply from the American belief that pressure and temperature data were paramount. To support their claims, Bjerknes, his son Jacob, and other adherents illustrated their scientific papers with maps and cross-section diagrams (fig. 523).

Meteorologists in the United States were reluctant to adopt the "Norwegian cyclone model" and used maps to support their counterarguments. Since a relatively dense network of stations in western Norway was used to develop the model, the number of stations in the United States would have to be at least doubled or tripled to adequately sample the atmosphere (Monmonier 1999, 67). Thus, when American graduate student Anne Louise Beck attempted to apply the Bergen theories to daily weather forecasting, starting in January 1921, many of her maps proved useless, although observational conventions of the time (such as rounding temperature to the nearest even degree) also contributed to the inaccuracy. Nonetheless, critics of the Bergen School used Beck's maps to argue against air mass theory. They claimed that careful study of past weather maps of pressure and temperature was more beneficial for forecasters. This method is best illustrated in *Weather Forecasting*, a 370-page Weather Bureau publication with more than one hundred maps illustrating the weather conditions associated with cold waves, nor'easters, summertime storms, and other atmospheric phenomena (Henry et al. 1916). Despite the Weather Bureau's antagonism toward air mass theory, younger meteorologists in the United States eventually began to appreciate the Bergen School's theories. In 1933 the Science Advisory Board of the Weather Bureau recommended adoption of air mass analysis (Whitnah 1961, 160). Even so, a full embrace of air mass theory did not occur until new leadership took over the Weather Bureau in 1941 (Monmonier 1999, 79).

Space technology gave meteorology another cartographic vantage point. The Soviet Union's surprise launch of the Sputnik satellite in 1957 shocked the United States and sparked the space race that culminated in the Apollo 11 moon landing in 1969. Sputnik also stimulated other forms of satellite technology. In April 1960, the National Aeronautics and Space Administration (NASA) launched the world's first weather satellite, TIROS 1 (Television Infrared Observation Satellite). Its orbit was relatively close to the earth's surface, on average about 725 kilometers above sea level. While the images from its two television cameras had limited resolution, failed to show polar regions, and had an oblique perspective, meteorologists immediately recognized TIROS's value in weather forecasting, especially by showing weather phenomena over the oceans and sparsely populated areas (Whitnah 1961, 239). Throughout the 1960s, NASA launched additional TIROS satellites, each with higher-quality sensors and more reliable transmission equipment. In the mid-1960s NASA replaced TIROS with the Nimbus series of satellites, also in low-earth orbits. A marked improvement was the Nimbus sun-synchronous polar orbit, which allowed a satellite to overfly the same area twice a day. More frequent imaging made it easier to track the evolution and movement of weather systems.

In late 1966, NASA supplemented Nimbus with the ATS (Applications Technology Satellite) series. Unlike the TIROS and Nimbus satellites, ATS satellites re-

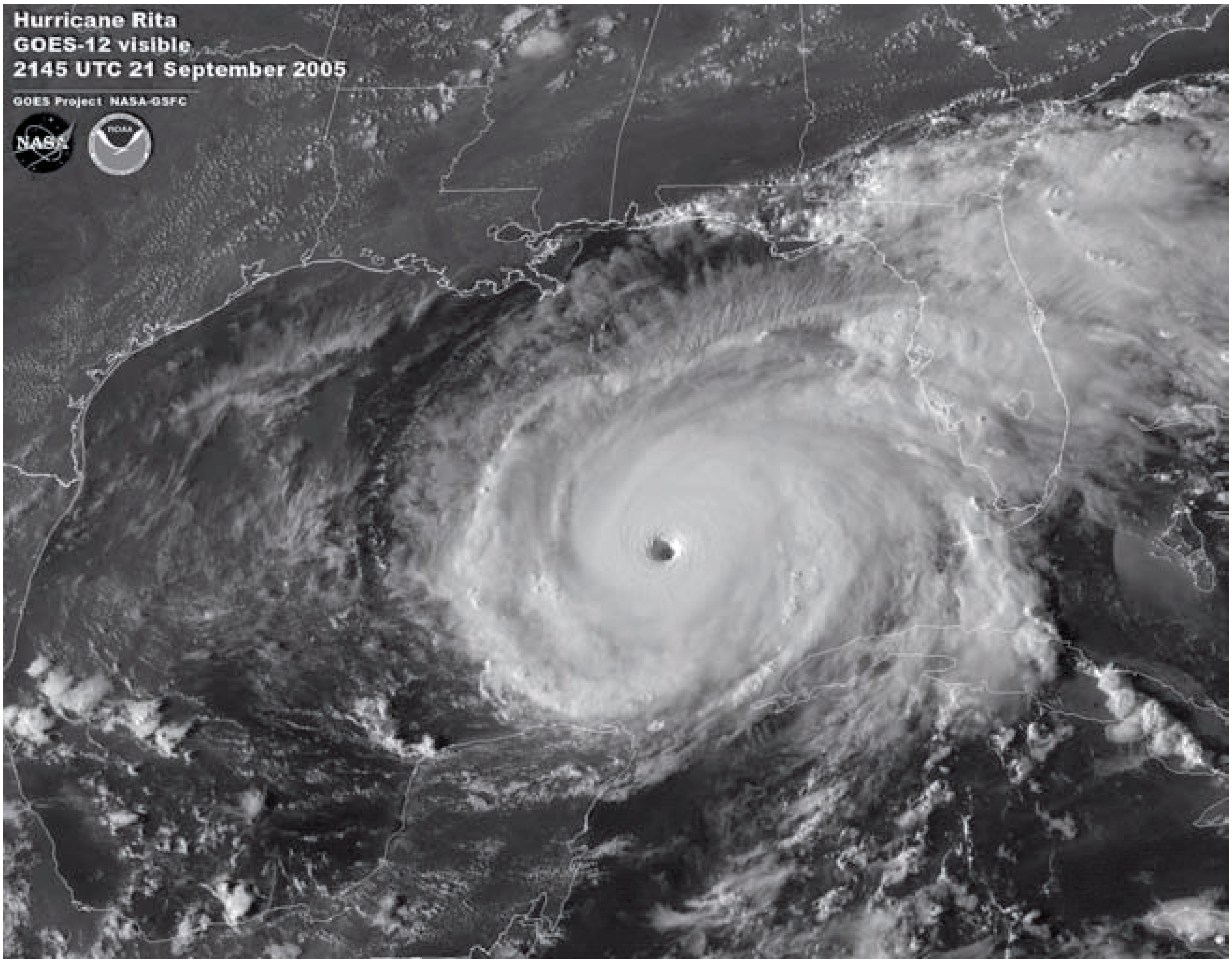

FIG. 524. SATELLITE IMAGE SHOWING HURRICANE RITA IN THE GULF OF MEXICO, 21 SEPTEMBER 2005. From NASA-Goddard Space Flight Center, GOES-12 (Geostationary Operational Environmental Satellite). Before satellites, forecasters had to rely on mariners' reports and land observations of clouds and waves for notice of an approaching hurricane.
Image courtesy of the NOAA-NASA GOES Project.

mained 36,000 kilometers above a fixed point on the equator. This so-called geostationary orbit had several distinct advantages. Because geostationary satellites produced sequences of images with an unvarying perspective, meteorologists gained a powerful tool for observing the evolution of tropical systems, mid-latitude cyclones, and even smaller phenomena such as thunderstorms and lake-effect snow. And because geostationary satellites could photograph large areas of the planet simultaneously, meteorologists received images more frequently—every fifteen minutes in some cases. Furthermore, fewer satellites were necessary to cover the planet. Only two satellites, located at 135°W and 75°W, could provide full overlapping coverage of the conterminous United States. Other geostationary satellites operated by Europe, India, and Japan provided coverage for the rest of the globe (fig. 524).

Radar, an acronym for radio detection and ranging, is another technology originally intended for military use that became an essential tool of meteorologists. Radar operation is relatively straightforward: a transmitter beams an electromagnetic pulse of energy in a known direction. This energy scatters in all directions when it strikes "targets," such as rain and snow (or even nonweather targets, e.g., insects), but a portion of it is reflected back to the radar. A computer then determines the approximate location of the targets and plots the intensity of the reflected energy on a map (Rinehart 2004, 5–7).

Radar systems were developed during World War II to spot enemy aircraft, but radar technicians and meteorologists soon learned that the large blotches on their screen were not thousands of enemy aircraft—fortunately, planes and atmospheric moisture produce distinctly different signals, readily distinguished by sophisticated signal processing systems. The Weather Bureau recognized the potential benefit of using radar to forecast severe weather and flooding, and in 1957, after a decade of experimentation, the agency commissioned its own system of radar stations, separate from those of the military. By 1971, forty-eight of these WSR-57 radars were operational, and the National Weather Service (NWS)—the Weather Bureau had been renamed in 1967—also had thirty-seven modified war surplus radar units available for use (Monmonier 1999, 140–41). Three years later, the NWS initiated the WSR-74 program, with improved visualization and algorithms for estimating amounts of rainfall. WSR-74 radars gradually replaced aging radar units and added coverage to underserved areas.

While maps from individual radar units were useful for monitoring weather and tracking individual storms within a local forecast area, in 1955 meteorologist Stuart G. Bigler made a cartographic breakthrough by compositing images from adjacent radar units onto a single map (Monmonier 1999, 141). These maps helped meteorologists discover phenomena such as squall lines (long lines of showers and thunderstorms often preceding a cold front) and meso-convective complexes (large nocturnal clusters of showers and thunderstorms) (fig. 525).

Doppler radar, first customized for monitoring weather in the mid-1950s, marked a significant leap forward for tornado forecasting (fig. 526). Doppler radar uses the principle of the Doppler shift (the change in wave frequency associated with movement) to detect precipitation velocity as well as intensity and location. (The Doppler shift is apparent when a vehicle with a siren, such as ambulance, passes a stationary observer, who notices a distinct drop in pitch.) Doppler radar can display the velocities of small "cells" of precipitation, which meteorologists can examine for the presence of low-altitude rotation—the sign (or precursor) of a tornado. The promise of significantly improved tornado warnings was the impetus for NWS Doppler experiments in the 1970s, which led, to implementation of the NEXRAD (Next Generation Radar) network in the 1990s. NEXRAD grew from a few units in 1991 to largely complete coverage of the conterminous United States by mid-decade. Although coverage was deficient in sparsely populated mountain areas, the overall results were impressive—average lead time for tornado warnings increased by nearly 80 percent in a decade, and the probability of tornado detection jumped from 35 percent to 60 percent (Simmons and Sutter 2005). Although less likely to experience tornadoes than the United States, Canada also installed a Doppler radar network between 1998 and 2004. Most of Canada's Doppler stations (thirty-one as of 2007) were near the U.S. border, but a corresponding concentration of population allowed Environment

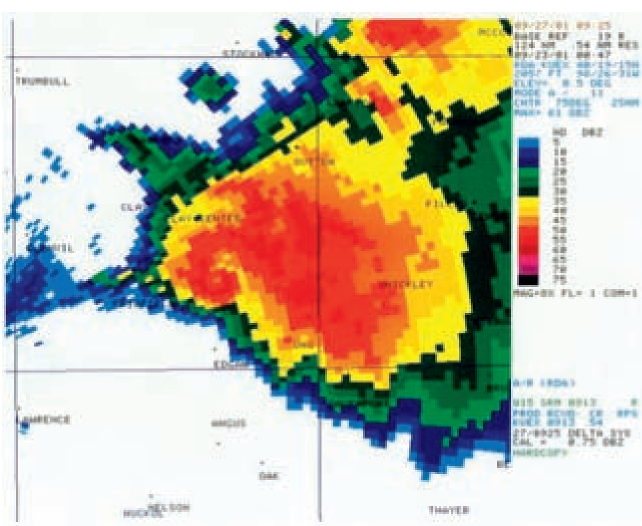

FIG. 525. RADAR IMAGE SHOWING A TORNADIC THUNDERSTORM. Visible is the characteristic "hook" indicating a tornado (located between Clay Center and Edgar), 22 September 2001. Compare figure 526.
Image courtesy of the National Weather Service Office, Hastings, Nebraska.

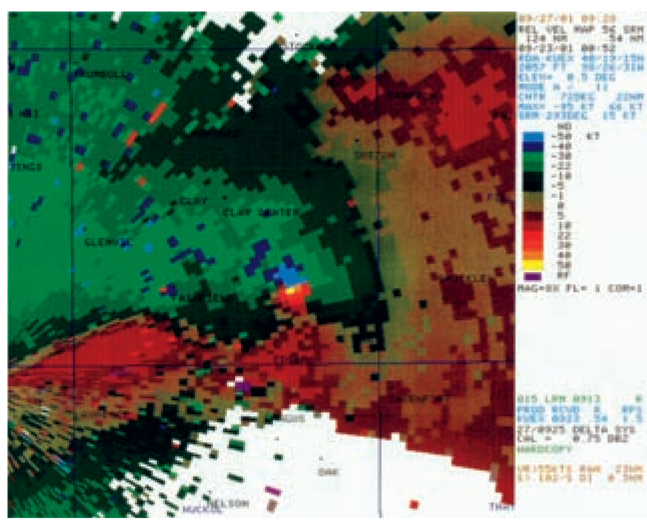

FIG. 526. DOPPLER RADAR IMAGE SHOWING TORNADO. This image, which is five minutes later than figure 525, shows the results of a Doppler velocity scan of the same storm. The tornado is located where adjacent pixels have a velocities of at least -50 and +50 knots relative to the radar.
Image courtesy of the National Weather Service Office, Hastings, Nebraska.

Canada to claim that more than 98 percent of the country's citizens were within the scanning radius of at least one station.

The computer revolution of the latter half of the twentieth century greatly benefited meteorology by offering a plethora of analysis and forecasting tools. Perhaps the most heavily used forecasting tools are computerized simulations of the atmosphere, known as models (Nebeker 1995). The British mathematical physicist Lewis Fry Richardson introduced the notion of a model of the atmosphere in 1922, well before the computer age (Lynch 2008). Although burdensome arithmetic forced Richardson to take shortcuts in computation, his model was constructed in a similar manner to the forecasting models in use at the end of the century. He treated the atmosphere as a spherical grid and calculated weather conditions for one central point in each "box." Richardson's model predicted not only surface weather but also conditions at four levels of the free atmosphere (Monmonier 1999, 92). While Richardson's model failed (largely because meteorologists were unaware of basic tenets of meteorology such as jet streams), his ideas served as the basis for later modeling attempts (Friedman 1989). Computer models largely function like Richardson's, but they have many more layers and a much finer grid.

Since the early 1990s, when World Wide Web browsers were first released, the Internet has grown into a ready source of weather information for anyone with a moderately fast Internet connection. Much of this information was freely available to both professional and amateur meteorologists courtesy of the governments, universities, and even a few private vendors. Although there are literally hundreds, if not thousands, of websites with static or animated maps of current and near-term weather, some of the most popular outlets were Intellicast, Weather.com, and websites run by the NWS, Environment Canada, and the United Kingdom's Meteorology Office. Dynamic websites that allowed users to customize the display were less common but increasingly prominent. Meteorologists could also download a variety of stand-alone weather visualization programs, often available as freeware, which offered innovative ways to visualize weather. For example, BUFKIT, a popular forecasting tool originally developed by employees at the NWS office in Buffalo, New York, could be used to display vertical profiles for lake effect snow and other convective phenomena such as thunderstorms (Mahoney and Niziol 1997). These profiles essentially serve as maps of the weather conditions in the atmosphere above an individual's location. Visualization tools like BUFKIT and other dynamic mapping and analysis programs most likely contributed to the large improvement in forecast accuracy realized in the late twentieth century (Dolan and Rutledge 2007).

Media maps, which heightened public awareness of weather forecasts and the importance of meteorology as a scientific discipline, greatly changed during the twentieth century. The first weather map in a popular daily newspaper appeared in 1875 in the *Times* (London) (Monmonier 1999, 154). In the United States, maps appeared haphazardly until the early 1910s, when a standardized weather map briefly appeared in more than one hundred U.S. newspapers. This map was the product of the energetic chief of the Weather Bureau, Willis L. Moore, who believed in broad dissemination of weather information. Moore developed and marketed the commercial weather map to newspapers. The map itself was a relatively straightforward yet necessarily esoteric weather presentation featuring isobars, selected isotherms, and detailed weather information for selected stations in the United States. Although the map proved popular, at least among newspaper publishers, its use faded as a result of Moore's firing by U.S. President Woodrow Wilson in 1913, a paper shortage during World War I, and the postwar recession (Monmonier 1999, 167). Even so, newspaper weather maps became widespread after World War II, thanks to the Associated Press's Wirephoto network, which provided rapid delivery to member newspapers for no additional fee. Newspaper weather presentations became larger and more colorful following the launch of *USA Today* in 1982, which featured a large color weather map and other graphics that dominated nearly an entire page. While most weather maps appearing in newspapers at the dawn of the twenty-first century lacked the isobars and wind barbs common one hundred years earlier, they included sufficient information to help most amateur meteorologists understand the weather (Call 2005).

Television weathercasts began soon after the first commercial television broadcasts in the late 1940s. Early weather maps were often hand-drawn—sometimes drawn live, on camera—on a background of frame-of-reference features, such as state boundaries. As weather radar and satellite imagery became more widely available, a few stations added weather visualization to their news programs, but not until the 1970s, when color television had become standard and the cost of computers had begun to plummet, did weathercasts start to resemble the visually rich presentations common at the century's end. "Rainbow radar," a colorized version of the previously black-and-white radar displays, was adopted by television stations in the 1970s (Henson 2010, 94). Instead of using various shades of white to indicate differences in the intensity of precipitation, a categorical color scheme typically progressed from blue or green at the low end to red for the most intense category. This color scheme was adopted by the larger meteorological community for temperature maps as well as radar displays. When weather graphics systems with chroma key technology appeared in the 1980s, a weathercaster working in the studio in front of a light blue or lime green wall could be seen at home as standing before a dynamic full-screen weather map. By watching a monitor, the "on-screen" meteorologist, who also typically created or contributed to the presentation, could point accurately to specific features. These carefully narrated, richly illustrated presentations made complex, otherwise overwhelming cartographic sequences intelligible to the viewing public. What's more, since the launch of the Weather Channel in 1982, American viewers with cable service no longer had to wait for the evening news program. Dedicated weather channels, which soon emerged in other countries, have educated countless amateur meteorologists in the dynamics of atmospheric circulation.

DAVID A. CALL

SEE ALSO: Chroma Key; Geophysics and Cartography; National Aeronautics and Space Administration (U.S.); Weather Channel, The (U.S.); Weather Map

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Metric System. The metric system is a decimal system of weights and measures intended to simplify arithmetic and promote international trade and scientific communication. Although the system provides world standards for a wide variety of measurements, including mass, temperature, volume, time, and electricity, the term *metric* (from the Greek *metron*, meaning measure) is most closely associated with the *meter*, the unit of length defined in the late eighteenth century by the French Académie des sciences as one ten-millionth of the distance from the North Pole to the equator. Like any scheme for standardizing weights and measures, the metric system depended upon an agreed set of definitions, procedures, and physical prototypes for calibrating measuring instruments and converting from customary units like the foot and the ounce. A major step toward worldwide agreement occurred in 1875, when representatives from seventeen countries signed the Treaty of the Meter (Convention du Mètre), which established "a scientific and permanent international bureau of weights and measures" in Paris. By 1900, thirty-four countries had made metric units compulsory or at least optional (Hallock and Wade 1906, 76, 105–8). In 1960 the Eleventh General Conference on Weights and Measures adopted a refinement known as the Système international d'unités, or SI for short. By century's end, all but a handful of countries had adopted the metric system. Although the United States was the most conspicuous holdout, some parts of the economy—most notably the distilled spirits industry—had "gone metric" decades earlier. Moreover, the United Kingdom and several other countries identified as officially metric were still in the throes of conversion, a particularly long and tedious process for mapmakers.

Metrication was comparatively simple in small-scale cartography because a scale bar graduated in kilometers could easily be added to any existing maps. Although metric bars scales were added with equal ease to topographic maps, true metric conversion typically meant adopting round-number metric scales like 1:10,000, 1:25,000, and 1:50,000—not a simple task for countries with map scales tied to customary units like the inch and mile (Balogun 1996, 4–5). Inch-to-the-mile mapping, with a scale of 1:63,360 (or its slightly more rounded variant, 1:62,500), became obsolete once map users embraced or capitulated to edicts favoring centimeters and kilometers. Because enlargement to 1:50,000, the closest metric scale, would yield an awkwardly sparse image whereas reduction to 1:100,000 would invite clutter and eyestrain, the most efficient strategy was to wait until the next major resurvey. Even so, inch-to-the mile maps (at 1:62,500) could be efficiently generalized to four-miles-to-the-inch maps (at 1:250,000) and were useful for compiling sixteen-miles-to-the-inch map sheets for the 1:1,000,000 International Map of the World, as long as contour elevations were generalized to a multiple of 100 meters.

Elevation proved more problematic than scale (Long and Burger 1973). Although 1:24,000 mapping, on which one inch represents 2,000 feet, is conveniently close to 1:25,000, the customary contour intervals of 5, 10, or 20 feet (equivalent to 1.524, 3.048, or 6.069 meters) were not easily accommodated by simple reduction and redrafting. In the late 1970s, when the United States was seriously contemplating widespread metrication—the Metric Conversion Act of 1975 had directed federal agencies to adopt metric units "to the extent economically feasible" by 1992—the U.S. Geological Survey (USGS) adopted an ambitious policy that mandated a contour interval of 1, 2, 5, 10, 20, 50, or 100 meters (Thompson 1979, 231–33). Although the USGS had produced a few experimental 1:20,000 and 1:25,000 maps with metric contours (Gilman 1983), the initiative died in the early 1980s because of lack of public support and assertive cost cutting by a conservative administration.

Metrication succeeded where a strong central government recognized the need for a new, more precise topographic survey or implemented deeper reforms, as in the Soviet Union, which updated earlier surveys based on the *verst* (3,500 feet or 1.0668 km) with metric measurements and replaced pre–World War I mapping at 1:21,000, 1:42,000, 1:126,000, 1:210,000, and 1:420,000 with metric scales between 1:25,000 and 1:500,000 (Ormeling 1974, 40). The need for international compatibility was a strong incentive for the metrication of military maps, especially among NATO (North Atlantic Treaty Organization) countries, which adopted standard scales of 1:25,000, 1:50,000, and 1:250,000 in 1947. As a member of NATO, Canada promptly adopted metric standards for its military maps and shortly thereafter for its civilian topographic maps as well—under these circumstances metrication was considered not only efficient but inevitable (Sebert 1971, 57). On large-scale USGS topographic maps the 1-kilometer tick marks of the Universal Transverse Mercator (UTM) grid have coexisted since the late 1940s with the 10,000-foot tick marks of the State Plane Coordinate system, devised in the mid-1930s.

Metric units have always been standard in remote sensing, where ground resolution was reported in meters or centimeters, but inches and feet have been pervasive in aerial photogrammetry in North America and Britain, where the focal length of a camera's lens was usually a multiple of 3 inches, and 9-by-9-inch prints were standard. In the graphic arts industry and web cartography pixels (or dots) per inch (ppi) remained a standard measure of image quality, perhaps because the common resolutions 300 and 72 ppi had convenient metric approximations of 12 and 3 pixels per millimeter, respectively.

MARK MONMONIER

SEE ALSO: Conventions, Cartographic; Coordinate Systems; Penck, Albrecht; Scale

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Michelin (France). In 1889 the brothers André and Edouard Michelin purchased a company founded in 1830 by their grandfather Aristide Barbier and his distant cousin Edouard Daubrée and specializing in the manufacture of rubber. Thus was born Michelin et Cie, long synonymous with the family that owned it and one of the world's leading producers of road maps and travel guides. The firm's preeminence as a mapmaker reflects in part the career of André Michelin, who studied to be an engineer at the École Centrale Paris and fulfilled some of his military service in the cartography department of the Ministère de l'intérieur, participating in surveys for the national map at a scale of 1:100,000.

By inventing the first pneumatic, removable tire in 1895, the two brothers anticipated the automobile's dramatic rise in popularity. They decided to promote their business by providing drivers with technical advice as well as information on obtaining parts and accessories, finding room and board while traveling, and getting around in large cities. These ideas gave birth in 1900 to the first Michelin *Guide rouge* for France, which, in addition to promoting Michelin products, contained a wealth of information useful to drivers. Beginning in 1902, the *Guide rouge* included a small map of France as well as more than 100 small maps of principal cities. In 1903 the Administration des Ponts et Chaussées lent its support by contributing information on roadways gathered by its supervisors and engineers. Updated every year, the guide was offered to drivers free of charge until the early 1920s.

The first Michelin map was published in 1905, on the occasion of the Coupe Gordon Bennett, an automobile race initiated by the American newspaper publisher James Gordon Bennett, Jr. The 1:100,000 map was designed to follow the racecourse, which took place that year near Clermont-Ferrand, where the firm was located. In 1906 André Michelin began to investigate the production of a set of maps of France. Information gathered by his tourism department was complemented by maps from local officials and civil engineers. Producing these maps required more than 3,000 sketches. At that time other publishers, notably Taride (since 1895), the Touring Club de France (since 1894), and De Dion Bouton (since 1900), were already producing road maps for motorists and cyclists.

In 1907 Michelin published a map of France at 1:1,000,000 as a fifty-six-page atlas. It was one of the first productions of the firm's cartographic department. Previously, maps in the guides had been taken directly from artwork provided by the Ministère de l'intérieur. Several pages in this edition also included a more detailed map of Auvergne. That year Michelin also produced a map of the area around Clermont-Ferrand and offered it locally free of charge.

In 1908 the company established a tourism office to help automobile travelers plan their itineraries. It was located on the Boulevard Pereire in Paris. In 1909 Michelin launched an ambitious project to produce and sell road maps covering the entire country. France was divided into forty-seven separate sheets at a scale of 1:200,000, but it was not until 1913 that all sheets were available. This first edition was produced jointly with Charles Delagrave, who provided editorial services, but from 1913 onward Michelin produced the maps itself.

Michelin improved its road maps in various ways. Competitors' road maps already included much of the information found on Michelin's new maps, including type of road, pavement, distance, grade, telegraphs, railroads, trams, and sidewalks (fig. 527). Features that distinguished Michelin's new maps included information on width and road conditions; an accordion fold that simplified planning and following a route; a cardboard

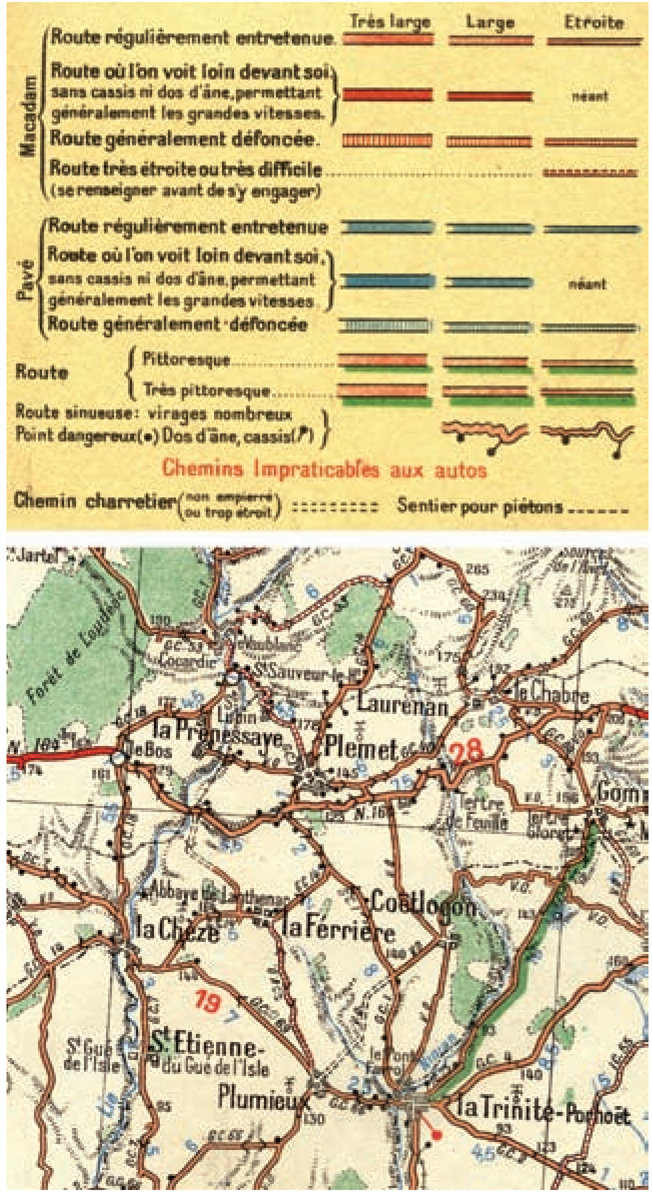

FIG. 527. LEGEND AND MAP DETAILS FROM *CARTE MICHELIN DE LA FRANCE, RENNES*, 1920. This portion of the legend shows road types and conditions. A *chemin impraticable aux autos* (road impassable for cars) is shown running northeast from Plumieux.
Size of the originals: ca. 7.3 × 8.9 cm (top) and ca. 8.9 × 8.9 cm (bottom).

casing attached to the map; numbered highways; and indications of intermediate distances, dangerous points and turns, scenic routes, prominent buildings, and signs marking scenic views. Equally important, Michelin updated its maps nearly every year.

Most road maps of the period consisted of a sheet of paper that was folded and inserted into a small pouch or cloth bag. To consult the map, the user had to unfold the entire sheet, which created a horrendous task for anyone not adept at refolding the map quickly. Buyers were enthusiastically appreciative of Michelin's innovative system of pleating, which allowed the user to view the map like one would turn the pages of a book rather than having to completely unfold the sheet. As was common at the time, Michelin maps were also available in a more durable version, with the printed map glued to a cloth support for increased resistance to tearing. Michelin's standard paper maps were sold individually in printed paper pouches until 1914 and then in a simple paper pouch of transparent, pale crystal-blue paper until just after the war.

In 1912 André Michelin launched a campaign to assign numbers and place corresponding signs on French roads, and he circulated a petition that gathered many signatures. French roads were already numbered, but only for administrative purposes. Michelin maps had included these numbers from their inception. The government took on the project in 1913, and within a few years highway numbers were listed on all milestones along with indications of direction. Around 1920 Michelin also began to manufacture road signs.

In 1914 Michelin began to produce maps for areas outside France, which provided a lucrative export market until the 1930s (fig. 528). A series of maps showing roads in the United Kingdom (twenty-two sheets) and Ireland (nine sheets) were based on data from the Ordnance Survey. Around 1920 the company added maps for Spain (nineteen sheets), and in 1922 maps for Belgium (two sheets) and Switzerland (four sheets). In 1924 maps for Italy and the United States began to appear, but these two series were never completed or reprinted. Only five sheets were produced for Italy, and maps for the United States were limited to the environs of principal cities on the East Coast: Boston (fig. 529), Providence, New York, Philadelphia, and Baltimore. The first Michelin maps for Algeria-Morocco appeared in 1928. In 1923 a new format divided France into thirty-six sheets and England into only fifteen sheets. A large part of Scotland was no longer covered, and only two sheets for Ireland remained. In 1934 the company stopped producing maps of the British Isles altogether, and in 1936 it discontinued maps of Spain, in the throes of civil war.

In the early 1920s, the Bureau de tourisme experienced marked development and became the Bureau des itinéraires, with nearly 100 employees, which continued to function until the outbreak of World War II in 1939. Between 1921 and 1925, the annual number of requested itineraries rose from 18,000 to 155,000. The most frequent requests became the subject of regional publications, starting in 1926 with the forebears of the famous *Guide vert Michelin*, which gradually replaced the itineraries.

In 1939 German troops equipped with copies of Michelin maps invaded Belgium and France. The Wehrmacht used copies of the 1938 edition. In 1940 two maps covering Holland appeared as well as three covering Algeria and Morocco. Michelin maps were heavily utilized during World War II. Among the Allies, airdrops over France organized in London relied on landmarks shown on Michelin maps because they were widely available. In preparing maps of roads and terrain for the June 1944 D-Day invasion, English and American military officials relied heavily on Michelin maps and the *Guide rouge*. Beginning in 1943, the United Kingdom's War Office printed traffic maps, which were reproduced directly from Michelin maps, as well as an exact copy of the 1939 *Guide rouge*, the only readily available document with detailed plans of all French cities, including the locations of principal official buildings. After liberation, Michelin was an abundant source of maps for American troops. Because of shortages of basic materials, some maps were printed only in black ink, and others were printed on the backs of confiscated German maps. In 1944 maps of occupied East and West Germany appeared as well as maps of France indicating the roads and bridges unusable due to war damage.

In the postwar years Michelin maps served a revived and expanding tourism market. Between 1953 and 1956 the company released general maps at a scale of 1:1,000,000 for European countries near France, and by 1974 Michelin maps covered all European countries at a scale of 1:400,000.

In 1989 the first Michelin atlas of France covering the whole country at a scale of 1:200,000 was published, and that year its itinerary service on Minitel (a videotex system developed by France Télécom) became Michelin's first digital cartographic application. An outgrowth of this itinerary service was a pocket organizer, introduced in 1994, that used memory cards to produce itineraries or lists of hotels based upon the *Guide rouge*. A website launched in 1997 became operational the following year, when Michelin also released its first compact discs (CDs) designed for personal computers and Global Positioning System–enabled in-vehicle navigation systems, including systems for the real-time tracking of company vehicles. In 2001 the subsidiary Viamichelin was created to oversee the development and commercialization of Michelin's digital and Internet products.

Michelin has always been, first and foremost, a tire manufacturer (fig. 530). Its cartographic work, which began as a service to promote automobile tourism, became an important product that helped spread the Michelin name and enhance the brand's worldwide reputation with its maps, guides, software, and web services. The company was also well known for its *Guide Michelin*, recognized for discovering and rating the world's best restaurants.

PASCAL PANNETIER AND ETIENNE HOUDOY

FIG. 528. COVERAGE OF MICHELIN MAPS OF FRANCE AND THE BRITISH ISLES. The *Nantes* section of the *Carte Michelin* is ca. 1920 (left), and the *Michelin Map of the British Isles, Colchester-Dover*, is ca. 1916 (right).

Size of the originals: 21.5 × 10.7 cm (left) and ca. 23.4 × 12 cm (right). Image on the right courtesy of the National Library of Scotland, Edinburgh.

SEE ALSO: Marketing of Maps, Mass; Road Mapping: (1) Road Mapping in Canada and the United States, (2) Road Mapping in Europe; Travel, Tourism, and Place Marketing

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FIG. 529. AMERICAN MICHELIN MAP OF THE BOSTON AREA, 1921. On the *Michelin Touring Map of the United States*, coverage is shown on the front (left) with an explanation of the folding system on the back (right).

Size of the original: ca. 25.7 × 12 cm. Images courtesy of Pascal Pannetier.

FIG. 530. TWO ILLUSTRATIONS OF BIBENDUM (MICHELIN MAN). Bibendum rolling a tire from the back of *Rennes*, ca. 1920 (left) and the back of *Nîmes-Avignon*, ca. 1923 (right). Size of the originals: 22 × 10.7 cm.

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MIIGAiK (Russia). See Moskovskiy institut inzhenerov geodezii, aerofotos"yëmki i kartografii (Moscow Institute of Geodetic Engineering, Aerial Photography, and Cartography; Russia)

Military Geographic Institute (Italy). See Military Mapping by Major Powers: Italy

Military Mapping by Major Powers.

- UNITED STATES
- NORTH ATLANTIC TREATY ORGANIZATION (NATO)
- GREAT BRITAIN
- FRANCE
- GERMANY
- ITALY
- AUSTRO-HUNGARIAN EMPIRE
- OTTOMAN EMPIRE
- ISRAEL
- RUSSIA AND THE SOVIET UNION
- CHINA
- JAPAN

This composite examines the activity of nation-states (and one multination alliance) that undertook significant military mapping both within and beyond their own borders.

Military Mapping by the United States. Prior to 1879 the U.S. Army Corps of Topographical Engineers and, from 1863, the U.S. Army Corps of Engineers had provided much of the mapping of the American West, but in that year the U.S. Geological Survey (USGS) took over responsibility for this work. Prior to the Spanish-American War there was little demand for mapping in support of the military beyond the boundaries of the United States. Provision of mapping for the army was put on a more systematic footing in 1909, when the Corps of Engineers established a map reproduction unit at the Army War College in Washington, D.C. A lithographic school was added later that year and in 1910 it became the Map Printing Plant of the Engineer School. In 1917 the name was changed to the Central Map Reproduction Plant. The Central Map Reproduction Plant was reorganized in anticipation of the U.S.'s entry into World War I, but the overseas facilities were able to cope with the demand for maps generated by the static warfare on the Western Front. Nine million maps were produced for U.S. forces during World War I (United States, Army Map Service 1960, 6–7).

Perhaps the single most significant event during the century for the development of American military cartography was the advent of the powered airplane, which would later give rise to the development of reconnaissance satellites, both of which are able to photograph the world with impressive clarity. The U.S. Army raised a balloon detachment as part of its Signal Corps toward the end of the nineteenth century at Fort Logan, Colorado. When the detachment was formed it had just one balloon in its possession. That balloon was in great demand after the outbreak of the Spanish-American War in 1898 (fig. 531). During the U.S. invasion of Cuba in June the observer in the Signal Corps' balloon gathered intelligence on Cuban terrain that enabled U.S. forces, which had landed at Daiquirí and Siboney on the southeastern coast, to map the territory and plot a route for the rapid delivery of troops for the battle of San Juan Hill and Kettle Hill, the decisive battle during the invasion. However, the Signal Corps deployed their balloon in view of Spanish artillery, which allowed the latter to deduce the position of the U.S. forces. Nevertheless, the Spanish-American War underlined the contribution that the balloon could make to mapping and reconnaissance, and four balloon squadrons were activated following the entry of the United States into World War I, with three being deployed on the front lines.

FIG. 531. BALLOON FOR AERIAL RECONNAISSANCE, 1898. The Army Signal Corps balloon at the battle of Santiago, Cuba, 1 July 1898.
Image courtesy of the U.S. Army Signal Center of Excellence.

The U.S. Army had started to take an interest in aerial photography from airplanes prior to U.S. involvement in World War I. The equipment and methods being used by the French and British armies were studied and allied training materials reproduced for use by U.S. forces. During the war, photographer Edward Steichen joined a U.S. Army reconnaissance unit bringing the expertise that he had developed as a military balloon observer to the new technology of airplane-based reconnaissance. Steichen and his colleagues were tasked with providing Brigadier General William "Billy" Mitchell, who commanded all U.S. Army flying units in France, with imagery intelligence. By early 1918, training schools had been set up in France by the U.S. Army to teach aerial observers how to take photographs with the proper overlap that would then complement printed maps (fig. 532). It is a truism

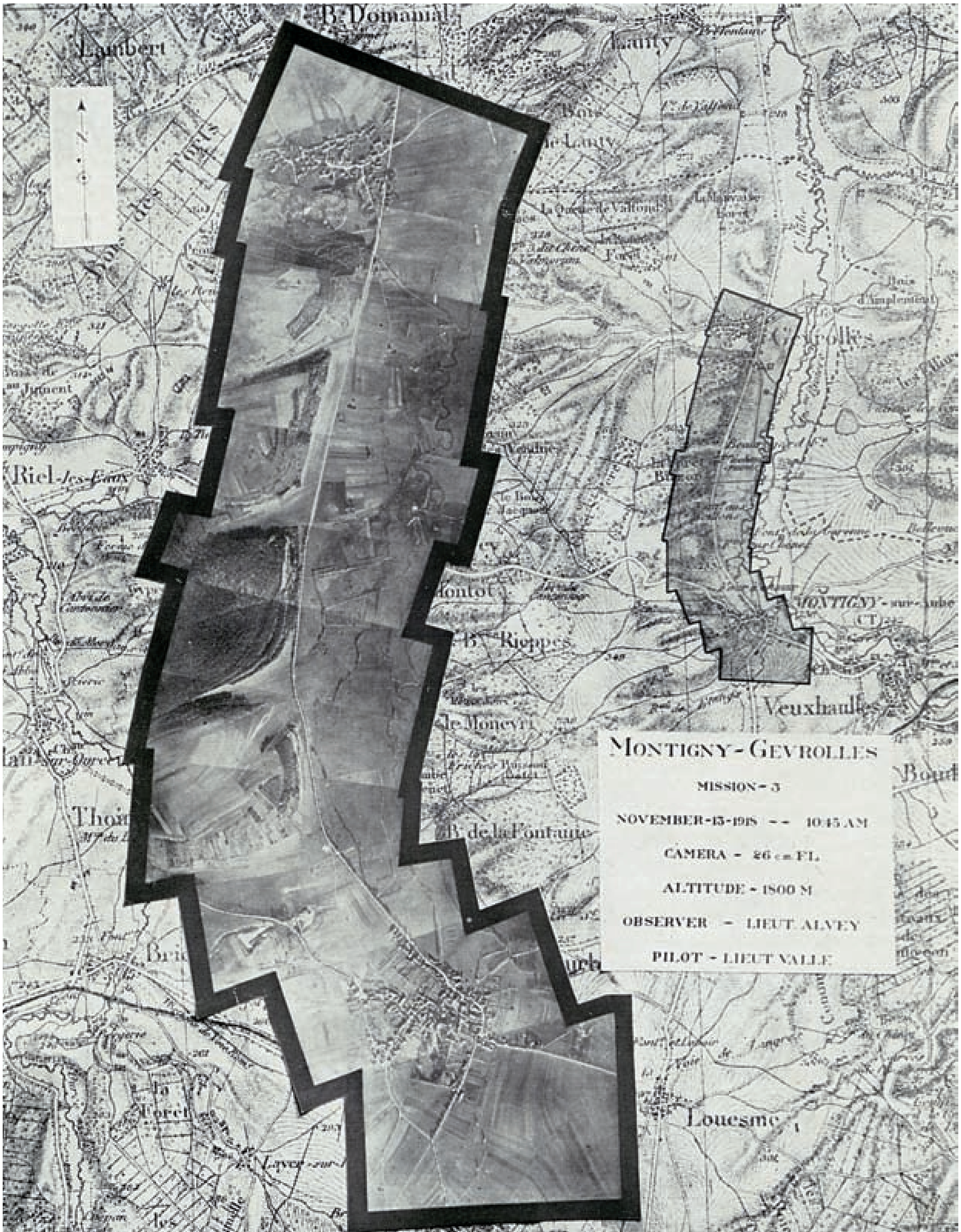

FIG. 532. AERIAL PHOTOGRAPHS AND CORRESPONDING MAP, 1918. Example from Montigny-Gevrolles, mission flown 13 November 1918.

From *The "Battle of Chantillon": A Graphic History of the Second Corps Aeronautical School, American Expeditionary Forces, France* (Grand Rapids: Dean-Hicks, 1919), 56.

that war accelerates scientific development, and by the end of the Great War, aerial reconnaissance had taken some major steps forward.

The expansion of the Army Air Service led to a demand for new maps specifically for air navigation. The Airways Section of the service was responsible for the compilation of information relating to military air routes, radio navigation aids, and airfields. In 1923 the Airways Section produced a specification for a series of air navigation strip maps at 1:500,000 scale to be compiled at the Engineer Reproduction Plant (which until a 1919 reorganization was the Central Map Reproduction Plant). By 1928 the Air Service, renamed the Army Air Corps, had published thirty-eight strip maps, and in December of that year the Map Unit was established and made responsible for the procurement and dissemination of all maps and charts to the Air Corps. The unit had no independent mapping capacity but relied on commercial companies and government agencies to provide the maps. Rand McNally's aviation maps and air trail state maps were among those procured in large numbers. In 1933 the Air Corps started to phase out its strip map program and agreed to use the Department of Commerce sectional charts produced by the U.S. Coast and Geodetic Survey (USC&GS).

The technological advances experienced in mapping occurred alongside the development of the bureaucracy that would draw, print, and disseminate maps for military use. The Engineer Reproduction Plant was tasked not only with producing maps but also with developing advanced cartographic techniques, such as ensuring that the printed maps were legible under varied light conditions. Among the important developments was the blue-line board method, used in drafting maps requiring color separations. Versions of this process continued in use until replaced by digital methods. The use of transparent media for the application of lettering also resulted from work in the Engineer Reproduction Plant, leading to the replacement of hand lettering. Similar developments meant that many of the methods that required craft skills could be replaced by quicker and less specialist methods, speeding production and reducing labor costs. These new methods allowed a rapid expansion in staff numbers following the U.S.'s entry into World War II. In 1940 the Engineer Reproduction Plant employed 100 civilians and 3 officers who were expected to serve as the nucleus of any future wartime expansion. As the political situation deteriorated the War Department started a recruitment drive to increase the cadre of highly skilled staff. In addition, the Library and Cartographic Section of the War Department General Staff was amalgamated with the Engineer Reproduction Plant to form a single organization.

Following the outbreak of war in Europe the U.S. Army's Map Unit was renamed the Map Section and expanded in anticipation of American involvement. Specifications were drawn up for aeronautical charts of various parts of the world that had not previously been covered. In carrying out this work, it was discovered that only 10 percent of the world had been adequately mapped, and much of that mapping was out-of-date. In 1941 several new map series were initiated to meet the needs of the Air Corps. The USC&GS was requested to prepare the Western Hemisphere aeronautical charts at 1:1,000,000, and the Engineer Reproduction Plant started work on the world long-range charts at 1:3,000,000. In November the USC&GS also started production of the world planning charts series at 1:5,000,000 as well as on a series of outline charts at 1:5,000,000 for plotting meteorological data.

In January 1942 the Map Section was renamed the Map-Chart Division and moved from the Intelligence Division of the Air Corps to its Air Traffic Services. The Map-Chart Division retained the same functions as the Map Section, primarily those of a control agency to manage the work of other federal agencies, such as the USC&GS and parts of the USGS and the Department of Agriculture, as well as commercial organizations that carried out work under contract for the Air Force.

The Engineer Reproduction Plant experienced a further reorganization after America's entry into World War II when in May 1942 it was renamed the Army Map Service (AMS) under Captain Charles H. Ruth. The AMS was responsible for producing maps for the U.S. Army General Staff, reproducing maps for field operations, and advancing cartographic and map printing techniques (fig. 533). It moved into new buildings in Brookmont, Maryland, and rapidly expanded its staff by about 3,000 to meet the increasing demand for maps from the Army and Army Air Force. Branch offices were also established in a number of locations throughout the United States to access new sources of labor. Private contractors were also increasingly used as the war progressed and the demand for maps outstripped the capacity of the AMS.

The pattern of work changed during the course of the war. In its early stages much of the work consisted of the simple revision of existing maps, including the addition of a grid and some marginal information to make the native maps suitable for English-speaking soldiers. In May 1942 Colonel Herbert B. Loper, chief of the Intelligence Branch in the War Department's Office of the Chief Engineer, and British Brigadier Martin Hotine, Geographical Section, General Staff, negotiated the Loper-Hotine Agreement between the United States and Great Britain under which the AMS assumed full responsibility for mapping North and South America, Australia, New Zealand, Pacific Ocean islands, Netherlands East Indies,

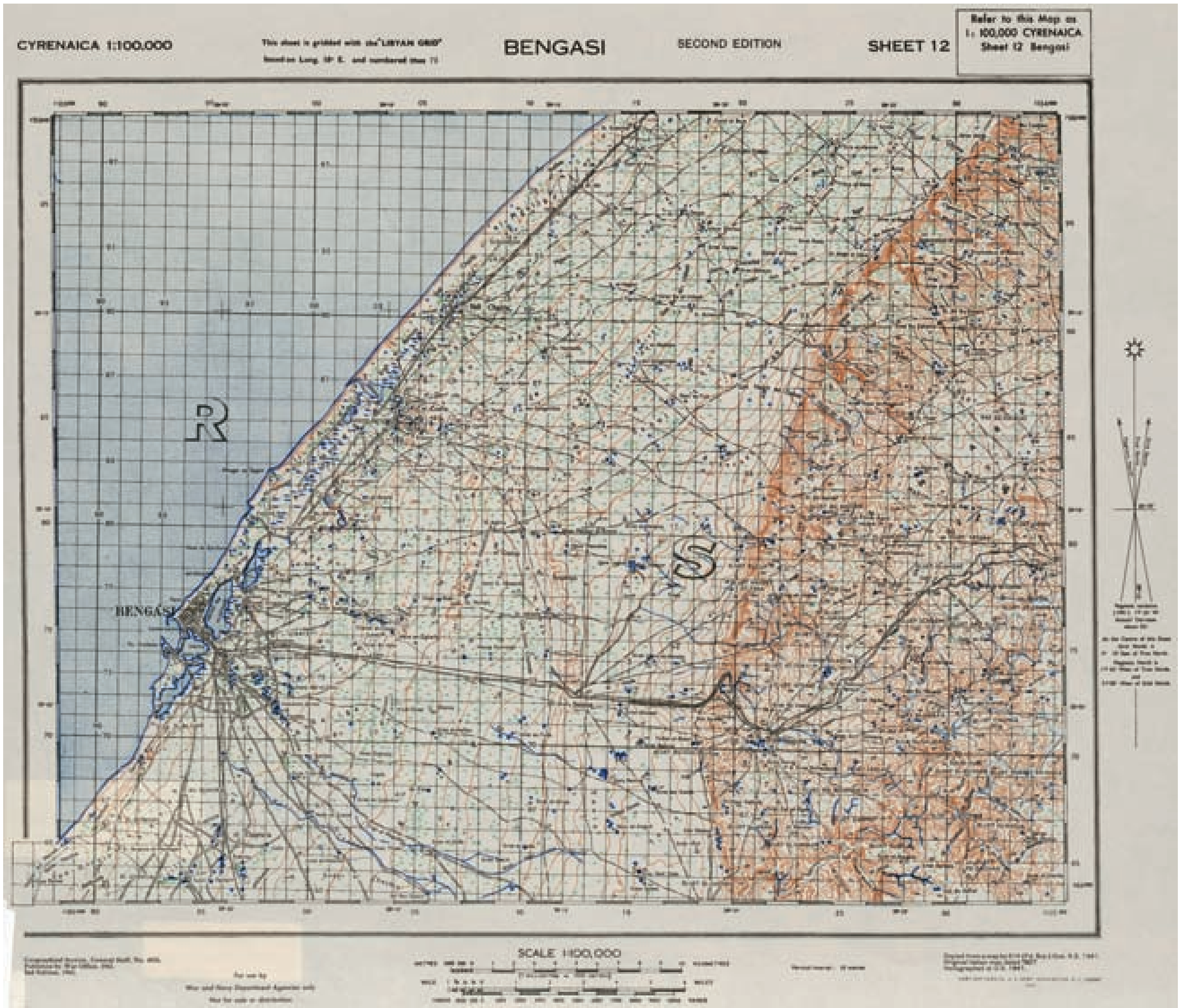

FIG. 533. *BENGASI*, 1:100,000, 2d ED., 1942. Cyrenaica sheet 12, Geographical Section, General Staff, no. 4076, published by the War Office, 1941; Army Map Service, U.S. Army, 1942.

Size of the original: 46.5 × 54.5 cm. Image courtesy of the Perry-Castañeda Library Map Collection, University of Texas Austin.

Japan, West Indies, Iceland, Greenland, and Bermuda (Clough 1952, 43), while the British were responsible for other arenas, including Europe, Africa, South Asia, and Southeast Asia. The British undertook supplying copies of any native maps of areas for which the AMS was responsible and also maps produced by the British of areas where U.S. forces were to be deployed.

By 1943 the nature of the work changed, as new medium- and small-scale maps were compiled from larger-scale native maps. This change meant that improvements in map design could be made and additional material incorporated to make the maps suitable for both strategic purposes and as road maps. Toward the end of the war this trend continued, but there was also an increase in the production of large-scale maps using photogrammetric methods. The AMS had printed nine million maps by the end of the war.

The AMS in Maryland had no photogrammetric capability of its own until the Photogrammetric Division was established in 1945. Earlier in the war instrumental photogrammetric work was contracted out to the USGS and the Tennessee Valley Authority. Some photogrammetric work, such as the photomapping of Jamaica, was contracted out to private companies. Engineer Topographical Battalions deployed overseas were equipped with multiplex equipment and involved in the preparation for campaigns in northwest Europe, Italy, and East Asia. Each U.S. Army division had its own Topographical Battalion, made up of a Battalion Headquarters and Headquarters Company, Company A, which carried out field survey tasks, and Company B, which carried out mapping, including air survey, map production, and printing. Company B was fully equipped with a truck-mounted reproduction plant.

Before the outbreak of the war, the predecessors of the AMS had been involved in a range of research and development. This work was expanded and accelerated during the war to meet the demands of both the AMS and the mobile mapping units. Significant advances were made in the development of reprographic methods for use in the hostile conditions encountered in the southwest Pacific and other theaters. The outcome of the research at the AMS was disseminated through the series *A.M.S. Bulletin*, which first appeared in August 1943.

The global scope of World War II created an unprecedented demand for aeronautical charts at a range of scales. After a series of discussions involving the various potential users, a number of scales were chosen: a world planning series at 1:5,000,000; world weather charts, also at 1:5,000,000; world long-range charts at 1:3,000,000; world pilotage charts at 1:1,000,000 and 1:500,000; approach charts of strategic areas at 1:250,000; and target charts at large scale. In early 1942 authorization was given for production of 1:1,000,000 aeronautical charts covering all land surfaces of the world. However, it was quickly realized that, according to Alfred H. Burton (1953, 39), "an astonishingly high percentage of land areas the world over were not covered by reliable map information." It was decided to implement a program of aerial photography to overcome the lack of existing maps. The trimetrogon system, which used one vertical and two oblique cameras, was adopted to acquire the photography. More than 10,000,000 square miles were photographed over a four-year period and used to compile the maps that served as a base for aeronautical charts.

While the production of base mapping could be subcontracted to other government agencies or approved private contractors, it was believed that the overprinting of aeronautical information should be carried out in-house. After a protracted search for a suitable building and arguments over the number of printing presses required, the Aeronautical Chart Plant was finally activated on 15 June 1943, in St. Louis, Missouri (Burton 1953, 51).

The AMS was reorganized at the end of World War II, with many staff returning to peacetime occupations. However, the General Staff and the Corps of Engineers realized that the need for mapping meant that the AMS needed a program to match the U.S. global role. A program was instituted that would provide adequate maps for all areas of vital interest to the U.S. Armed Forces, replacing map substitute products where necessary and providing map coverage where none existed. There was also an expansion of the program to collect existing map coverage of foreign areas and intelligence data. A new uniform military grid system, the Universal Transverse Mercator (UTM), was adopted to replace more than 100 grids used during World War II. The design of maps was overhauled to meet user requirements, and interservice map standardization was adopted (United States, Army Map Service 1960). These changes did not take place in isolation, as cooperation with the British continued into the postwar era. With the formation of the North Atlantic Treaty Organization (NATO), the changes in map design and the adoption of the UTM grid took on a wider international role.

With the establishment of the Central Intelligence Agency (CIA) in 1947, the United States acquired an additional organization with a responsibility for military mapping, taking over the wartime Cartography Section and Map Intelligence Section of the disbanded Office of Strategic Services (Robinson 1979, 98). The postwar extension of mapping in Central Europe and the Soviet Bloc was, in part, made possible by the work of Floyd W. Hough and his team of specialists who were sent to Europe in October 1944 to collect as much mapping-related material as possible (Cloud 2002). The extensive geodetic data collected by the Hough team was subsequently used in covert mapping programs covering parts of the Soviet Bloc. The team also collected as much German mapping of Central and Eastern Europe as it could, together with any aerial photography. These materials were subsequently used to create mapping of areas behind the Iron Curtain.

In East Asia, captured Japanese maps were copied for use by United States forces acting as military advisors and instructors to the army of the Republic of South Korea. Following the outbreak of the Korean War, these maps were reprinted and revised for use by United Nations forces operating in Korea.

The experience of strategic aerial reconnaissance that the militaries of all sides gained during World War II, and the contribution that this information made in planning military operations, would prove to be of major importance during the Cold War. While aircraft-based aerial reconnaissance had made its debut during the Great War, it was during World War II that it came of age. The Cold War would see an increasing maturation of both aerial reconnaissance and its contribution to military cartography.

President Harry S. Truman sought to pursue a policy of containment of the Soviet Union. This strategy entailed learning as much about Soviet intentions as possible, and such a strategy placed a major emphasis on intelligence gathering. To this end the range of the reconnaissance airplanes operated by the U.S. Air Force was increased still further from those used during World War II. Airplanes such as the Boeing RB-47E Stratojet (fig. 534) had a range of around 4,000 miles, allowing the aircraft to overfly large parts of Soviet and Warsaw Pact territory. The photographs acquired by these new airplanes helped to map potential targets as the United States began to enlarge its stockpile of nuclear weapons following the first Soviet atomic bomb test in 1949.

FIG. 534. BOEING RB-47E STRATOJET. The RB-47E was a photo reconnaissance version of the B-47E bomber and first flew in 1953. Used in the 1950s and early 1960s, they were lengthened by thirty-four inches to add an air-conditioned section for cameras. Their high speed and high altitude extended the range of aerial reconnaissance.
Image courtesy of the National Museum of the U.S. Air Force, Dayton.

An intensive program of mapping put in place by the AMS resulted in coverage at 1:50,000 of the European parts of the Soviet Union together with parts of the Soviet Far East, southern Sakhalin, and the Kuril Islands (fig. 535). The western Soviet Union and the southern border were mapped at 1:250,000, and there was complete coverage at 1:1,000,000 east of 60°E. The British provided 1:1,000,000 mapping of areas west of 60°E (United States, Department of the Army 1963, 198). Similar programs were put in place in other Soviet Bloc countries. For example, in Albania between 1948 and 1954 AMS reprinted Italian large-scale and British medium-scale maps with the addition of a UTM grid and some minor revisions (fig. 536), but by the early 1960s it had compiled several new 1:50,000 maps from aerial photography and had initiated production of a new series at 1:250,000.

Performing reconnaissance flights over the Soviet Union and Warsaw Pact was a dangerous occupation and risked causing political embarrassment. It became clear to the U.S. government that a new aircraft would be needed to take photographs over Soviet Bloc territory while remaining safe from air defenses. The Lockheed U-2, which performed its first flight in August 1955, was designed to meet this need. The U-2 was able to fly at over

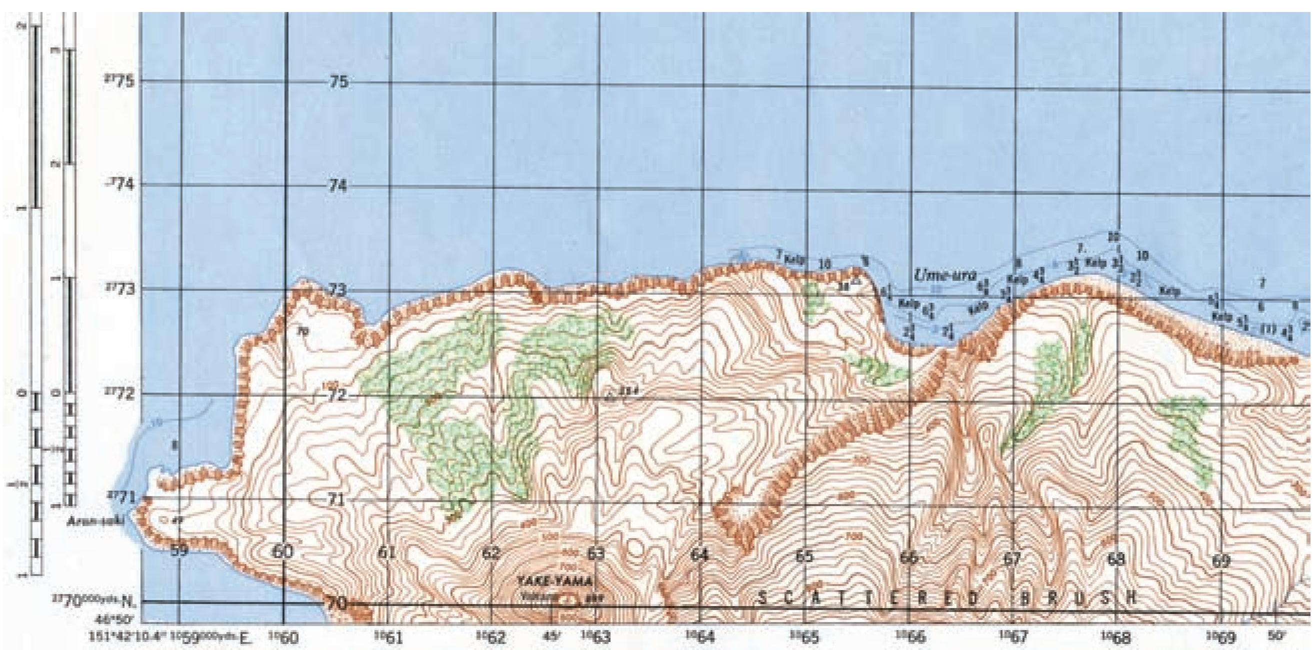

FIG. 535. DETAIL FROM *SHIMUSHIRU-WAN*, KURIL ISLANDS, 1:50,000, 1946. Sheet 8487 I, Washington, D.C.: Army Map Service, U.S. Army.
Size of the entire original: 48.7 × 49.1 cm; size of detail: 11.2 × 22.8 cm. Image courtesy of the Arthur H. Robinson Map Library, University of Wisconsin–Madison.

FIG. 536. DETAIL FROM *TIRANË*, THE BALKANS, 1:250,000, 1948. Sheet G 1, Army Map Service, Corps of Engineers, Department of the Army; originally British Crown Copyright. A portion of the west coast of Albania is shown, the UTM grid is added.

Size of the entire original: 57.8 × 87.7 cm; size of detail: 17.7 × 21.6 cm. Image courtesy of the Arthur H. Robinson Map Library, University of Wisconsin–Madison.

70,000 feet and could reportedly provide two-and-a-half-foot-resolution pictures of the ground from 60,000 feet. However, the U-2s were not to remain invulnerable, and on 1 May 1960 a Soviet SA-2 surface-to-air missile downed the airplane of Francis Gary Powers. Following the resultant political embarrassment, President Dwight D. Eisenhower banned all similar missions. However, it did not prevent the airplane performing other important missions, such as the aerial surveillance over Cuba that led to the Cuban Missile Crisis.

Despite the early successes of the U-2 program it was clear that manned aircraft would not be able to provide the systematic coverage of the Soviet Bloc that a mapping program required or provide all the targeting information. The Corona satellite program was designed to meet those needs (fig. 537). After a number of failures the first pictures were successfully returned to earth in August 1960 (Oder, Fitzpatrick, and Worthman 1988). Corona satellites physically returned their imagery to earth using a capsule ejected from the spacecraft. Imagery from this and subsequent generations of satellites was used by the AMS and the U.S. Air Force Aeronautical Chart and Information Center (USAF-ACIC) to map the Soviet Bloc. To take full advantage of the imagery being captured by satellites and reconnaissance aircraft, a new agency, the National Photographic Interpretation

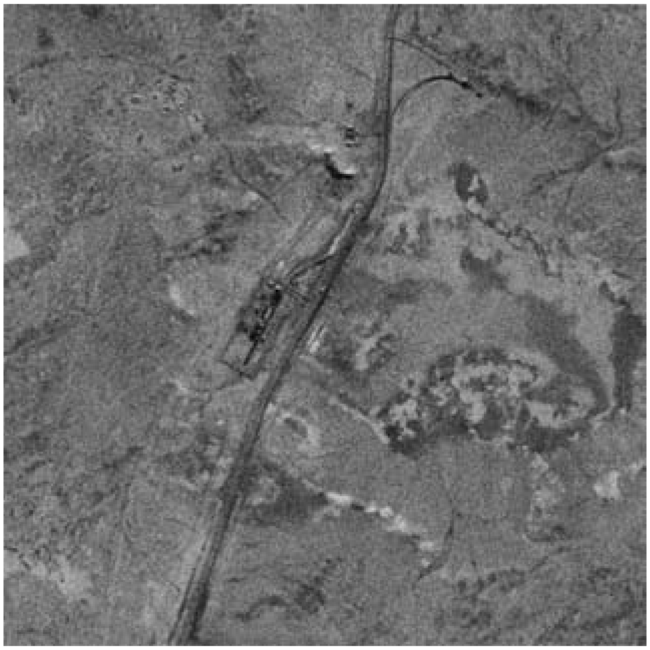

FIG. 537. DETAIL OF CORONA SATELLITE IMAGERY. A road and transportation facilities about twenty miles east of the Aral Sea in Kazakhstan, 7 December 1960. Details like this provided basic intelligence about Soviet infrastructure.
Image courtesy of the USGS Earth Resources Observation and Science Center (EROS).

Center (NPIC), was created in 1961 to perform photographic analysis as part of the CIA's Directorate of Science and Technology.

The U.S. Department of Defense developed the World Geodetic System 1960 (WGS60) as a result of its work to define an ellipsoid of best fit with an earth-centered orientation system. WGS60 replaced the many different reference systems that had been in use and allowed the merging of data from a wide range of sources. Subsequent revisions resulted in WGS84, the system in use at the end of the century and the one used for the Global Positioning System (GPS).

American involvement in military operations in Southeast Asia created a new demand for mapping. In 1954 the AMS had provided charts of the northern Vietnamese city of Hanoi and the southern city of Saigon should the United States intervene militarily in support of the French military forces following their defeat at Dien Bien Phu in northwest Vietnam (then part of French Indochina). By 1963 the surveillance and mapping of Vietnam had enabled the NPIC to identify and chart possible targets and also accurately map known North Vietnamese air defenses. The AMS provided huge quantities of maps to troops on the ground and also recorded the positions of Air-Delivered Seismic Intrusion Detector (ADSID) sensors that had been air-dropped to spot the movement of people and vehicles on the supply routes used by the North Vietnamese army moving into South Vietnamese and Cambodian territory. However, the Vietnam War highlighted shortcomings in coastal charts, which were largely based on cartographic information collected during World War II. By 1966, it was clear that these charts did not give the U.S. Army an accurate depiction of Vietnam's complex systems of river deltas. This resulted in increased efforts by the U.S. Navy Oceanographic Office to revise the relevant charts. The Oceanographic Office was one of several agencies that contributed to reconnaissance and military mapping initiatives during the 1960s; another was the National Reconnaissance Office (NRO). Established in 1960, the NRO was an ultra-secret agency tasked with coordinating the U.S.'s spy satellites.

Many technical innovations in mapping were developed during the Vietnam War including orthophotography. The U.S. Army had used photomaps during World War II, but they were simple monochrome maps derived from photographic mosaics of rectified aerial photographs. During the Vietnam War the AMS started to produce true orthophotomaps as substitutes for conventional line maps (Powell 1972). Conventional line maps took much longer to produce and gave a poor impression of the densely forested areas of South Vietnam. The U.S. Army's Universal Automatic Map Compilation Equipment (UNAMACE) was developed to meet the need for orthophotography, but it could also be used to generate contour plots and digital terrain models (Dowman 1977, 43). New imaging technologies were developed for use during the war, including side-looking airborne radar (SLAR), the forerunner of the airborne and satellite sensing systems in wide use by the end of the century.

In 1972, as U.S. involvement in the Vietnam War was ending, the mapping functions of the AMS, the ACIC, and the charting branch of the U.S. Naval Hydrographical Office were consolidated in a new agency, the Defense Mapping Agency (DMA). In addition to providing maps and charts, the DMA was responsible for providing geodetic and geophysical information for the U.S. intercontinental ballistic missiles (ICBMs) and, starting in 1975, the data for the Terrain Contour Mapping (TERCOM) navigation systems used by cruise missiles. Satellites such as GEOS-3 (Geodetic and Earth Orbiting Satellite-3), which was launched in 1976, played a major role in providing information on the earth's gravitational field.

In 1982 DMA started to implement the Hermann Panel Report, which recommended the development of a modernized production line based on the use of digital data. Prior to the implementation of the Digital Production System (DPS), the DMA was still heavily reliant on film-based source materials and a hybrid of analog and digital processes (Krygiel 1999, 50–52). At the outset of the ten-year development program only 10 percent of the technology required was commercially available. Much of the technology developed to meet the DMA's requirements was subsequently developed to meet commercial demands. Although a major aim of the program was to enhance the integration of data sources, reduce costs, and increase the speed of conventional map production, it was also anticipated that there would be an increased demand for digital production from the armed forces. The DPS was fully operational in November 1992. However, as intelligence specialist Annette J. Krygiel (1999, 67–68) noted, by 1992 the agency had migrated from producing traditional cartographic products toward the provision of geospatial information and service.

The end of the Cold War, marked by the fall of the Berlin Wall in 1989 and the breakup of the Soviet Union in 1991, changed the strategic demands on U.S. forces, but the invasion of Kuwait by Iraqi forces in August 1990 forced a reassessment of how their needs for maps and other geospatial information were to be met in the future. Although a number of new technologies were deployed in large-scale operations for the first time during Operation Desert Shield and Operation Desert Storm, the liberation of Kuwait still generated a tremendous demand for conventional maps. The DMA produced approximately thirty-five million maps during the buildup of forces and was reported to have produced in excess of 110 million maps for service personnel by the end of operations. In addition, digital photogrammetry was widely used to create terrain models for cruise missile attacks on Iraqi targets. GPS was also widely used by coalition forces. Initially, it was thought that Selective Availability, a blurring of spatial resolution, would need to be implemented to prevent Iraqi use of GPS for targeting. As receivers capable of dealing with encrypted GPS signals were in short supply, this would have limited coalition use of GPS. However, it was realized that the Iraqis possessed few GPS receivers, and that it would be possible to issue civilian GPS receivers to coalition forces.

Desert Storm had illustrated military cartographers' continual reliance on aerial photographs, and this helped to prompt a further reorganization of U.S. military mapmaking functions in 1995. Secretary of Defense William Perry along with General John M. Shalikashvili and John M. Deutch, director of the CIA, wrote a joint letter to Congress encouraging the formation of a single Department of Defense mapping agency. In 1996 the new agency, the National Imagery and Mapping Agency (NIMA), was established within the Department of Defense by merging eight predecessor agencies and departments: the DMA, the Central Imagery Office, the Defense Dissemination Program Office, the CIA's NPIC, together with parts of the Defense Airborne Intelligence Office, the Defense Intelligence Agency, the NRO, and the CIA's Directorate of Science and Technology. The aim of the new agency was to provide mapping, charting, imagery, and geospatial information and products to both the armed forces and the government (fig. 538). In some ways this could be seen as turning the clock back to the first decades of the century, before the proliferation of different mapping and image intelligence agencies that grew out of World War II and the Cold War.

NIMA shared the DMA's interest in digitization and proposed replacing paper map production with the use of digitized databases of maps that could be stored and accessed via computer. NIMA also found itself tasked with providing increasing levels of support to civil authorities and other nations. Examples of this work include the provision of geospatial data (maps and overhead imagery produced using pictures taken from space) during the negotiations at Dayton, Ohio, which resulted in the Dayton Accords of December 1995 and helped to end the bitter civil war that had torn apart the former Yugoslavia. NIMA was able to construct three-dimensional models of Balkan terrain for the negotiators that were known as "fly-throughs" because of their ability to virtually fly the viewer across sections of terrain on their computer screens. NIMA mapping products were also used during the negotiations between Peru and Ecuador regarding their disputed border, which was resolved with U.S. arbitration in May 1999 following the signing of a comprehensive peace agreement between the two countries.

Over the course of the century the U.S.'s military mapping capability had grown from being a relatively small and ill-equipped part of the Corps of Engineers to the largest and most powerful mapping agency in the world. In doing so, it also played a major role in bringing about transformations in which geospatial data were collected and used. By the early 1990s it had been transformed from a post–World War II agency built around the mass production of worldwide map coverage into a major producer and user of digital data. The development of digital photogrammetry, GPS, digital mapping, and geographic information systems would all have occurred without the inputs from U.S. military mapping agencies, but the perceived needs of those agencies and budgets available to them meant that those developments happened much sooner than would otherwise have been the case.

THOMAS WITHINGTON

SEE ALSO: Aeronautical Chart; Cold War; Coordinate Systems; Digital Worldwide Mapping Projects; International Civil Aviation Organization; Military Mapping of Geographic Areas; Projections:

FIG. 538. OPERATIONAL NAVIGATION CHART, STRAIT OF HORMUZ, 1:1,000,000, 1995. Prepared and published by the Defense Mapping Agency Aerospace Center, St. Louis, Missouri; reprinted by NIMA in 2002.

Size of the original: 110 × 151.2 cm. Image courtesy of the Perry-Castañeda Library Map Collection, University of Texas Austin.

Projections Used for Military Grids; U.S. Intelligence Community, Mapping by the

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Military Mapping by the North Atlantic Treaty Organization (NATO). NATO came into being in 1949 to counter the threat of further westward expansion of the Soviet Bloc. Within NATO, individual member nations contribute defense forces to geographically defined NATO major subordinate commands, principally AFNORTH, AFCENT, and AFSOUTH. In return, member nations enjoy the collective protection of NATO, which pledges that "an armed attack against one or more [member country] shall be considered an attack against them all" (North Atlantic Treaty, art. 5).

The many challenges to interoperability in multinational defense organizations apply to geographic products as well as equipment. Geographic interoperability was achieved under NATO Geographic Policy. This defined the areas in which standard geographic products would be produced by nations at various standard scales. Principally the series were Operational Navigation Charts (ONC) at 1:1,000,000; Tactical Pilotage Charts (TPC) at 1:500,000 and Series 1501(A) at 1:250,000 for aeronautical charts; and Series 1501 at 1:250,000; in addition there were national 1:50,000 topographic maps and town plans at various scales. It also defined the nation responsible for the production of each sheet. In the case of the joint series small-scale aeronautical charts, production was mainly undertaken by the United States and the United Kingdom. With certain exceptions, reproduction material and stocks were freely exchanged between nations. Each main subordinate command had defined geographic areas for which reserve stocks of maps were held.

While NATO was a defensive alliance, it was recognized that in the event of conflict with the Soviet Union and its Warsaw Pact allies, NATO forces might need to operate in the territory of Pact members. To that end, maps of Pact countries were also produced to NATO standards. Thus the 1:50,000 mapping of East Germany (series M745) produced by the United States complemented but was not identical with the M745 mapping produced by West Germany of its own territory.

A notable achievement of NATO Geographic Policy was the early resolution of the plethora of British Military Grids in use over Europe at the end of World War II by the introduction of the Universal Transverse Mercator (UTM) grid on NATO maps and aeronautical charts. GEOREF (World Geographic Referencing System) was also introduced, but its use was mainly limited to aeronautical charts, and it had fallen out of use by the end of the century.

Standardization of the design and content of geographic products was achieved by geographic standardization agreements (STANAGs), which applied to many aspects of map specification including symbolization and marginal languages, even though each nation's topographic products retained a recognizable national style. Examples include STANAG 1022, which covered the design of combat charts, amphibious charts, and combat/landing charts, and STANAG 2019, which laid down the military symbols for land based systems.

NATO did not produce any cartographic products. The role of its geographic staff was purely in the coordination of national efforts. With the move to digital data a Digital Geographic Information Working Group (DGIWG) was established by eleven member nations in 1983 to develop standards and support exchange of digital data between NATO member states. The DGIWG produced the Digital Information Exchange Standard (DIGEST), which drew on standards already developed by, among others, the U.S. National Imagery and Mapping Agency (NIMA). Although the DGIWG was not an official NATO body, its work was recognized by NATO, and NIMA became the official custodian.

For the first forty years of its existence the role of NATO was largely confined to preparing for and deterring possible aggression from the Soviet Union and its Warsaw Pact allies. During that time NATO forces had never been engaged in military action under NATO command. This situation changed as a consequence of the outbreak of ethnic violence in the former Yugoslavia. Following United Nations Security Council Resolution 713 in 1991 there was a growing involvement of NATO forces in the region, initially in monitoring and ultimately in enforcement operations. Mapping produced under NATO agreements was used operationally for the first time with the commitment of 60,000 peacekeepers as part of Operation Joint Endeavor in December 1995. It very quickly became apparent that the mapping was out-of-date and did not meet the needs of the troops being deployed. However, stocks of high-quality and up-to-date Yugoslavian mapping were obtained, and these were quickly modified and reproduced for use by NATO forces (Rigby and Fagg 2009).

THOMAS WITHINGTON

SEE ALSO: Cold War; Coordinate Systems; Military Mapping of Geographic Areas; Projections: Projections Used for Military Grids; Topographic Mapping: Western Europe

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Rigby, Nick, and Andy Fagg. 2009. "The Dayton Peace Agreement and Its Implementation: Operation Joint Endeavour." *Ranger: Journal of the Defence Surveyors' Association* 2:26–32.

Military Mapping by Great Britain. In 1900 Britain was engaged in the Anglo-Boer War, one of a long series of colonial wars that marked the latter half of the nineteenth century. Most of those wars had been fought against poorly equipped and trained enemies, and the superiority of British firepower more than compensated for any lack of geographical knowledge of the territory. The Anglo-Boer War, fought against a highly motivated enemy equipped with modern weapons, clearly demonstrated the price to be paid for poor intelligence. Although there had been some attempt to map areas bordering the Boer Republics, it was too little and too late to make a significant contribution. Consequently, the maps produced for the huge theater of operations

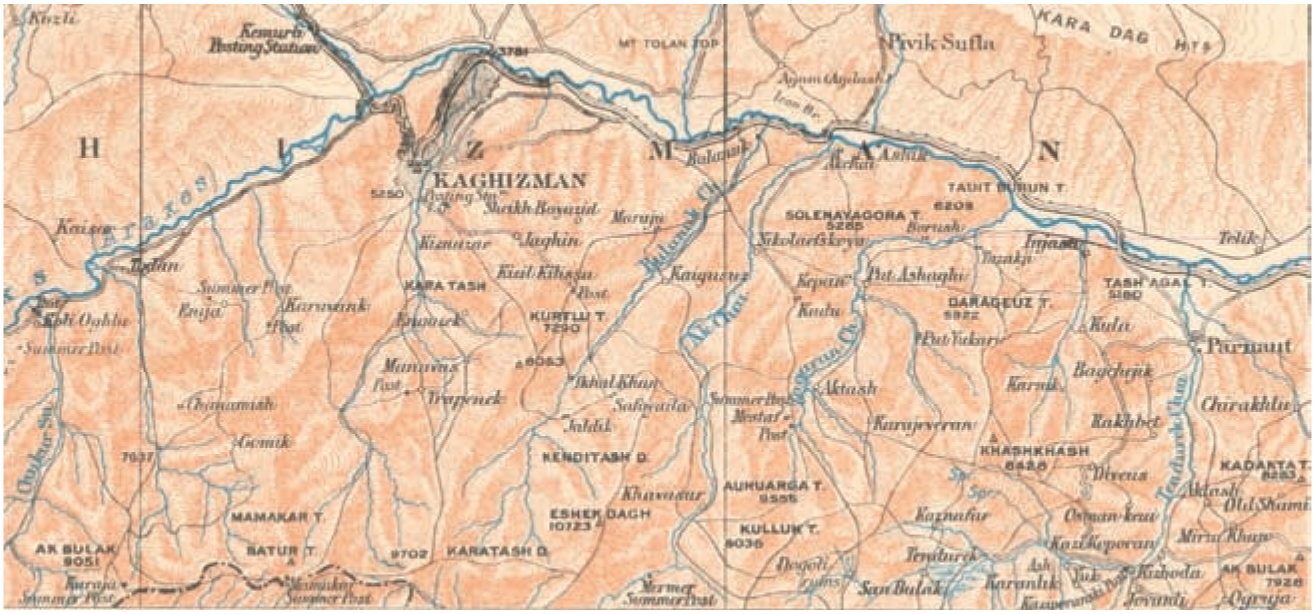

FIG. 539. DETAIL FROM *KARS*, 1:250,000, ADDITION 1920. IDWO 1522, sheet 7. Originally published in 1901, the maps of this series were one of the first British attempts to produce military maps in anticipation of future military needs, in this case to intervene on the side of the Ottoman Empire if attacked by Russia. The maps of this series were almost entirely the work of Francis Richard Maunsell, a colonel in the Royal Artillery, who carried out much of the survey work covertly, while variously posing as an archaeologist or as a military consul.
Size of the entire original: 56.8 × 52.8 cm; size of detail: 8.9 × 19.1 cm. Image courtesy of Peter Collier.

were mainly poor-quality compilations from cadastral and miscellaneous sources.

One result of the problems encountered was the formation in 1904, for the first time in Britain, of a General Staff, and one component of that General Staff was a Topographical Section, which was later renamed the Geographical Section, General Staff (GSGS). The organization was also known as Military Intelligence 4, or more commonly MI-4. In addition, it was recognized that any field force should be supported by survey sections.

The Topographical Section was not an entirely new organization but rather a rebranding of an existing organization that had been in existence since the aftermath of a previous war, in Crimea in the mid-1850s. The department went through a variety of names and organizational structures, ending the nineteenth century as the Intelligence Department of the War Office (IDWO). In 1881 it started to issue numbered maps (Jewitt 1992, xi), in a sequence that was to be maintained for most of the twentieth century. In a real sense, the GSGS numbered series are the history of British military mapping.

The Committee of Imperial Defence, which was established in 1902, carried out a series of reviews of the defenses of overseas territories as well as strategic locations in Great Britain. Mapping for these reviews formed a significant part of the GSGS's work in the period leading up to World War I. The mapping covered not only the fixed defenses around ports and towns but also showed which beaches might be vulnerable to enemy invasion. In 1904 the Colonial Survey Committee was set up under indirect military control to oversee the work of colonial survey departments, in part to ensure that they provided the maps needed for colonial defense (Collier 2006).

As the early GSGS was essentially just a drawing office capable of producing derived maps but ill-equipped to collect original data, the War Office was dependent on the services of other parts of the army, the Ordnance Survey, or colonial survey departments if it wanted to create new mapping (fig. 539). The army had, however, decided in 1892 what kinds of maps it required, at least for use within the United Kingdom. In contrast to the monochrome and hachured maps being produced as General Staff maps on the European mainland, the British Army required colored maps with contours, hachures, road classification, and the use of symbols rather than names to indentify landmarks. Trials of the early sheets revealed that the use of hachures obscured the contours and other detail. In addition, there was a significant increase in cost associated with using hachures, which were subsequently omitted from new mapping

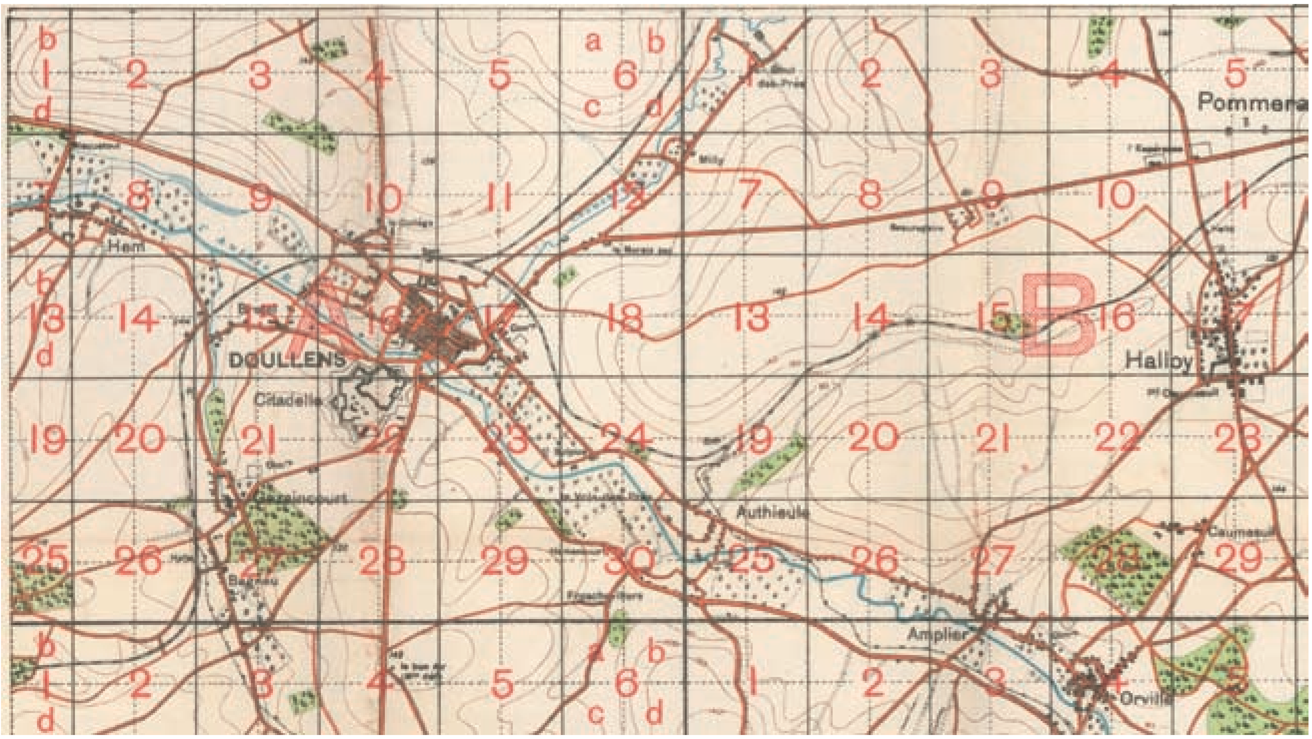

FIG. 540. DETAIL FROM *FRANCE*, 1:40,000, 1915. GSGS 2743, sheet 57D. Map shows the grid system used in World War I.

Size of the original: 58.0 × 84.3 cm; size of detail: 13.6 × 24.4 cm. Image courtesy of Peter Collier.

programs. The first series to benefit from the new clear style of mapping was the half-inch (1:126,720) map of the Orange River Colony produced after the Anglo-Boer War.

In 1902 the appointment of Charles Frederick Close as the chief instructor in surveying at the School of Military Engineering led to a thorough overhaul of the curriculum and the adoption of the methods Close had used in India, including the plane table. The great flexibility that British military surveyors displayed during World War I, and the high quality and utility of the maps they produced were a consequence of the reforms instituted by Close and the experience gained in colonial survey work in the decade before the outbreak of war.

The unprecedented demand for maps generated by the fighting in World War I led to a huge expansion in the numbers engaged in military survey. The British Expeditionary Force deployed to France in August 1914 had no survey component; the three existing Survey Sections remained with the Ordnance Survey although the First Printing Company left for France on 11 August 1914 (Chasseaud 1999, 11). The new static warfare that followed the First Battle of Ypres (October and November 1914) led to the realization that the existing French mapping was inadequate for the new kind of warfare, which required accurate and up-to-date mapping of the British area of the front. Over the next four years the small Survey Sections that carried out this initial work grew into Survey Companies, and finally into Survey Battalions.

With the Ottoman Empire's entry into the war, the conflict spread to the Mediterranean and Middle East. Personnel from the Survey of Egypt were mobilized to meet the needs for mapping in the eastern Mediterranean, while the Survey of India became responsible for mapping in Mesopotamia. After an initial period, during which existing local scales were used, the mapping in the eastern Mediterranean conformed to the standards adopted for the Western Front, namely, maps at 1:40,000, 1:20,000, and 1:10,000 (fig. 540). In Mesopotamia the Survey of India personnel continued to use imperial units for survey measurement and map publication (Collier and Inkpen 2001, 145, 148, 152).

Bulk printing of maps was carried out by the Ordnance Survey in the United Kingdom, by the Survey of Egypt in the eastern Mediterranean, and by the Survey of India for the Mesopotamian campaign. Some map printing capability was available in the field, but this was limited to the production of small-format maps and the overprinting of additional information, such as trench lines, on the bulk-printed base maps.

The end of hostilities in 1919 was followed very quickly by a reduction in military mapmaking. Mobilized staff who returned to their peacetime posts disseminated new ideas about mapping from aerial photography. These ideas were met with greater acceptance in India than in Britain at the Ordnance Survey. Cost-cutting by the British government as it struggled to repay war loans led to a reduction in Ordnance Survey staffing, decreasing its capacity to assist the War Office. A campaign in support of air survey, however, led to the formation of the Air Survey Committee, which was charged with investigating all areas of new technology. Although the director general of the Ordnance Survey served on the Air Survey Committee, it was mainly concerned with techniques that were thought most useful to the army. In the aftermath of the war to end all wars, it was thought that the British Army's main requirement would be maps for colonial campaigns, a future European war being out of the question. This thinking led the committee to favor rapid low-technology methods. The development of radial line methods by Martin Hotine was a direct consequence of this philosophy. Another legacy of the war was the gradual adoption of the British Military Grid, which replaced the Map Square that had been introduced in the late nineteenth century.

In the 1920s the limited capability of the mapping staff attached to the GSGS was mainly engaged in meeting the needs of the army for maps of overseas territories. Mapping of the United Kingdom, including the provision of base maps for military exercises, remained the responsibility of the Ordnance Survey. A number of significant overseas mapping projects were undertaken by the GSGS in the 1920s. The most important of these were the mapping of Hong Kong using aerial photography taken by floatplanes on the HMS *Pegasus* (Nolan 2008) and the mapping of Malta using photography taken by the Royal Air Force. Both of these surveys were carried out at 1:31,680, although intelligence officer Frederick William Winterbotham had expressed a preference for surveys at 1:20,000 (Nolan 2008), a scale widely used during World War I. Because of political instability in China, the GSGS had to produce derived mapping of selected parts of the country to support an anticipated intervention. This delayed work on the Hong Kong map, which was in the process of being compiled within the GSGS. A similar scheme to replace an old survey of Cyprus, undertaken by Horatio Herbert Kitchener in the late 1870s and early 1880s, with a map based on aerial survey was initiated in the 1930s but not completed due to the growing threat of war and the need to deploy resources elsewhere.

The early 1930s were characterized within the GSGS by the need to provide mapping of overseas territories to meet future threats and the need to produce mapping of the latest international trouble spots. Malcolm MacLeod's tenure as head of the GSGS from 1929 to 1935 led to one significant change, the adoption of standard scales for military operations: 1:250,000 for strategic use, 1:50,000 for mobile operations, and 1:25,000 for the battlefield (Hodson 2008). MacLeod's experience in World War I and his time as head of survey instruction at the artillery school had led him to conclude that 1:25,000 was the optimal scale for operations using artillery support. Thus in December 1930 a new series at this scale was introduced for the United Kingdom and Eire as the GSGS 3906. When MacLeod took over as director general of the Ordnance Survey in 1935, among the changes he initiated was the introduction of a new map at 1:25,000 for the United Kingdom, thus relieving the overstretched staff in the GSGS of the need to carry out the compilation work.

In 1931 the formation of the Nineteenth Field Survey Company was authorized as part of the Survey Battalion to provide experience in map production in support of maneuvers and exercises. This was the initial step in developing the concept of mobile map production in the field, including the design and development of mobile trucks equipped with cartographic and reprographic facilities. These were subsequently deployed to France following the outbreak of World War II, but all the equipment was lost or destroyed at the Battle of Dunkirk in May–June 1940.

Preparations for a future war in Europe started in spring 1936 and included the start of a new map at 1:50,000 covering northeast France and Belgium, but because the staffing level in the GSGS was totally inadequate to carry out the extensive mapping program, most of the work was allocated to the Ordnance Survey (Clough 1952, 2). Although staffing levels were subsequently increased, in early 1939 the section still had only about seventy staff.

At the outbreak of war the GSGS had a very limited map printing capability. It operated just three flatbed presses and one twenty-inch camera, and all bulk stocks of maps were printed by the Ordnance Survey. Following the Munich crisis in 1938, the War Office had identified five lithographic printing companies that could be used if required. On the outbreak of war these five companies were given orders and additional companies were identified. By war's end thirty-five companies had been used, printing approximately 148,640,000 maps. The Ordnance Survey was responsible for printing another 193,775,000 maps (Clough 1952, 554). While happy to rely on the Ordnance Survey and civilian companies to provide for much of its needs, the GSGS also required its own printing where, in the words of map historian and former army officer A. B. Clough (1952, 549), "speed of output or high security were necessary." This led to the establishment of a fully equipped Survey Production Centre with four single-color and seven two-color offset lithographic printing presses. This enhanced printing capacity was to be retained after the war.

Following the outbreak of World War II in September 1939 survey units were deployed to France to support the British Expeditionary Force. Bulk stocks of maps were printed by the Ordnance Survey, but reprographic material was also taken to France to permit printing there to meet local requirements. The units deployed in France carried out revision of existing maps from aerial photography, with annotated tracings of revisions also sent back to Britain to revise the plates for bulk stock printing. Following the German attack on Britain in May 1940, the survey units were withdrawn to Britain and forced to abandon most of their equipment and map stocks.

On the outbreak of war the Geographical Section was moved from London to Cheltenham, both to free up space at the War Office and to avoid the anticipated bombing. But it soon became apparent that the separation of the section from the operations, intelligence, and planning staff at the War Office and the Air Ministry Map Section in Harrow, West London, created serious difficulties. Despite the critical stage of the war, and the disruption another move would entail, GSGS was moved back to London, to Eastcote, near Harrow. The drawing and printing facilities, however, could not be housed at the Eastcote site and were located several miles away in Hanwell. Failure to recognize that the GSGS needed to be close to the War Office, and that premises capable of housing all the GSGS's functions needed to be identified in advance, was to undermine the efficiency of the GSGS until the end of World War II.

During World War I most bulk map production was carried out at the Ordnance Survey. Survey Sections and Field Survey Companies, ultimately battalions on the Western Front, also produced maps in varying quantities for their Commands in France, the Dardanelles, Egypt/Palestine (also supported by the Survey of Egypt), Macedonia, Mesopotamia, Italy, East Africa, and northern Russia. Bulk map printing for the Western Front was also carried out by the Overseas Branch of the Ordnance Survey in France in 1918. The deployed survey units could print only short runs of maps or overprint base maps supplied by the Ordnance Survey in Britain or the Survey of Egypt. As Clough (1952) notes, experience during and after World War I had shown that all stages of map production needed to be under one basic control. To achieve this it was recognized that production centers needed to be created wherever possible within the zone of conflict. The first of these was established in Egypt in early 1940, about three months before Italy entered the war. The unit deployed, the 512th (Army) Field Survey Company, was equipped to carry out all stages of map production, including printing (figs. 541, 542, and 543). It could also call on the Surveys of Egypt and Palestine to carry out reproduction work on an agency basis.

FIG. 541. BRITISH MILITARY SURVEYORS PLANE TABLING IN THE WESTERN DESERT IN WORLD WAR II. Although aerial photography was by then widely used for mapping behind enemy lines, plane tabling was still used for mapping of British rear areas.
Image courtesy of Defence Surveyors' Association, U.K.

Plans were developed in March 1939 for the establishment of a military survey organization in East Africa (Clough 1952, 141). This organization would draw on personnel from the local survey departments, together with personnel from Southern Rhodesia and South Africa. From June 1940 aerial photography was provided by the South African Air Force. Following the end of hostilities in East Africa, the South Africans were transferred to the Mediterranean, where they played a major role in the mapping program.

With Japan's entry into the war it became necessary to establish a survey organization to provide military mapping of South and Southeast Asia. In the Survey of India, Britain could draw upon an organization with highly proficient surveyors and mapmakers (Clough 1952, 205). Even so, institutional problems had to be

FIG. 542. DETAIL OF A GOINGS MAP OF EGYPT. *Khâlda East*, 1:100,000, 1942 (sheet 8E). Used to show the nature of the surface and its suitability for traffic, this type of mapping was pioneered in North Africa during World War II.
Size of the entire original: 74.0 × 57.4 cm; size of detail: 14.4 × 11.4 cm. Image courtesy of Peter Collier.

overcome in adapting the Survey of India to the needs of the War Office. In addition, the survey had only a limited printing capability, which needed to be increased by importing staff and equipment from Great Britain.

Toward the end of 1941 Colonel Martin Hotine was appointed head of the Geographical Section, a post he held until the end of the war. The growth in the activities of the Geographical Section, and the need for survey to be considered when policy was being decided, resulted in the section becoming a Directorate of the War Office under Hotine, who was promoted to brigadier. The agreement reached by Hotine with Herbert B. Loper, his American counterpart, on the division of labor between the two allies was of immense importance for the provision of mapping during the war and created the model for postwar cooperation.

Most mapping carried out by the British during the war was either direct copying of existing mapping produced by foreign mapping agencies, with just the addition of a military grid and some marginal information, or the compilation of derived maps from foreign maps at a larger scale (figs. 544 and 545). After Dunkirk, the main mapping effort was in the Mediterranean, where Italian and French mapping of the North African coastal zone was adapted for British needs. A program of mapping was also initiated for the eventual reopening of the Western Front. This involved adapting French, Belgian, Dutch, and German material and initiating the Benson Project, which involved mapping the Normandy invasion area at 1:25,000. When suitable aerial photography became available, it was used to revise the copies of foreign maps. In some cases, such as for Operation Husky (the invasion of Sicily) and the subsequent operations in Italy (fig. 546), individual map sheets went through multiple revisions over a very short time.

Within Europe, original mapping was carried out on a significant scale only as part of the preparations for the Allied invasion of northwest Europe in June 1944. The most important of this mapping was the so-called Benson series of 1:25,000 maps covering the whole of northern France and Belgium. The Belgian sheets and some of the French maps were in part derived from local 1:20,000 maps, but even these were heavily revised using aerial photography. Initially, the basic methodology for this mapping was that developed by Hotine in the 1920s (Hotine 1927, 1929) and subsequently codified by John Scarlett Alexander Salt (1933) in what became the standard textbook for military use. The mapping was based on a framework of existing triangulation, which was intensified using minor control plots. The detail was then plotted by radial line methods with contouring based on stereoscopic examination of the images and parallax measurements. After the United States entered the war, American military surveyors brought with them the technique of slotted templates and multiplex, and Canadian surveyors contributed to the effort. Adopted gradually by the British Army, these techniques replaced the more labor-intensive British methods (fig. 547).

Outside of Europe original mapping was carried out in support of operations in North and East Africa, but the level of detail shown on the maps was very low compared with that on European maps, making compilation a much more rapid process. Mapping suitable for military operations was lacking for large parts of Southeast Asia, necessitating either extensive revision of existing maps or entirely new mapping where the existing scales were too small (Clough 1952, 243). In the early years of the war a lack of suitable airplanes and cameras impeded efforts, and a combination of cloud cover and turbulence from April to October 1943 limited the amount of photo coverage that could be obtained even after additional resources became available late in the year. The Survey of India ultimately produced a vast quantity of reprinted or revised basic and medium-scale maps of eastern India, Burma, and Southeast Asia. In addition,

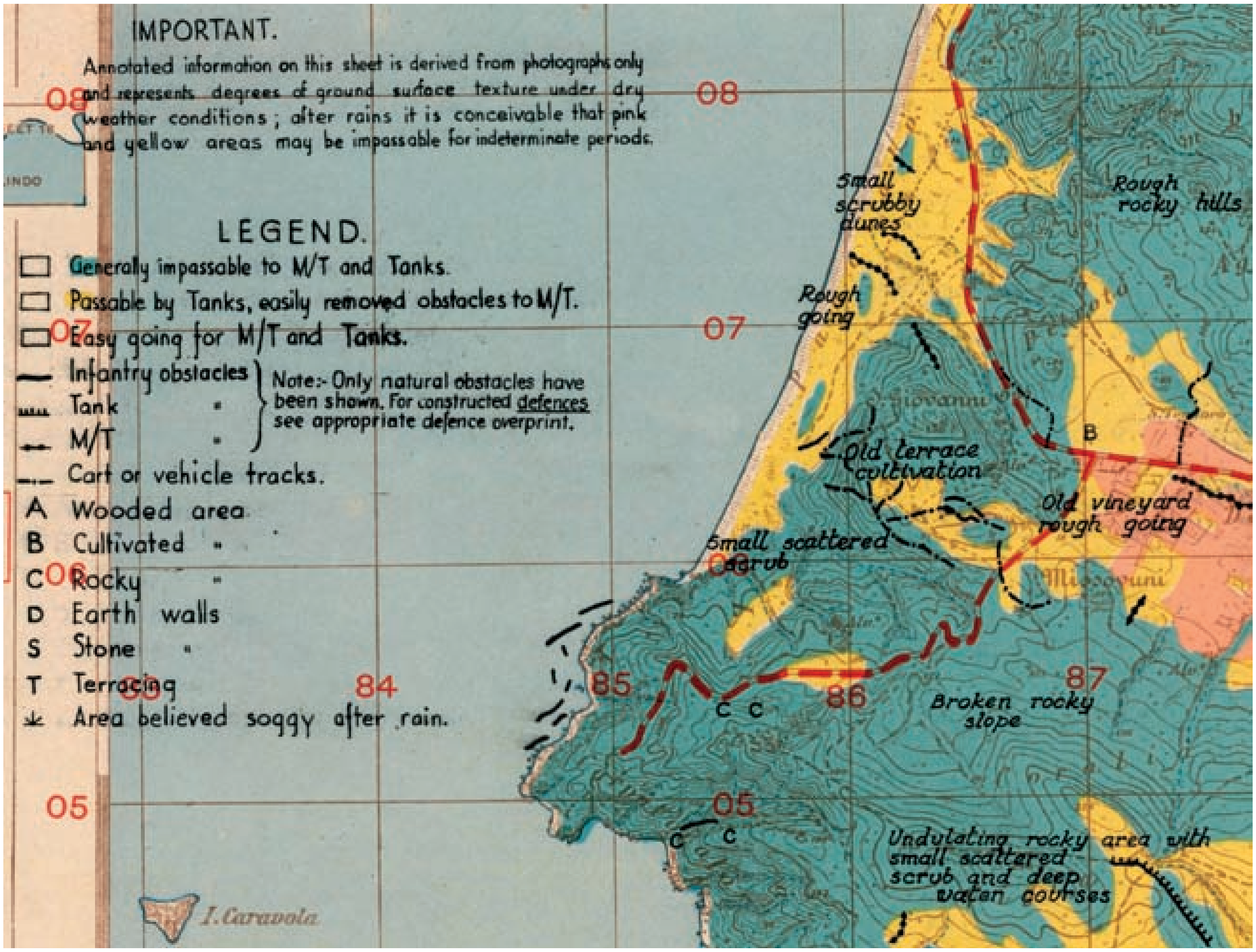

FIG. 543. DETAIL OF A GOINGS MAP OF RHODES. *Cattavia*, 1:25,000, 1943 (sheet 19). The difficult nature of the terrain on Rhodes would have made cross-country movements very difficult. In the event, these maps were not needed for an invasion due to the withdrawal of German forces.
Size of the entire original: 43.9 × 59.7 cm; size of detail: 16.1 × 21.3 cm. Image courtesy of Peter Collier.

1:25,000 mapping was produced for potential invasion areas in southwest Burma and the route of advance of the Fourteenth Army from Assam to Rangoon.

At the end of the war most British military survey personnel were overseas in Europe, North Africa, or Southeast Asia, with the exception of those undergoing training. By this time all production work in Britain was in the hands of civilians employed in the Survey Production Centres. The reduction in staff to a prewar level that took place at the end of World War I did not happen at the end of World War II, nor was there a return to the employment of military surveyors by the Ordnance Survey. As wartime units were disbanded, the remaining field units were concentrated in Germany and Egypt. There were a number of reasons for this. Within Europe the British Army had become an occupation force in Germany and Austria, and those forces needed up-to-date mapping of their occupation zones. There were also substantial British forces still in Egypt and the former Italian colonies in North and East Africa. British forces had very quickly become engaged in military action in Greece, Palestine, the Netherlands East Indies, and subsequently in Malaya as well. There was also a greater recognition of the need for mapping to cope with future demands. The rapid cooling in relations between the Soviet Union and the Western Allies became an important factor in the maintenance of an enhanced mapping capability. It was recognized that the British Army might need maps to defend their sector of Germany and possibly for actions within the Soviet Zone.

Despite the gradual withdrawal from empire following World War II, the eruption of insurgencies and so-called small wars resulted in a number of deployments of military surveyors to trouble spots. The

FIG. 544. TARGET MAP OF WORMS, GERMANY, 1:100,000, 1943. Produced for a night bombing raid on Worms gasworks, the coloring was designed to assist navigation and target identification using the H2S radar bomb sight.

Size of the original: 42.5 × 32.0 cm. Image courtesy of Peter Collier.

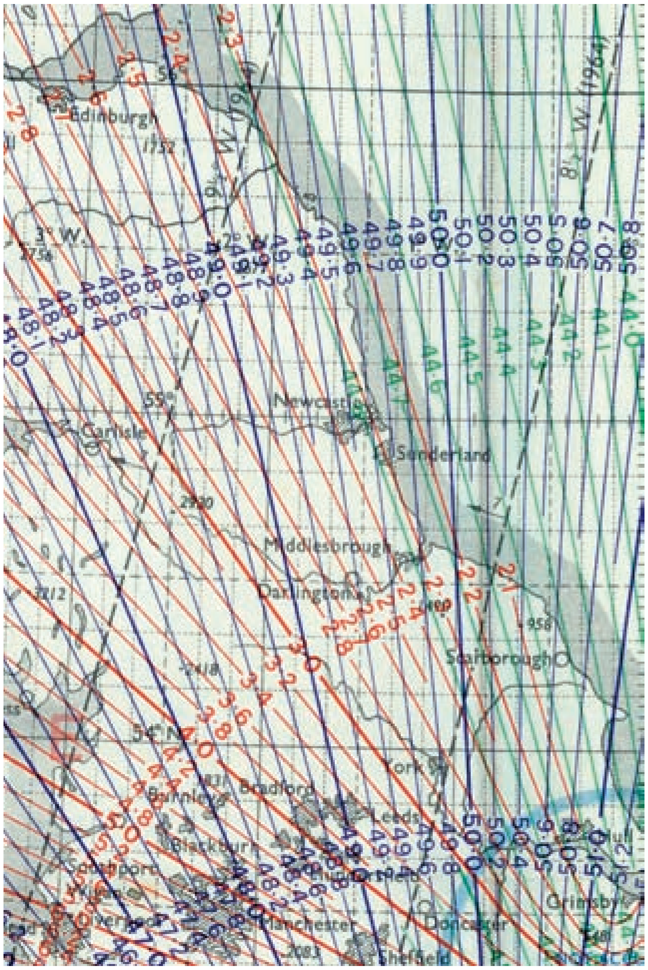

FIG. 545. DETAIL FROM *GEE LATTICE CHART (EASTERN CHAIN)*, 1:2,000,000, 1963. GSGS 4829, sheet 1 (British Isles), Ed. 3. Gee was an early radio navigation system allowing airplanes to fix their position relative to three transmitters. Sets of differently colored parabolic curves define the distances from each transmitter.
Size of the original: 80.5 × 102.5 cm; size of detail: 16.2 × 10.8 cm. Image courtesy of Peter Collier.

Mau Mau uprising in Kenya (1952–60) resulted in the formation of the Eighty-ninth Field Survey Squadron to assist the local survey department in the production of topographic maps. The Eighty-fourth Survey Squadron was deployed in Malaya during the Communist Insurrection (1948–60) to assist in the maintenance and revision of the one-inch and other series of the country. The Indonesia-Malaysia Confrontation in Borneo (1962–66) led to the deployment there of the Eighty-fourth Survey Squadron, which worked alongside other agencies, such as the Directorate of Overseas Surveys, in the production of 1:50,000 topographic maps of Sarawak, Sabah, and Brunei.

The British retained a military mapping capability of some kind in the Middle East until 1967. In Egypt, which had been the main center for mapping in the region, the British withdrawal in 1954 was followed in 1956 by the Anglo-French invasion of the Suez Canal area using military maps based on Survey of Egypt data. This mapping was produced in both the United Kingdom and Zyyi, Cyprus, where the Forty-second Survey Engineer Regiment was based. Further mapping work was carried out in the Middle East, mainly by the Nineteenth Topographic Squadron, which was based successively in Maʿān, Habbaniya, Bahrain, and Oman.

The most long-running overseas military mapping commitment was in support of the British forces in Germany. The Fourteenth Field Survey Squadron and a small base plant facility, the Survey Production Centre BAOR (British Army of the Rhine), were mainly engaged in producing of maps in support of the North Atlantic Treaty Organization (NATO) and the training requirements of British forces. A map printing unit based on six ten-ton trucks with semitrailers provided a mobile print capability until the late 1960s, by which time it had become obsolete. It was replaced by a three-ton Taciprint vehicle, which contained a press able to meet the needs of division-sized units.

The development of a digital approach to map production started in the 1960s and gained momentum during the 1970s. However, this was a digital mapping system designed to improve the supply of paper maps, not to provide digital data sets to users. The chief advantages were seen to be economic, although the development of seamless coverage was also seen as a great benefit as it allowed maps to be centered on points of interest rather than tied to traditional sheet lines. The move to a system designed to produce digital data for users began in the mid-1990s with the adoption of geographic information systems. This adherence to hard copy map delivery meant that the early moving map display fitted to combat airplanes such as the Harrier used images of maps stored on spools of film.

At the time of the Argentine invasion of the Falkland Islands in 1982, the only mapping available was out-of-date topographic maps produced by the Directorate of Overseas Surveys (DOS). It was therefore necessary to derive military maps from this existing coverage while the task force was en route for the Falklands. There were a number of problems with map supply for Operation Corporate, such as differences in grid zones between East Falkland and West Falkland on the 1:250,000 Joint Operations Graphics (JOG) charts, which could have caused confusion insofar as the existing 1:50,000 DOS mapping was all on the same grid (Manterfield and Peaty 2007, 24). Moreover, the British Army had no digital coverage of the Falkland Islands because it had not anticipated the need to intervene in the South Atlantic. It was therefore unable to generate maps centered on particular locations. This meant that the landings in San

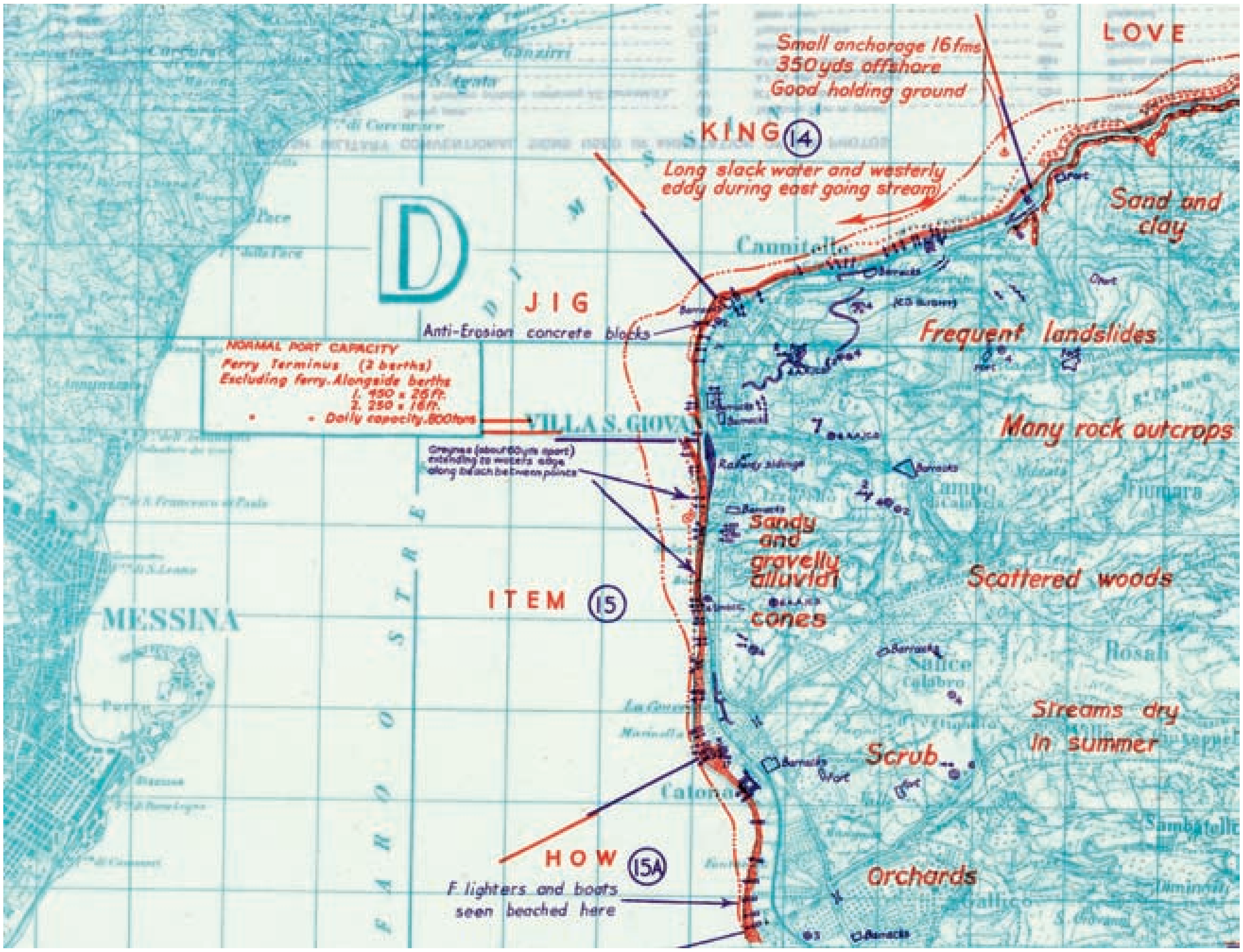

FIG. 546. DETAIL FROM *MESSINA*, 1:50,000, 1943. GSGS 4229, 2d ed., sheet 254-IV. Produced in July 1943 for the Allied invasion of Italy, the map has a topographic and beach overprint in red and a defense overprint in purple, both derived from aerial photography.

Size of the entire original: 43.0 × 55.5 cm; size of detail: 19.9 × 26 cm. Image courtesy of Peter Collier.

Carlos Water were the last actions of the British Army to take place at the junction of four map sheets.

For Operation Granby during the First Gulf War (1991), the British Army refurbished its mobile mapping trucks for use in support of the forces engaged there. However, TACISYS (Tactical Information System), a vehicle-mounted unit that contained a workstation with mapping and image processing software, a large-format scanner, and a large-format printer, had been introduced by the time that the British Army became involved in the Bosnian War (1992–95), in which it gave geographical support to other NATO forces. A separate printing unit was available if large print runs were required. By the end of the century military mapping was entirely digital. No attempt was made to maintain up-to-date mapping of potential trouble spots or to provide bulk-printed stocks of maps. Any British Army unit being deployed would initially be supplied with outline mapping derived from the Digital Chart of the World. This would then be enhanced during the early stages of operations by the addition of detail and contours captured from imagery, the work being carried out in the TACISYS vehicles accompanying the unit.

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SEE ALSO: Coordinate Systems; Military Mapping of Geographic Areas; Ordnance Survey (U.K.); Projections: Projections Used for Military Grids; Topographic Mapping: Western Europe; World War I; World War II

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FIG. 547. SLOTTED TEMPLATES BEING USED IN 1948–49 FOR MAPPING JORDAN. A total of 9,989 templates were used in this survey, which covered Jordan and parts of Saudi Arabia, and was one of the first surveys in which radar fixes were used as part of the control.
Image courtesy of Peter Collier.

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Military Mapping by France. By the beginning of the twentieth century, French military cartography had benefited from a long tradition. The Corps des ingénieurs géographes du Roi, established in the middle of the eighteenth century, had accomplished the mapping of the French territory at various scales. The carte d'État-Major was completed in the nineteenth century, and in 1802 a commission fixed the rules of standardization for the drafting of topographic maps (1:80,000 scale), including the adoption of metric scales. Napoleon expressed a strong desire for a new map of France to replace the one of Cassini (eighteenth century), which by then was regarded as out-of-date.

However the military conditions at the time made it necessary to await the creation of a royal commission in

1817 to start Napoleon's project. The commission decided on a topographic map combined with a general cadastral survey. In 1824, an ordinance established a ground survey at a scale of 1:40,000 to be engraved at 1:80,000 on the Bonne projection using the ellipsoid of the carte d'État-Major. The survey work was completed in 1864, and the compilation, design, and engraving at 1:80,000, in 274 sheets, were achieved in 1875.

Real displeasure with the series appeared soon after the Prussian defeat of the French in 1870–71. During battles in Lorraine and Alsace all the deficiencies of the maps for military uses were revealed. The maps of the territory were insufficient in number, and production did not keep up with the demand of the soldiers serving on the ground, which led to novelist Émile Zola's General Bourgain-Desfeuilles's comment about the theater of Lorraine: "How on earth are we meant to fight in country we don't know?" (Zola 2000, 80). To mitigate the absence of maps, the officers were obliged to take the advice of the inhabitants of the area. More surprising is that the German officers had maps of the territory of much better quality and in sufficient quantity. Consequently, from the year 1870 revolutions both in technology and in military mentalities occurred with military geographic thought reflecting current trends and military cartography improving along with it.

The modernization of cartographic production and institutions clearly began with the creation of the Service géographique de l'armée (SGA), founded by decree on 24 May 1887. The SGA was classified as a special organization and obtained an enhanced capacity for action. It included sections on geodesy, precision surveys, topography, cartography, the construction of relief models, and precise instrumentation. In December 1911, the SGA ceased to belong to the staff of the army and gained new autonomy as an institution within the army. Its missions consisted of survey, execution, publication, and printing of topographic and geographic maps. The SGA constituted a true military institution, which continued throughout the World War I.

During that war combatants had a need for maps at 1:10,000 or 1:20,000 (fig. 548). The effectiveness of

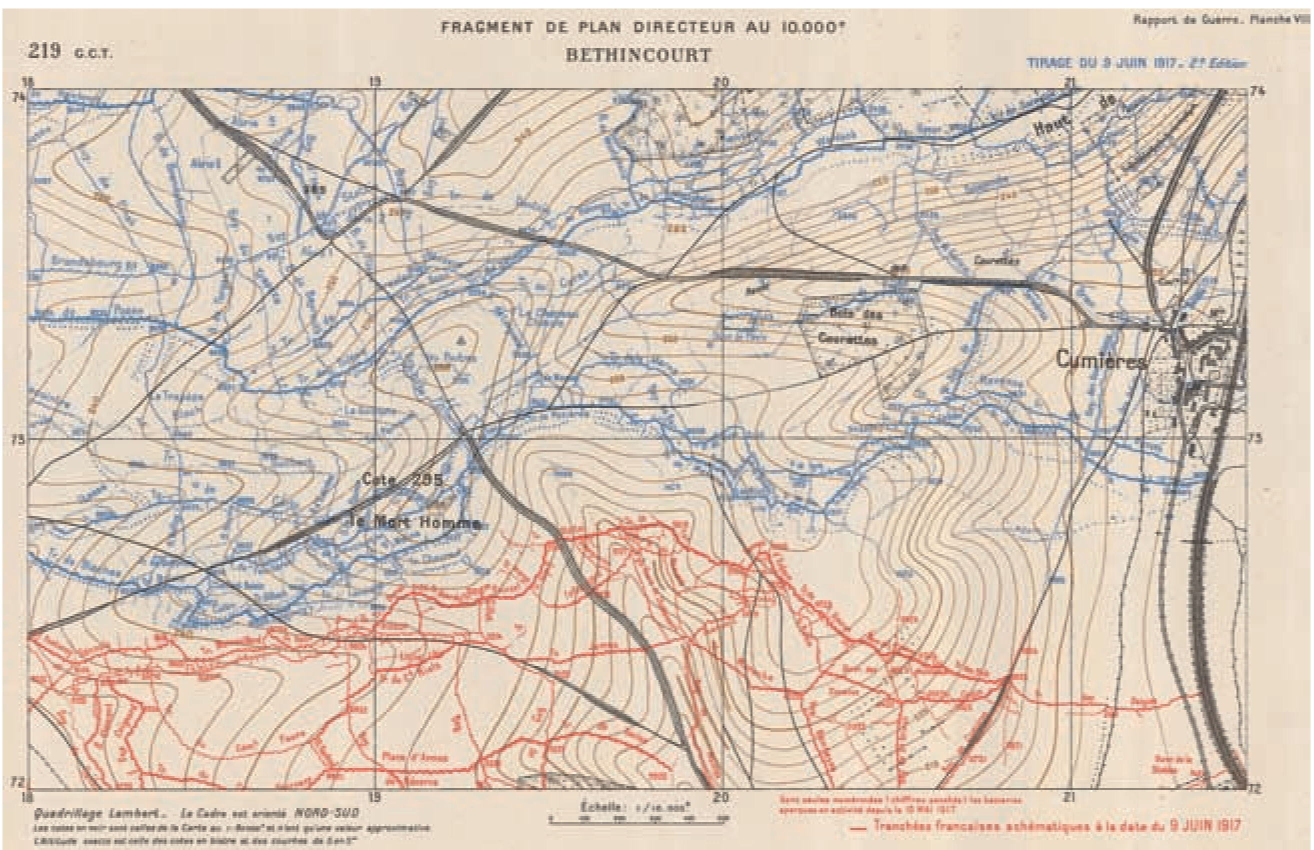

FIG. 548. *FRAGMENT DE PLAN DIRECTEUR AU 10.000e: BETHINCOURTH*, 2d ED., 9 JUNE 1917. This plan is high-precision mapping. It gives the location of all the trenches with a resolution of five meters to one centimeter and illustrates the work of military cartographers. Blue corresponds to German trench lines; red to the French. The Mort Homme sector was one of the bloodiest in Lorraine.

Size of the original: 23.7 × 37.1 cm. Image courtesy of the Cartothèque, Institut géographique national.

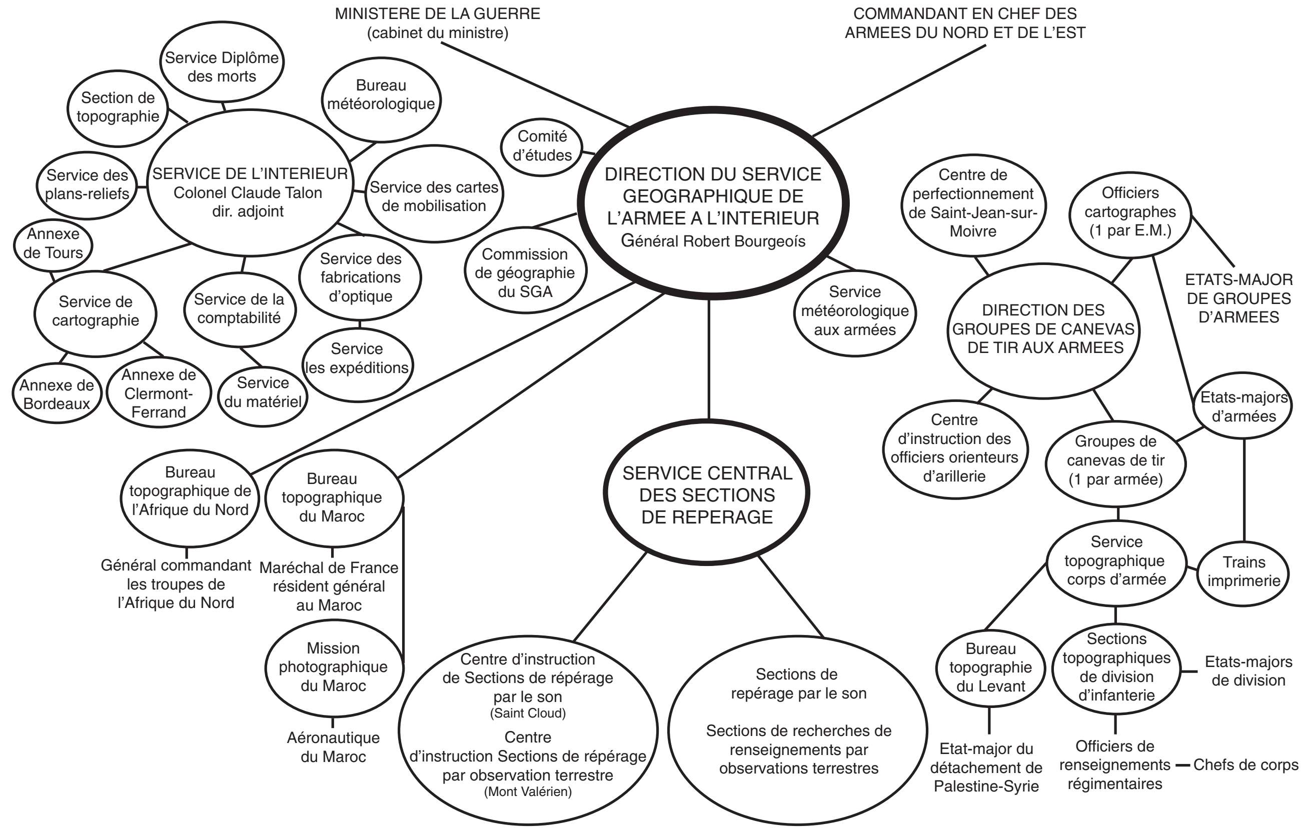

FIG. 549. ORGANIZATION OF THE SERVICE GÉOGRAPHIQUE DE L'ARMÉE IN 1918. Compiled from information in the *Rapport sur les travaux exécutés du 1er août 1914 au 31 décembre 1919: Historique du service géographique de l'armée pendant la guerre* (Paris: Impr. du Service Géographique de l'Armée, 1936).
After Boulanger 2002, 208

the artillery was limited by the absence of a network of points of precisely determined coordinates and a lack of detailed maps of the terrain. To meet those needs, the SGA evolved into a genuine machine of war. Its manpower grew from 300 to more than 9,000 men by the end of the war. Beginning in December 1914, groups of surveyors, composed of members of the topographic sections of the army corps and topographic sections of divisions, surveyed baselines daily at large scales (1:5,000, 1:10,000, 1:20,000 on the Lambert conformal conic projection overlain with a system of rectangular coordinates). By 1918 production reached industrial dimensions, with sixteen million maps at 1:80,000 and 1:50,000, and more than seventeen million baselines surveyed and mapped during the war. Other sections were created: the manufacture of modern optics, centers of instruction for technical training of officers and orientators, determination of location by sound and by flares (fig. 549). A commission of geographers was charged with establishing notes on the various theaters of operations, and survey office annexes were established in most of the metropolises and in Morocco, the Balkans, Italy, Algeria, Beirut, and Mainz. The war supported the emergence of a genuine war machine using the best cartographic technologies of the era (fig. 550) (Villèle, Beylot, and Morgat 2002).

After the armistice of November 1918, the SGA returned to a peacetime rhythm of work. Several reforms followed that decreased its departments and its manpower, but the nature of its functions was no less important. Until the fall of France to German forces in June 1940, work was dominated by the creation of a new map of France at 1:50,000. The idea was old and dated back to the beginning of the nineteenth century. One early test of a map at this scale had been launched in 1900 by the Commission des Travaux de Paris from 1:10,000 surveys of Paris and its fortifications, which circle the periphery of the city. The project was tried again in 1922, making use of technical progress made during World War I. The use of the Lambert conformal conic projection, a rectangular frame of reference coordinates with kilometer spacing of tic marks along the edge of the sheet, the simplification of the representation of elements on the ground (woods, vegetation, build-

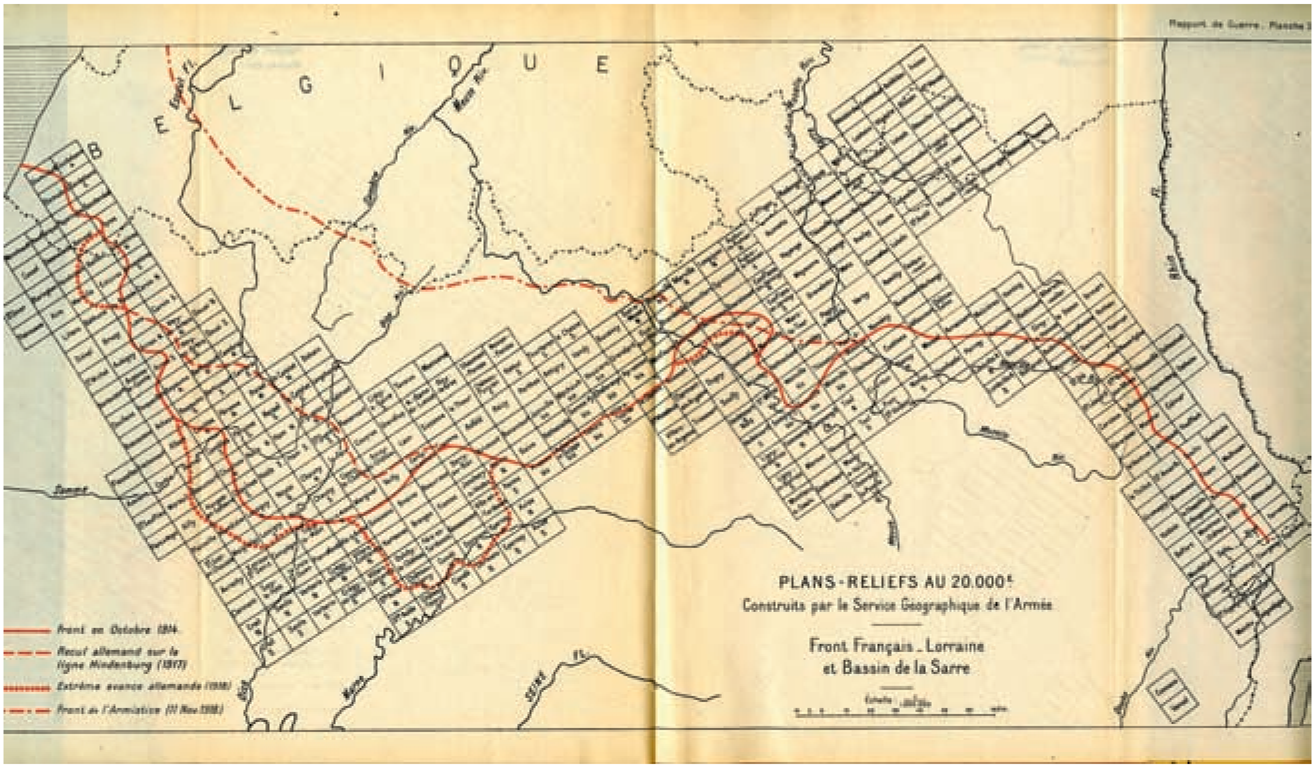

FIG. 550. *PLANS-RELIEFS AU 20.000e: CONSTRUITS PAR LE SERVICE GÉOGRAPHIQUE DE L'ARMÉE.* This map is a representation of SGA's plans during the war. Each map (at 1:20,000) of the front concerns German and Allied sectors. This planning allowed preparation for future major military offensives and shows the important role the SGA played in conducting the war in France.

Size of the original: 25.3 × 43.7 cm. Image courtesy of the Cartothèque, Institut géographique national.

ings), and the use of photogrammetry (generalized after 1934) all contributed to the modernization of military cartography. However, production fell behind, and the 1:50,000 series was far from complete when the hostilities with Germany started in 1939. The basics for a modern cartography were, however, present.

German occupation beginning in 1940 transformed the French military cartographic institution. The SGA was dissolved by a statutory order of 27 June 1940 and was replaced by the Institut géographique national (IGN). The IGN, a civil organization, was placed under the authority of the Ministry of Public Works and consisted of the old SGA in large part. In addition, in the army of Free France, which was reestablished in Italy and moved to France in 1943, new organizations served as cartographic sections, entirely equipped with U.S. materials.

Multiple reforms followed the end of the war (Mathieu 1997, 57). In 1945, cartographic units were established in France, French-occupied Germany, Indochina, and Algeria. In France, the Groupe géographique autonome de Joigny (GGA) was formed on 16 May 1946 (Bonnerue 1992, 165). It was equipped with U.S. materials such as GMC (division of General Motors) trucks uniquely outfitted as workshops for each technical section (drawing, mylaring, photo restitution, copying). Its mission consisted of satisfying the topographic and cartographic needs of the units and staffs, maintaining the stocks of maps, developing and researching the techniques in use, and attending to instruction in connection with the IGN. The GGA was supported by the Centre de documentation géographique from 1952 and was charged as the depository of maps between 1950 and 1977. The cartographic institution was restructured on several occasions. It became successively the Régiment géographique in 1972, the Batterie géographique in 1976, the Groupe géographique in 1979, and the 28e Groupe géographique in 1999. In 2010, this service established its headquarters in Haguenau in Alsace. Its mapping activity for the army is the global production of geographic data. This activity is supplemented by those of the Service hydrographique et océanographique de la Marine nationale and the Bureau géographique: hydrographique, oceanographique, meteorologique (BG HOM; formed by joining two agencies in 2010).

During the Cold War, cartographic production underwent several modifications. The principal one related to a general agreement on the use of techniques, largely inspired by a new model used by the U.S. armed services. Beginning in 1949, the North Atlantic Treaty Organization (NATO) standardized the scales of maps and charts and adopted the use of a single coordinate system, the Universal Transverse Mercator (UTM), based on the conformal transverse Mercator projection. This system made it possible to determine coordinates of points with the same precision anywhere on earth. With respect to French territory, IGN had a mandate to publish coverage at 1:100,000 and 1:250,000. During the 1970s these maps were known as tourist versions. The model of the 1:50,000 map of France continued but was improved with a new version in 1954. Finally, thematic maps, such as the *enfouissement* (buried treasure) map that comprised geological information, were created and used for military purposes. Additional information was added to the civil version of the IGN map for use by the armored units or by the survey engineers charged with managing the terrain.

Other maps produced by the Centre national de la recherche scientifique (CNRS) and the IGN were also used by the military. Botanical charts of France, at the 1:200,000 (vegetation) and 1:20,000 (detailed vegetation groups), were published beginning in 1954. These charts gave information on vegetation and properties of the soil and highlighted more clearly than the topographic maps the diversity of the environment and its qualities. For those reasons, they were directly exploited for military exercises, operational plans for camouflage, and the movement of the infantry and armored tanks. Both the civilian and military methods of production gradually evolved into systems working in parallel. In addition to the traditional methods of surveying on the ground, air photography was used to gather information, and data processing and generalization started to be used in the 1970s.

Military cartography was used in potential and active theaters outside French territory. In the French zone of occupied Germany, maps at 1:50,000 were produced from German sources based on the Service géographique des Troupes d'Occupation en Allemagne (SGTOA). From May 1946, the Batterie géographique d'Extrême-Orient replaced the 1e compagnie topographique du Corps expéditionnaire, created in 1944. It worked directly for the artillery until 1954 in order to provide the coordinates of the points in the zones of intervention, air photography, and maps at 1:25,000 to 1:100,000. This battery was transferred to Oran, Algeria, after the independence of Indochina, under the name 53e Batterie géographique autonome. In 1955, it was renamed the Service géographique de l'Algérie. In the Algerian War (1954–62) this service answered topographic and cartographic requests from the general army for the whole territory and carried out localized work for significant zones of operations. All in all, this period of the Cold War supported new cartographic methods while continuing the heritage of high-level cartographic quality noted during the prewar period. However, the arrival of new communication and information technologies created a revolution in military cartography.

The end of the Cold War, the 1991 Gulf War, and the multiple operations undertaken to maintain peace created deep upheavals in the French army. Until 1991, military cartography was based on providing answers to an identified threat in the European theater of operations. Each river, communication trunk road, and population center was charted and included in a plan of operation against an invasion by the Warsaw Pact. Beginning in 1990, the French army underwent deep reforms and the supporting cartographic institutions had to adapt. However, a clear separation between air-land geography and maritime geography remained. One of the first consequences of those reforms was the amalgamation of all existing cartographic services and programs, about ten services in all. In particular, the Bureau géographique interarmées was tasked with reorganizing the majority of the existing services by the end of the year 2000. In addition to the reforms and consolidation, the geographical origin of the threat was perceived as having changed. It was no longer just the northeast border of France; now the whole world had to be considered.

The 1991 Gulf War also illustrated deficiencies in the military intelligence service. Since then, space applications have come to constitute a priority for military cartography. The launch of the SPOT 5 satellite (Système Probatoire d'Observation de la Terre) in May 2002 by an Ariane 4 rocket, gave France the autonomy of its own imagery source and the capacity to create ground digital models with high stereoscopic resolution. Following SPOT 5, two identical optical satellites, Helios 2A and 2B (France, Belgium, and Spain), were launched in December 2004 and December 2009. They have night infrared capabilities, a resolution of less than one meter, an image capture rate three times as great, and a transmission speed twice that of Helios 1B, launched in 1999. In 2011, all three satellites were still operational. The Helios system was scheduled to be replaced at the end of its life by a European system of reconnaissance satellites, the Multinational Space-based Imaging System (MUSIS). MUSIS would also take over the tasks performed by the German radar reconnaissance satellites SAR-Lupe and Italian COSMO-SkyMed when they reach their end in 2015–17.

New charts in three dimensions are possible with a high degree of locational accuracy. The paper map is not intended to disappear, but the modern manufacturing processes are faster and more flexible. At the beginning of the twenty-first century, for example, the Programme de données numériques géographiques en trois dimensions (DNG3D), a program for digitized geographic data in three dimensions, was conceived for use in weapon systems and for information systems on areas of interest outside the national territory. It also allowed up-to-date information for urgent work or the confidential production of 3-D target models. Cartographic data obtained and used in this way guaranteed a precision strike, the absence of collateral damage, and greater staff safety in the theater of operations. The DNG3D lies within the broad scope of the Multinational Geospatial Co-Production Program (MGCP), which fostered the sharing of cartographic data with other NATO countries. Thus, French military cartography evolved into a new phase anchored in the era of geospatial intelligence.

PHILIPPE BOULANGER

SEE ALSO: Coordinate Systems; Military Mapping of Geographic Areas; Projections: Projections Used for Military Grids; Topographic Mapping: Western Europe; World War I

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Military Mapping by Germany. Prior to World War I military officials in Germany controlled topographical mapping at scales larger than 1:1,000,000. There was no separate military mapping establishment. Prussia was the most important German state, and its General Staff surveying office, the Königlich Preußische Landesaufnahme, headquartered in Berlin, was responsible for mapping most of the country's territory besides Prussia through diverse contracts with smaller states, except Bavaria, Saxony, and Württemberg, which had their own General Staff and survey organizations. The Preußische Landesaufnahme was divided into trigonometry, topography, photogrammetry, and cartography branches; a section for large-scale artillery materials; a colonial section; and a section for dissemination, called Plankammer. From 1880 onward, the main task was to produce the *Karte des Deutschen Reiches* at a scale of 1:100,000. Prussia was responsible for 545 sheets, Bavaria 80 sheets, Saxony 30, and Württemberg 20. From 1877 Prussia also published topographic base maps at 1:25,000, and states not surveyed by Prussia also produced cartography at 1:25,000.

Map coverage of neighboring territory was generally inadequate and consisted largely of reprints of available medium-scale maps. Starting in 1900 the Preußische Landesaufnahme produced general maps such as the *Topographische Übersichtskarte des Deutschen Reiches* (1:200,000), which extended into eastern France; the *Übersichtskarte von Mitteleuropa* (1:300,000), which included large parts of Russia; and the *Operationskarte* (1:800,000), not available commercially, covering all of Europe and extending into western Asia.

The navy's nautical department, located in Berlin, was responsible for marine charting and produced charts with the help of a commercial hydrocartographic institute and seven copperplate engraving firms. In 1914, 508 naval charts were produced, particularly of the North and East Seas, as well as of the coasts of Germany's overseas colonies. The previous year 88,000 prints were sold, and in the decade prior to 1914, 66 percent of all prints went to the naval forces.

Maps of German colonies were produced for the colonial office by the Kolonialkartographisches Institut of Dietrich Reimer Verlag, based in Berlin. Maps for the General Staff were printed infrequently. Examples include a 1:50,000 map of the environs of Windhuk (Windhoek), published after the Herero uprising of 1904–6 in German Southwest Africa, along with the seven sheets published up to 1914 of the planned thirty sheets of a general map of the area at 1:400,000 (Demhardt 2000, 206–13).

Military Mapping during World War I

After mobilization on 1 August 1914, the Preußische Landesaufnahme was disbanded, and its staffers joined the army. Lieutenant General Hermann von Bertrab, chief of the surveying office, became commander of the Thirty-ninth Infantry Division, while operations in Berlin retained only a cartographic division for reprinting and maintaining maps. The assumption that the war would be a short, highly mobile conflict proved false. Trench warfare began in September 1914, and the dearth of maps and survey data became noticeable shortly thereafter. Captured enemy maps partly alleviated the problem, and the army formed field survey squadrons, *Feldvermessungstrupps*, and the air force formed about fifty *Bildauswertetrupps* (picture analysis squadrons). By summer 1915 military officials had a large-scale, albeit cursory, cartography of the Western Front.

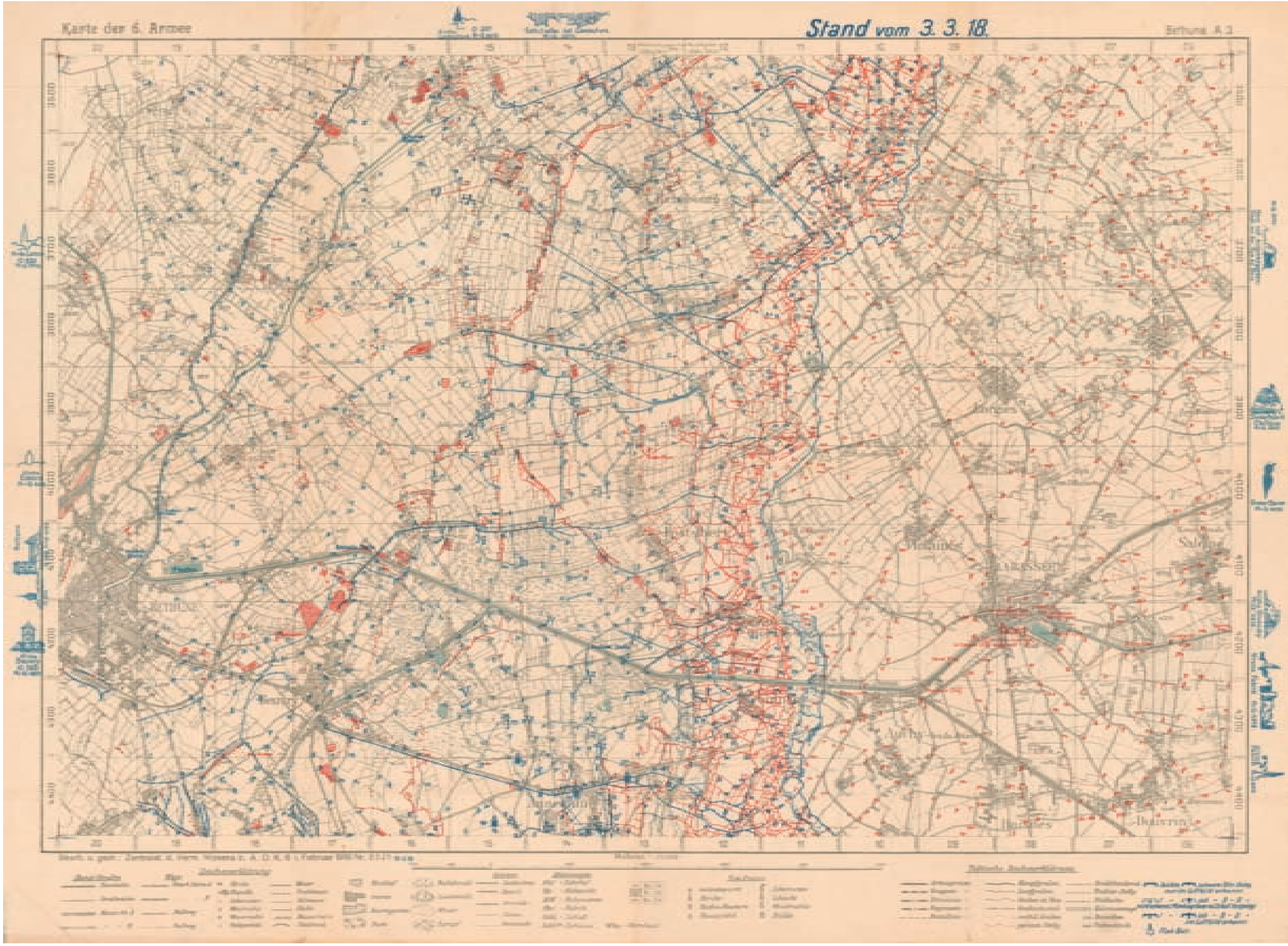

FIG. 551. *BÉTHUNE A3*, TRENCH MAP, 1:25,000, MARCH 1918. The town in northern France was virtually destroyed by German bombardment in May 1918. Size of the original: 47 × 66.5 cm. Image courtesy of Peter Collier.

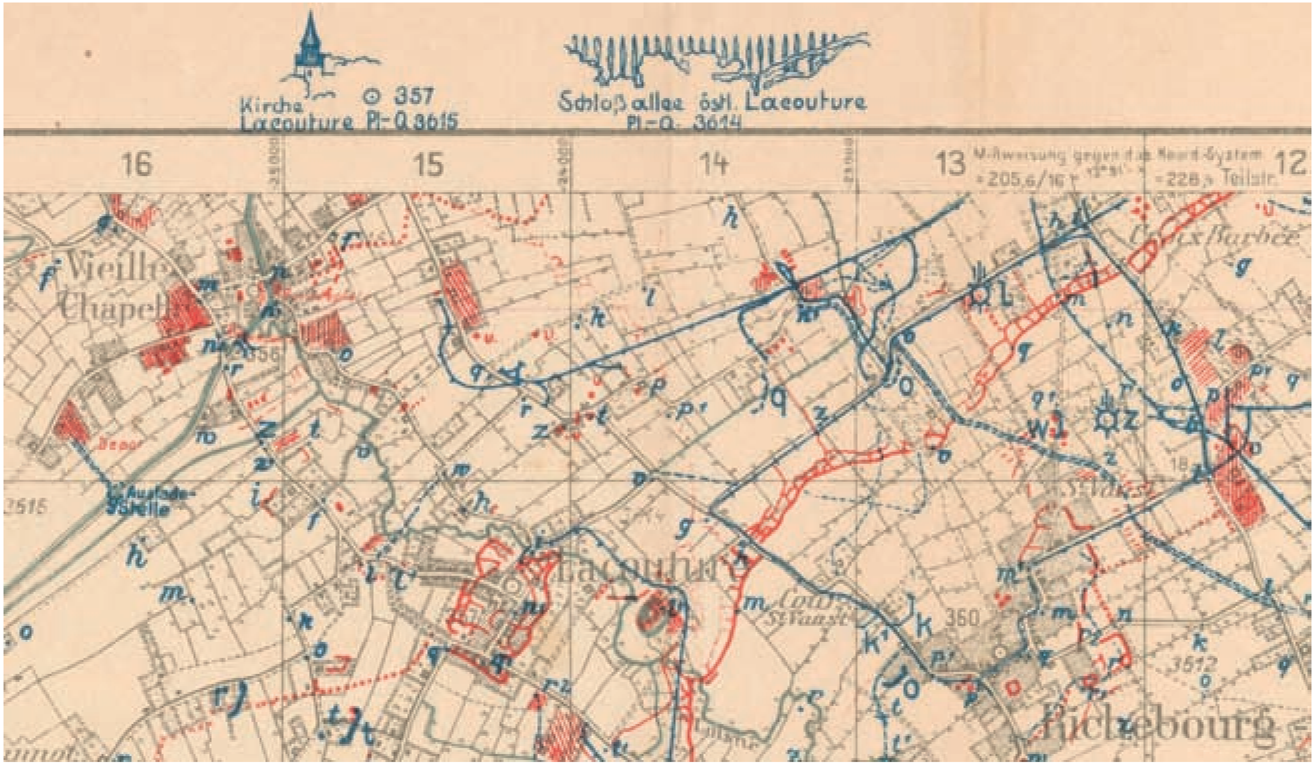

FIG. 552. DETAIL FROM *BÉTHUNE A3*, TRENCH MAP. See figure 551. Image courtesy of Peter Collier.

On 4 July 1915, after it was clear that trench warfare would continue indefinitely, army officials ordered the establishment of the Kriegsvermessungswesen, a war survey division within the General Staff to coordinate terrestrial and aerial mapping, cartography, and map printing; military geology joined its list of responsibilities on 6 September 1916. Major Siegfried Boelcke, who commanded the new division, had belonged to the Preußische Landesaufnahme from 1911 to 1912 and had led an artillery unit once the war began. By the war's end, twenty-nine survey units had been established, each with an average of 300 soldiers and officials. Most had previously worked in the states' survey divisions or were extracted from other parts of the army. Among them were surveyors, graphic artists, lithographers, and printers. Max Eckert, one of Germany's foremost academic cartographers, was placed in charge of an 800-man survey unit on the Western Front. On the Western and Eastern Fronts the survey units mapped artillery within its area, interpreted aerial photography, compiled topographic maps of friendly and enemy positions, and not only printed the maps but delivered them to the battlefield.

Map scales reflected varying needs for detailed or broad coverage. Maps for *Minenwerfer* (literally mine thrower; mortar) and raiding patrols were produced at 1:2,500, trench maps at 1:5,000, and special-purpose maps at 1:10,000. The standardized topographical map of France had a scale of 1:25,000 (figs. 551 and 552). Onto single-color *Leerkarte* (outline maps) friendly positions were printed in blue, enemy positions in red, and occasionally, contour lines were added in green or brown. Maps for planning and coordinating attacks were produced at 1:50,000 (fig. 553); generals were provided with position maps at 1:80,000 (figs. 554, 555, and 556) or 1:100,000; and maps supporting long-distance artillery, the air force, and motor transport were generally at scales of 1:80,000 to 1:100,000.

Timeliness was as important as geometric accuracy. Updated maps showing enemy positions were delivered to the troops by 11 a.m. Generally, maps were printed on stationary lithographic and offset presses. For mobile operations as well as emergencies, nine printing trains with their own locomotives were available. All maps were sufficiently precise in their positional and elevational accuracy to support military planning for short-range combat (using accurate artillery maps at scales of 1:25,000) and for long-range artillery attacks (at 1:100,000), reaching even to Paris by mid-1918.

A five-meter contour interval was used for portraying elevations on 1:25,000 maps. To graphically depict terrain, cartographer and sculptor Karl Wenschow developed relief models and photomechanical shading. Another innovation was a local rectangular coordinate grid based on the Cassini-Soldner projection. Although Ger-

FIG. 553. DETAIL FROM MILITARY GEOLOGY MAP OF DUNKIRK, 1:50,000, 1918. Titled *Kriegsgeologische Karte von Nord-Frankreich*, and labeled *Geheim!* (secret) (title not shown).

Size of the entire original: 58 × 87 cm; size of detail: 43.5 × 63.7 cm. Image courtesy of Peter Collier.

many and its allies agreed in 1917 to use the conformal Gauss-Krüger projection (a form of the ellipsoidal transverse Mercator), this decision did not have a noticeable impact before the war ended. Map coverage was most dense along the 750-kilometer Western Front in northeastern France. By contrast, the Eastern Front in Russia and the Southeastern Front in Romania, Macedonia, Italy, and Palestine were less affected by military action as well as much longer (2,250 km) and more difficult to survey.

After three years of war, the surveying office was reinstated on 29 April 1917, again under the leadership of von Bertrab. The office was now also responsible for occupied territories just beyond the front and for the production and printing of medium- and small-scale war maps, such as the 1:200,000 aeronautical charts and the twenty-sheet *Navigationskarte für Luftfahrzeuge* (1914), which covered large parts of Europe at 1:1,000,000. By 1918, a total of 1,200 officers and 8,000 noncommissioned officers and privates were working on Germany's war cartography. The surveying units had printed more than 500 million maps, most multicolored. The cartographic division of the surveying office had also sent 275 million maps to the front lines. German nautical charting, too, had increased substantially because of the war effort, particularly coverage along Russia's Baltic coast and the North Sea. In April 1919, 664 charts existed. In addition, a large number of charts with different thematic content had been edited or newly drafted to reflect innovations in marine technology such as directional maps for radio signal position determination using gnomic projections and water-level estimation charts for submarines, which had become highly important. Print runs were considerably larger than before 1914, and more than 1 million maps were in circulation after the war.

The Interwar Period

The 11 November 1918 truce almost instantaneously ended German war cartography. The Kriegsvermessungswesen was phased out, and only four surveying units

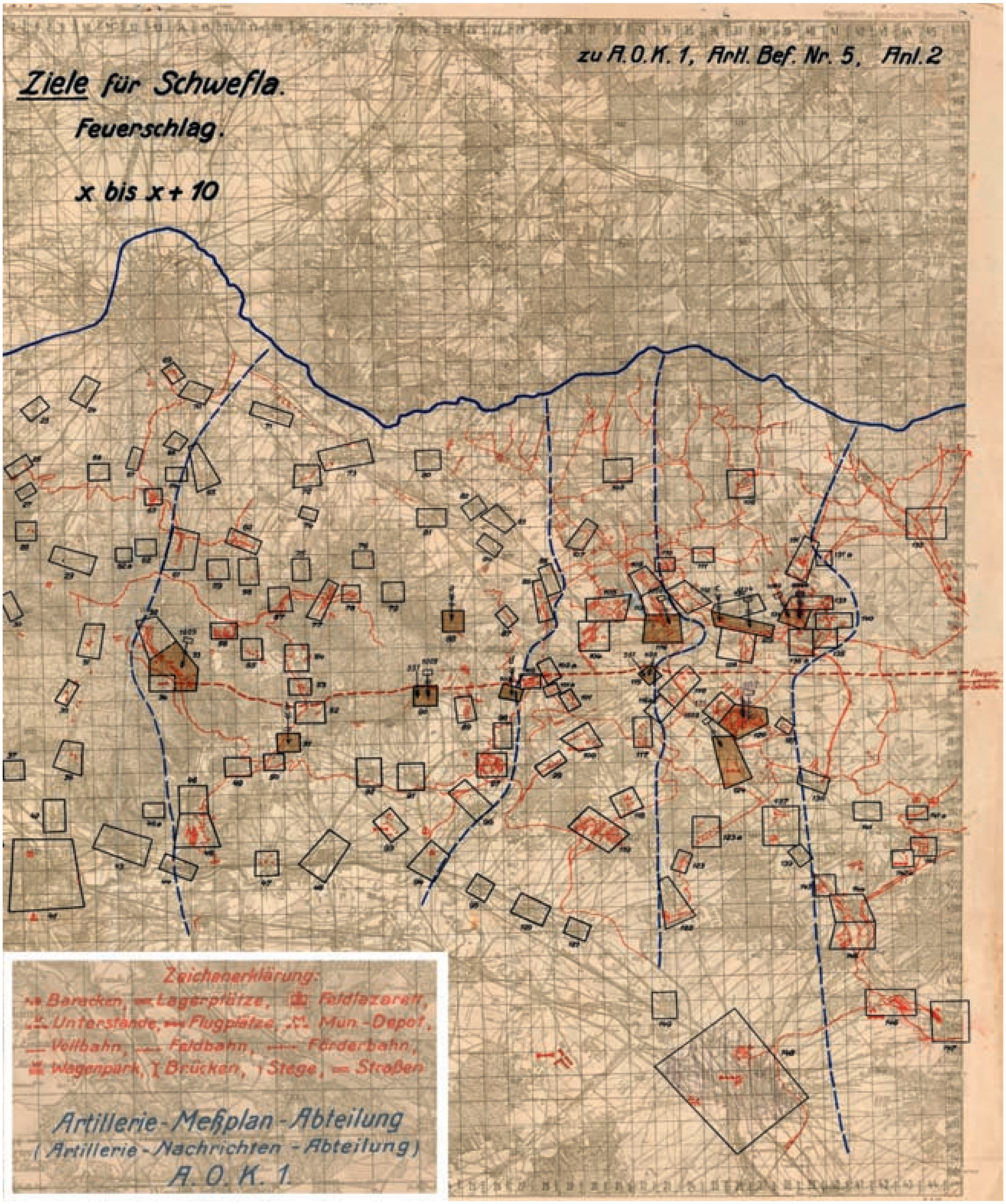

FIG. 554. DETAIL FROM ARTILLERY TARGET MAP FOR AREA AROUND ÉPERNAY, FRANCE, 1:80,000, 1918. Base map dated 18 June 1918 with overprinting (undated). Legend has been inset. Size of the entire original: 62 × 88.5 cm; size of detail: 62 × 52.4 cm. Image courtesy of Peter Collier.

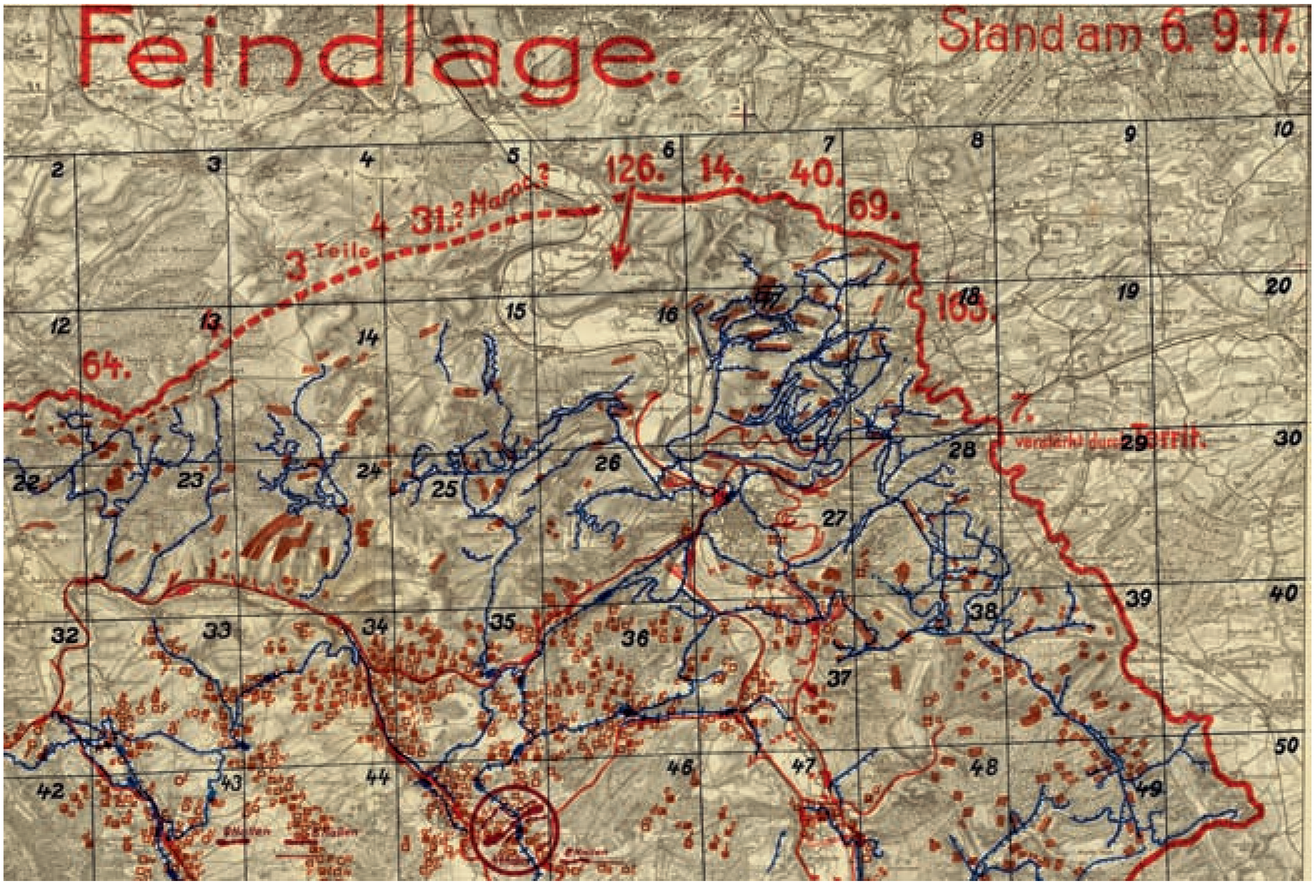

FIG. 555. DETAIL FROM ENEMY POSITION AND REAR ORGANIZATION MAP OF VERDUN AREA, 1:80,000, 6 SEPTEMBER 1917. Note the crude overprinting carried out by a field print unit.

Size of the entire original: 107 × 78 cm; size of detail: 36.5 × 54.4 cm. Image courtesy of Peter Collier.

survived as part of the *vorläufige Reichswehr* (provisional German army), used until the end of 1919 in the skirmishes along the border of the newly reestablished Poland. The Treaty of Versailles (signed 28 June 1919; effective 10 January 1920) stipulated that the General Staffs of the German states and war ministries be dismantled and restricted the army and the navy to 100,000 and 15,000 active members, respectively. The treaty prohibited Germany from having an air force, and it was disbanded in 1920.

Numerical restrictions on military personnel forced surveying and nautical charting into the civilian sector. The Preußische Landesaufnahme was moved to the Interior Ministry on 1 October 1919 and transformed on 11 July 1921 into a German office of topographic surveying, the Reichsamt für Landesaufnahme, which combined the Prussian and Saxon bureaus. Bavaria and Württemberg were accorded independent authority over their topographic surveying. The navy's nautical department was significantly reduced. These changes made the cartographic needs of the land and naval forces the responsibility of the new Ministry of Defense. To facilitate the implementation of military surveying and the provision of tactical maps, railroad maps, fortification maps, and military exercise maps as well as maps of troop movement, a military surveying office, the Heeresvermessungsstelle, was set up on 2 April 1921.

Beginning in 1929, each military district had its own regional surveying unit. While topographic surveying and military surveying were officially distinct, there were close ties between them. The Oberste militärische Vermessungsstelle, founded in 1917 to standardize military and civilian surveying and mapping, had little impact before the end of the war. On 18 November 1919 the minister of the interior appointed von Bertrab a commissioner in charge of reorganizing surveying, and by 1921 an advisory board for surveying was organized to make recommendations for voluntary standardization. At the

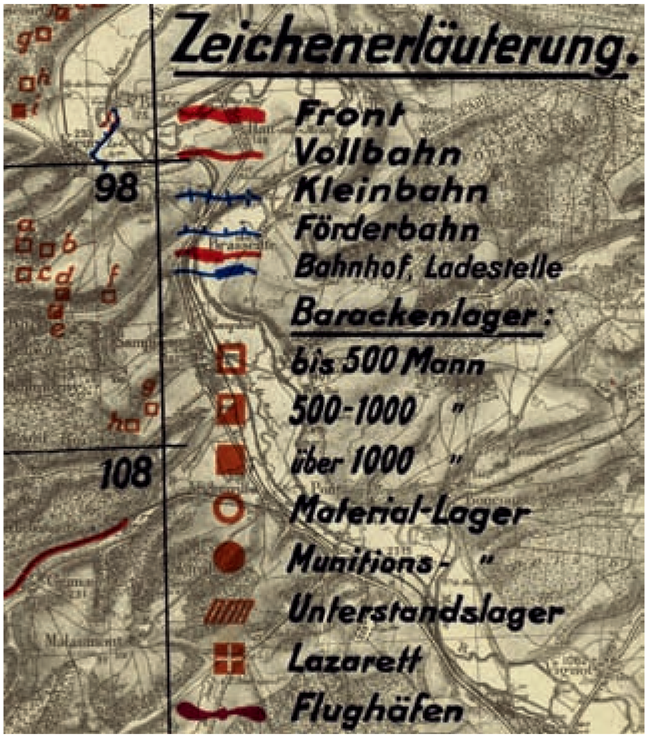

FIG. 556. LEGEND OF MAP OF VERDUN. See figure 555. Size of legend: 16.5 × 14.5 cm. Image courtesy of Peter Collier.

board's first meeting, the Gauss-Krüger projection was accepted for general use at the request of the military. Later on, other military purposes were considered.

Adolf Hitler's appointment as Reich Chancellor on 30 January 1933 changed the nature of mapping and surveying almost completely. With the consolidation of German states by the 3 July 1934 law, surveying and mapping became a national concern. Despite the ban imposed by the Treaty of Versailles, the military had retained a small nucleus of an air force in the central army command, and this group worked on aeronautical charts. After Hitler's takeover, Hermann Göring was put in charge of aviation and soon formed the Reichsluftfahrtministerium with its own department for cartography and aerial imagery.

On 1 March 1935 the German government admitted the existence of its air force, and on 16 March 1935 Hitler decreed the buildup of the military, in direct violation of the Treaty of Versailles. On 1 July the General Staff of the army was formed. Its Ninth Division, dedicated to military mapping and surveying and military geography, was established on 6 October 1936, with Gerlach Hemmerich in charge. Hemmerich, who had worked on topographic surveying in the Ministry of Defense in 1919–20 and later became a banker, was recommissioned as a soldier in 1936. To implement increased map production, the Heeresplankammer, the army map service, was reestablished. The Reichsamt für Landesaufnahme began civil topographic mapping at a scale of 1:50,000, also beyond the borders of the Reich, including maps of France, Poland, southeastern Europe, and Czechoslovakia. To further improve coordination, the Reichsamt established regional surveying departments to expedite topographic surveying assignments as well as provide support, if needed, to defend the homeland. Starting in the fall of 1935, civilian surveying officials took part in large-scale surveying exercises intended to facilitate their service as reserve officers in surveying units in the event of war. During 1937 and 1938, the Reichsamt für Landesaufnahme began to retrain graphic artists. With the annexation of Austria and Czechoslovakia, the Ninth Division expanded to include military institutes from Vienna and Prague. In the Luftwaffe, the air command office became the General Staff of the air force in 1937, formed with divisions for cartography and aerial imagery.

Military Mapping during World War II

In the last week of August 1939 the army was mobilized, reservists were drafted, the Ninth Division became the division for war maps and surveying (Kriegs-Karten- und Vermessungswesen), and motorized mapping and surveying units were formed and assigned to army groups, armies, and divisions. These units, which provided base maps for tactical planning, operated close to the front from 1941 onward and produced 1:100,000 and larger-scale maps, many as annotated reproductions of maps captured from the enemy. German occupation of neighboring countries required the assignment of senior officers of the Kriegs-Karten- und Vermessungswesen to oversee mapping operations outside of Germany, where they supervised German military mapmakers and guaranteed that foreign mapping and surveying activities benefited the German army.

After 1941 the Heeresplankammer in Berlin, which had previously worked on maps for all theaters of war at a variety of scales, focused largely on scales of 1:300,000 (fig. 557) or smaller. These maps were based mainly on foreign maps, including city maps (fig. 558), a small fraction of which had been purchased before the war. The majority came from the occupied military-geographical posts such as Prague, Warsaw, and Paris as well as from enemy maps and lists of coordinates captured on the front lines. An exception was the British maps of Egypt at a scale of 1:50,000, which were available through the Baedeker publishing house in Leipzig. The archives of the Heeresplankammer, which had held 20,000 foreign maps in 1935, grew to 200,000 maps by

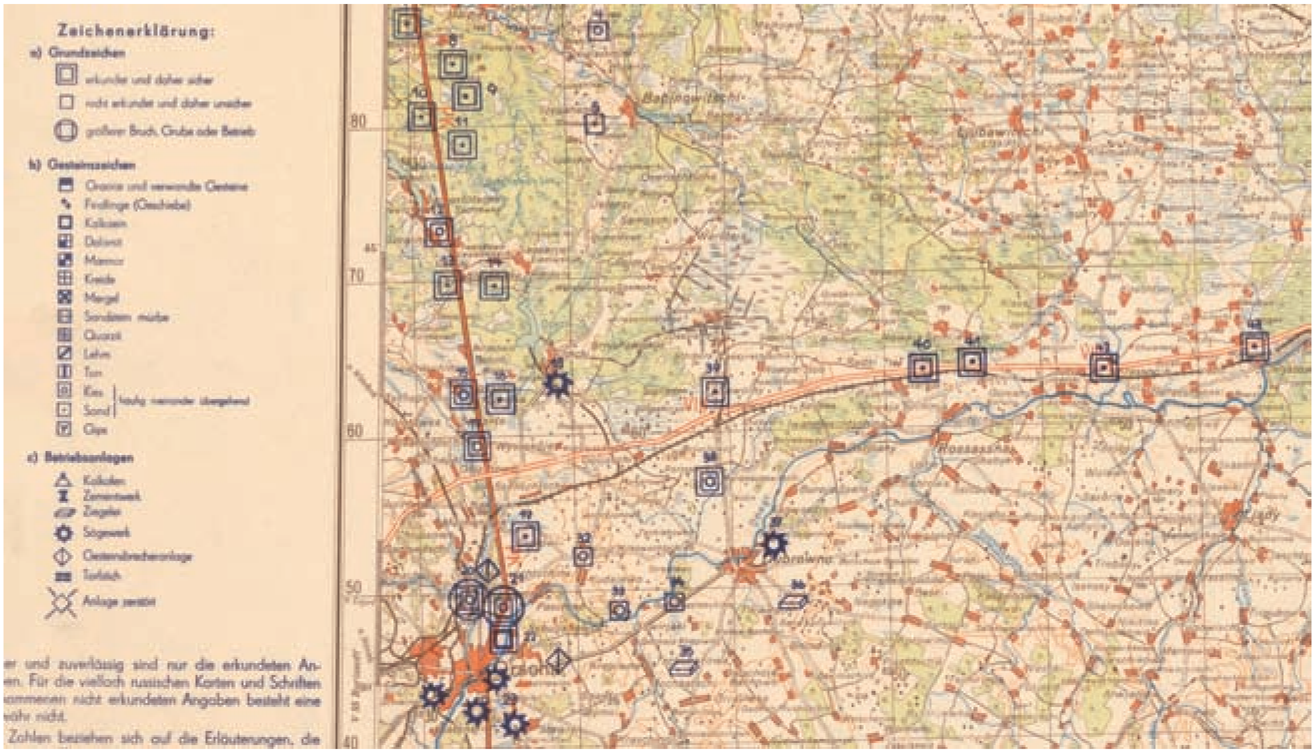

FIG. 557. DETAIL FROM *BAUSTOFFKARTE* (BUILDING MATERIALS MAP), 1:300,000, MARCH 1943. A portion of the legend and area around Orsha, west of Smolensk, Russia, are shown. Deutsche Heereskarte, sheet W 55. Size of the entire original: 48 × 62 cm; size of detail: 15.9 × 27.9 cm. Image courtesy of Peter Collier.

1943. Other sources were aerial photographs furnished by the Luftwaffe and various espionage efforts. The maps were printed by the Heeresplankammer, the Reichsamt für Landesaufnahme, and eighty commercial printing plants scattered throughout Germany. The maps reprinted from foreign originals became "special editions" (fig. 559). Although intended to resemble standard German cartography, the maps exhibited differences due to the time and effort required to provide foreign-language and German keys; Germanized place-names; and scales, symbols, and sheet divisions standardized for military use. A 450-sheet map of the western portion of Eastern Europe at a scale of 1:300,000 was produced from scratch in five months, as was a 1:200,000 map of North Africa.

Map scales ranged from 1:25,000 for a map of the French Atlantic coast to 1:1,000,000 for an operations map based on the International Map of the World. Map corrections were crucial; for example, the 1:100,000 sheet for Alexandria, in the African war theater, was revised five times. To simplify the laborious process of standardizing the different map formats, four scales were generally used: 1:50,000, 1:200,000, 1:500,000 (fig. 560), and 1:1,000,000. These efforts resulted in a tentative European standard. Following Russian practice, the *Deutsches Heeresgitter* (German army grid) was based on the Gauss-Krüger coordinate system, with meridians 6° apart for the zones, and the German military sheet system was based on the International Map of the World. This enabled German cartography on the Eastern Front to copy Russian originals without modification. These innovations also proved useful for Finland, Africa, and central Asia.

Map booklets contained necessary information for surveying and mapping assignments for all European countries and neighboring territories in North Africa and central Asia. Reprinted versions of existing German military maps and other maps, as well as the original maps of the occupied country, provided complete cartographic information, geodetic facts of military relevance, and brief geographic summaries. Additional geodetic data were contained in the reference books of military specifications for military-geographic maps and charts. The *Mitteilungen des Chefs des Kriegs-Karten- und Vermessungswesens*, the *Arbeiten der Heeresvermessung*, and other professional publications were released on a

FIG. 558. LARGE-SCALE *STADTPLAN VON TAGANROG*, 1:5,000, MARCH 1941. Shown here without the numerical legend listing public buildings in the left margin.
Size of the original: 48 × 41 cm. Image courtesy of Peter Collier.

regular basis. To escape air raids on Berlin, which had become more frequent, the Heeresplankammer was moved to Saalfeld, in Thuringia, and other offices were relocated to surrounding regions. In 1944, an expanded Heeresplankammer was renamed the Kriegskartenhauptamt; however, all military-cartographic duties were not consolidated into a single agency. About 15,000 employees worked in the Kriegs-Karten- und Vermessungswesen; of the approximately 1,500 officers almost all were reserve officers. In total, about 1,300,000,000 maps were produced.

In the Luftwaffe, which included the flak batteries, cartography became increasingly important through technological advances such as radar. In 1942, the Luftwaffe added a Seventh General Staff Division, Kartenwesen und Luftgeographie. In 1943, this division was moved to Saalfeld with the Heeresplankammer. It produced various types of maps, including large-scale aerial photographic plans and planning maps, large-format *Zusammendrucke* (combined sheets) of the army map at 1:300,000 with a red overprint of the Luftwaffe's information graticule, the aeronautical chart at 1:500,000 (fig. 561) with photomechanical shading, the air navigational map of Germany on the Mercator projection at 1:1,000,000 and 1:2,000,000, and a three-sheet map of Europe and western Asia at 1:4,000,000 as well as many others. Geographic coordinates helped link the Luftwaffe information graticule with a specialized fighter graticule. Other features described airports, radio navigation facilities, closed areas, and isogonic lines (useful for airplanes equipped with magnetic compasses).

In the navy, the nautical unit was assigned to the nautical division in the naval command office between 1939 and 1941 and was integrated with the Sixth Division of the naval war administration from 1941 to 1945. By 1944, 1,050 nautical charts had been produced. The collection of nautical charts was evacuated from Berlin in 1943–44 and moved to Kaufbeuren in southern Germany. Military intelligence participated in the production of war maps. When Italy joined the German war effort, North Africa became a war theater, and the Deutsches Afrikakorps had to intervene. To ensure geographic and cartographic protection against a possible flank attack from Central Africa, the intelligence office in Münster set up Operation Theodora. Because of more frequent air raids, the command center was soon moved to Rheda, in Westphalia. The fieldwork ("Dora") took place in Africa, while the maps ("Theo") were prepared in Rheda and printed by the Heeresplankammer. Work continued at Rheda even after the African campaign ended in May 1943. In 1944, the navy took charge of Theo, which was responsible for maps used in direct combat, and moved the institution to Raumkoppel/Schönberg near Lübeck. Special maps for combat in Germany were produced on short notice in 1945.

Military Mapping after World War II

Following Germany's unconditional surrender on 8 May 1945, the German armed forces were disbanded and the Allied military forces took over German mapping and surveying in the four occupation zones controlled by the Americans, the British, the French, and the Russians. In these occupation zones, new or old German states were reassembled and given the authority, previously held by the Reich, to officially conduct mapping and surveying through their respective state survey agencies, Landesvermessungsämter. Later, small-scale maps and regional maps at 1:200,000 became the responsibility of the Institut für Angewandte Geodäsie (IfAG), a federal agency based in Frankfurt am Main. The three zones occupied by Western Allies formed the Bundesrepublik Deutschland (BRD, known as West Germany) in 1949, and the Soviet zone became the Deutsche Demokratische

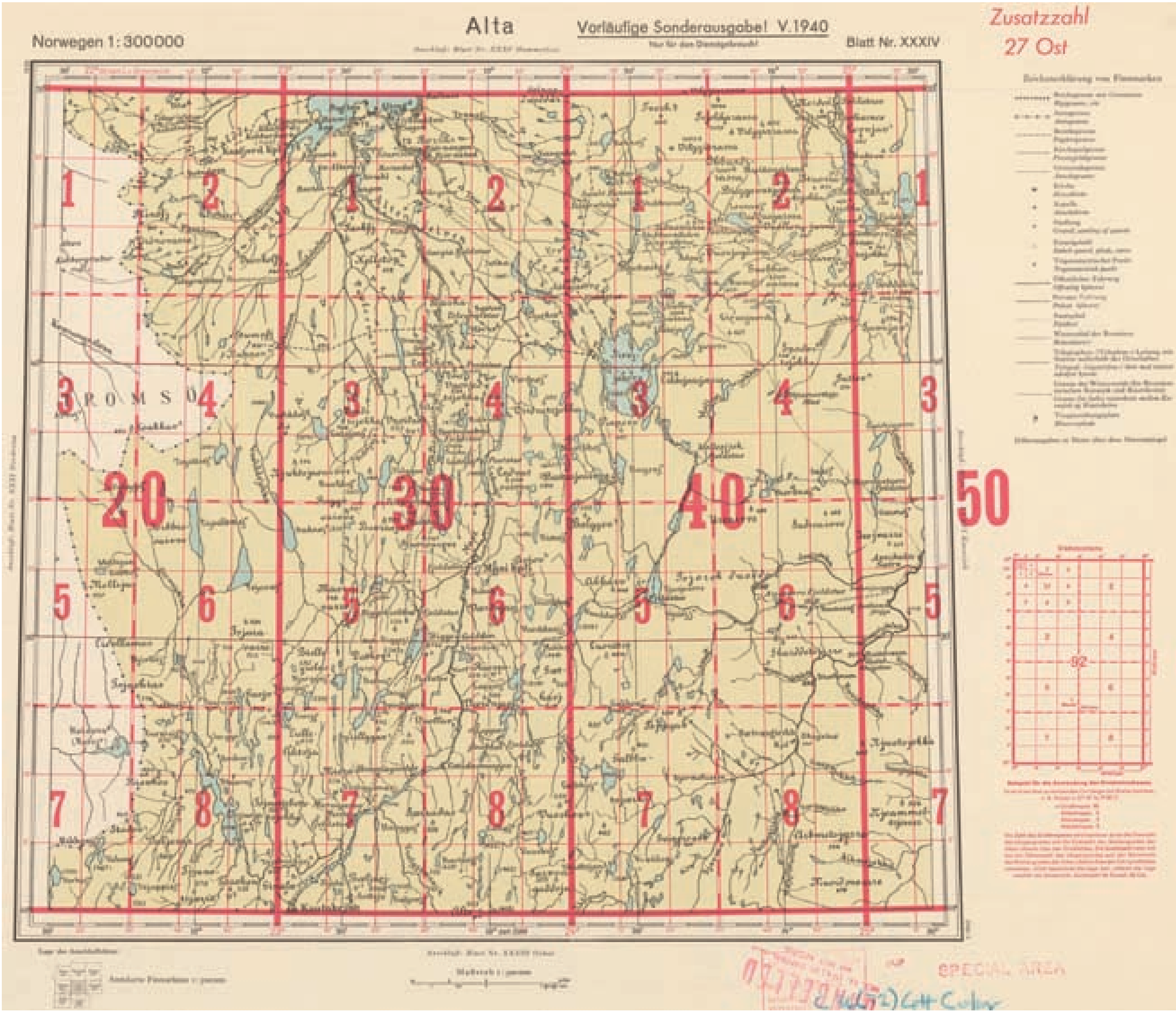

FIG. 559. *ALTA*, NORWAY, 1:300,000, MAY 1940. Sheet 34, "Vorläufige Sonderausgabe" (preliminary special edition), overprinted with military grid. Size of the original: 45 × 53 cm. Image courtesy of Peter Collier.

Republik (DDR, known as East Germany), part of the Soviet Union's Eastern Bloc

Nautical charting was dealt with differently. Because of the need to remove war wreckage and mines, interruption of charting efforts was brief, with the British consolidating existing institutions into the German Maritime Institute, and the office in Kaufbeuren, which miraculously had not suffered any war casualties, became the German Naval Chart Establishment. On 12 December 1945 the Allied Control Council formed the Deutsches Hydrographisches Institut, which was the only institution covering all four occupation zones. With headquarters in Hamburg, the Institut became a federal agency in 1949, independent of the navy, and in 1990 was renamed the Bundesamt für Seeschiffahrt und Hydrographie. Because the Germans were not allowed to fly, aeronautical charting by Germany was suspended. With the gradual reclaiming of sovereign authority, the Bundesanstalt für Flugsicherung was formed in 1953 and charged with producing aeronautical charts.

In 1954, West Germany reinstated its military and joined the North Atlantic Treaty Organization (NATO). As a result of treaty negotiations with three Western Allies in 1955, Germany regained jurisdiction for military mapping, based on NATO directives and specifications. The Bundeswehr established an integrated military-

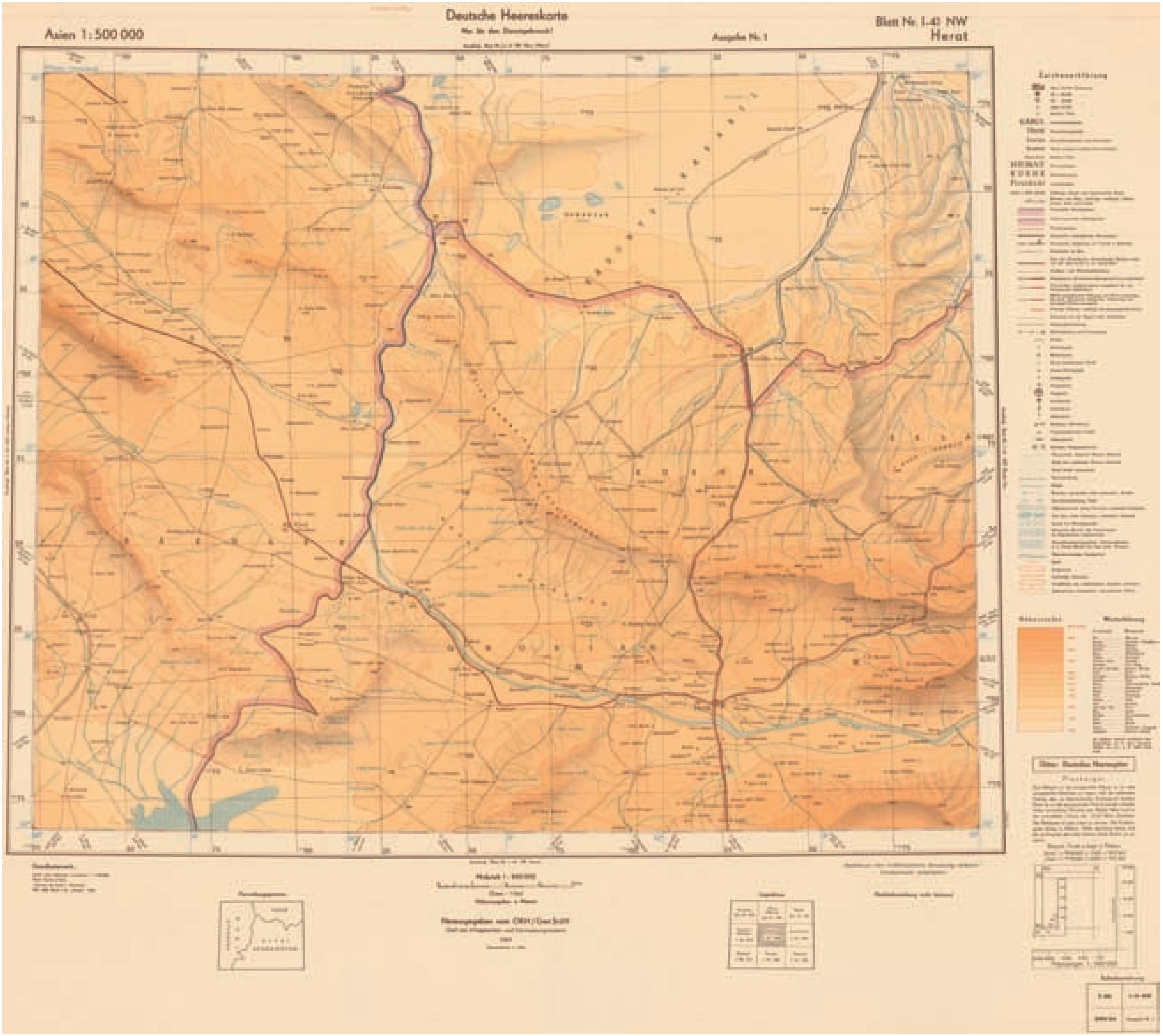

FIG. 560. HERAT, AFGHANISTAN, 1:500,000, 1943. *Deutsche Heeresekarte*, sheet I-41 NW *Herat*. Other versions of this type of map were overprinted with a grid for air navigation. Size of the original: 60 × 68 cm. Image courtesy of Peter Collier.

geographic service for the army, navy, and air force led by a technical officer for military geodesy, geography, and geology based in the Defense Ministry, with headquarters in the temporary capital Bonn. The Militärgeographisches Amt (MilGeoA) was established as a specialized agency on 15 June 1956, and renamed the Amt für Militärisches Geowesen (AMilGeo) in 1985. The office was located in Bonn–Bad Godesberg and featured surveying, aerial photogrammetry, cartography, geography, and geology departments. Located in the Mercator barracks in Euskirchen, west of Bonn, since 1985, the agency was responsible for the production, stockpiling, and revision of military geographic data, which had to keep pace with advances in geoinformatics as well as meet the cartographic needs of the German military and its allies. The Institut für Angewandte Geodäsie and the Landesvermessungsämter produced the official civilian German topographic maps on which MilGeo maps were based. The Universal Transverse Mercator replaced the German Gauss-Krüger grid, and the legends became trilingual, according to the NATO specifications. MilGeo also produced customized military maps. As Germany

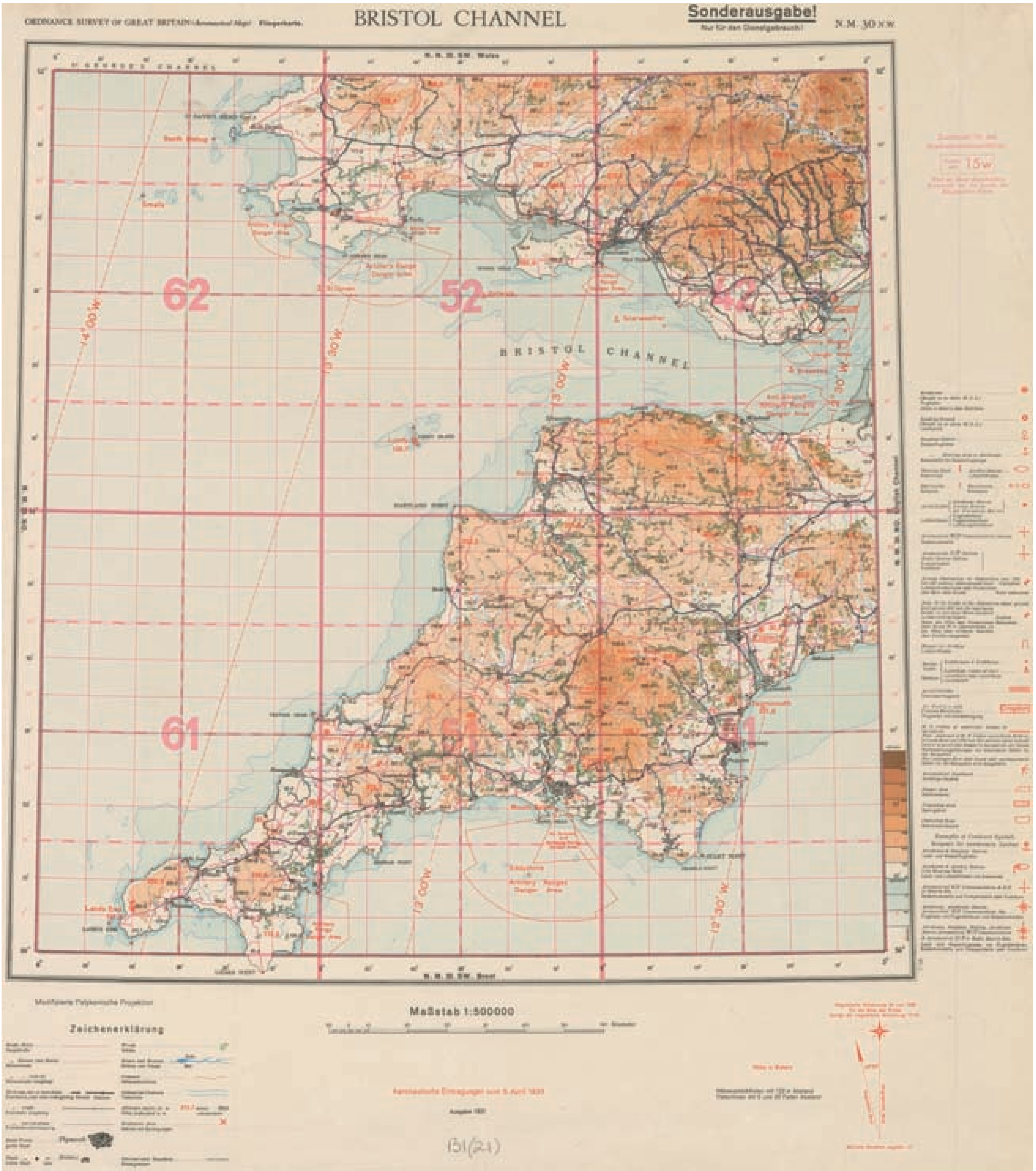

FIG. 561. *BRISTOL CHANNEL*, FLIEGERKARTE, 1:500,000, 8 APRIL 1939. Map copied from the Ordnance Survey map with the addition of marginal information and a German grid.

Size of the original: 58 × 51.5 cm. Image courtesy of Peter Collier.

would be a likely war theater in any East-West conflict, many editions were printed—one sheet of the map series M745 at 1:50,000 attained a circulation of 330,000. Although 30 million maps were printed annually in the late 1980s, when the Cold War ended map production fell to one-tenth its former level.

With Germany's reunification in 1990, the Nationale Volksarmee of the DDR was disbanded, along with its Militärtopographischer Dienst (MTD) and Militärkartographischer Dienst (MKD). In the DDR, topographic maps typically were classified, as in the Soviet Union, and were worked on as military maps in the MKD. After reunification, the Landesvermessungsämter of the restored states (such as Saxony) took over topographic operations with help from MilGeo. After the demise of the Soviet Union, NATO, the Bundeswehr, and MilGeo faced new challenges: assisting humanitarian missions, reacting to political crises, and conflict resolution. Increasingly, the Bundeswehr took part in foreign interventions, requiring MilGeo to cover much more territory than before. The Foreign Ministry discontinued its geographic service in 1997, and relied instead on MilGeo's cartographic information and research. Early in the twenty-first century the Landesvermessungsämter abandoned separate civilian and military series of topographic maps in favor of a single series of standardized civil-military maps. In 2003, all of the geosciences and even biology were combined within the Amt für Geoinformationswesen der Bundeswehr (AGeoBw) in Euskirchen, which has approximately 1,000 civil and military members.

JOACHIM NEUMANN

SEE ALSO: Akademie für Raumforschung und Landesplanung (Academy for Spatial Research and Planning; Germany); Coordinate Systems; Military Mapping of Geographic Areas; Preußische Landesaufnahme; Projections: Projections Used for Military Grids; Topographic Mapping: Western Europe; World War I; World War II

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Military Mapping by Italy. When Vittorio Emanuele II of Savoy was declared king of the newly unified Italy in 1861, large-scale map coverage was neither consistent nor complete and mapping the new nation became one of the kingdom's first priorities. The task was assigned to the Ufficio tecnico del Corpo di Stato Maggiore, renamed the Istituto topografico militare in 1872 and the Istituto geografico militare (IGM) in 1882. Located in Florence since 1865, the IGM is Italy's national mapping organization.

Established principally to provide maps for the Italian army, the IGM has served both military and civilian needs with maps series at several scales. The *Carta topografica delle province meridionali alla scala 1:50.000* was completed in 1876, and the *Carta geografica d'Italia e regioni adiacenti alla scala 1:500.000* was created between 1883 and 1889. Of the three colors used for this latter map, one (*bistro*, a light brown) is common to all IGM maps, including a road map of Italy at the scale of 1:300,000, initiated in 1886.

The most important and ambitious project of the IGM's early years was the *Carta d'Italia alla scala 1:100.000* (also known as the *Gran carta d'Italia*), authorized by the Parliament in 1875. This series was instrumental in the political and economic development of Italy (Cantile 2004a) because it provided a systematic, coherent, and exhaustive representation of the human and physical geography of the country. The first maps were published in 1879, and work was completed by 1903. Each of the 277 sheets covered 20′ of latitude and 30′ of longitude, an area of roughly 1,500 square kilometers. The prime meridian was located at Monte Mario, near Rome. The first edition of the map was monochromatic (printed in black ink), but later editions, starting in 1903, were published in color (fig. 562), and from the 1920s and 1930s the series used blue, *bistro*, black, green, and red. A final edition was started in 1961, but the series was discontinued in 1974.

In initiating the 1:100,000 series, the IGM introduced a hierarchical system of nested quadrangles that anticipated later series at larger scales. Each 1:100,000 sheet was divided into four *quadranti* (quadrants) for mapping at 1:50,000, and each quadrant was further divided into four *tavolette* (sheets) for mapping at 1:25,000. In 1878 the Parliament authorized the *Carta topografica d'Italia alla scala 1:25.000*. Although created principally for military purposes (Farinelli 1976), this national base map became the IGM's most important work. Each *tavoletta* encompassed 7′30″ of longitude and 5′ of latitude, an area of about ninety-six square kilometers. The contour interval was twenty-five meters generally but five meters in areas of low relief. The prime meridian was at Monte Mario, and the first edition was printed entirely in black.

World War I briefly interrupted cartographic activities, but map production recovered in the 1920s and 1930s, when the IGM implemented new surveying techniques developed by Ermenegildo Santoni and started using aerial photography to complement field surveys (fig. 563). A new edition of the 1:25,000 series was produced between 1946 and 1953 using three colors: black for place-names, elevations, roads, and mountains; blue for water and coastlines; *bistro* for topography. In 1957

FIG. 562. DETAIL FROM *M. ADAMELLO*, 1950 (F. 20, ED. 4). This early edition, compiled in 1929 and updated in 1950, of the 1:100,000 series shows a mountain landscape characterized by glaciers, parallel ridge lines, and wide valleys.
Size of the entire original: 46.2 × 52.8 cm; size of detail: 10.5 × 8.5 cm. Reproduced with permission of the Istituto Geografico Militare, Florence (authorization n. 6785 dated 04.06.2014).

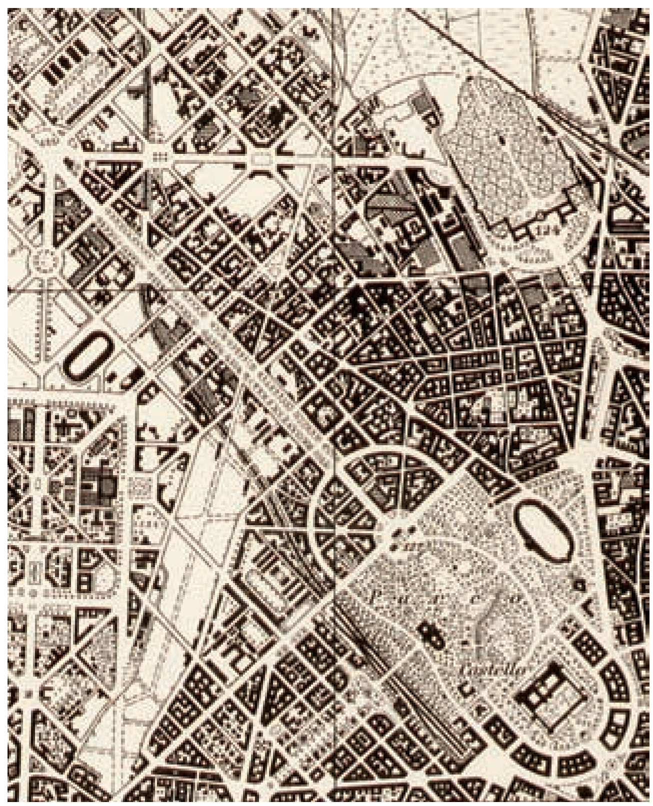

FIG. 563. DETAIL FROM *MILANO OVEST*, 1936 (F. 45, III N.E), 1:25,000 SERIES. Note the detail in the cartographic representation of the urban form, including buildings, railroad tracks, parks, and gardens.
Size of the entire original: 46.4 × 45.6 cm; size of detail: 11.3 × 9.1 cm. Reproduced with permission of the Istituto Geografico Militare, Florence (authorization n. 6785 dated 04.06.2014).

aerial survey completely replaced field survey. A third edition of the 1:25,000 series, initiated in 1961, was published in three versions: one for the military, one for the general public, and one labeled "classified." The new edition used five colors, with pink added for the roads and green for vegetation. The military version used a sixth color, magenta, for Universal Transverse Mercator (UTM) grid coordinates as well as labels and supplementary text in English.

The third edition remained in production until the mid-1980s, when the IGM introduced a new series (Serie 25) based on computer technology. Serie 25 used four colors: black, blue, *bistro*, and green. The first of the planned 2,300 sheets (called *sezione*, or section) was published in the early 1990s. Serie 25 used the UTM coordinate system and Greenwich as the prime meridian, and each *sezione* encompassed 10′ longitude by 6′ latitude, a larger area than earlier editions (fig. 564). After the compilation of about 800 sheets, Serie 25 was replaced in 2000 by Serie 25DB, the addition of DB (database) reflecting a shift in format from the printed map to electronic cartography.

The third major project at the IGM started much later than the 1:100,000 and 1:25,000 series. Derived from the 1:25,000 series, the *Carta topografica d'Italia alla scala 1:50.000* was initiated as a prototype in the late 1950s and was put into production in 1964. The decision to create this series was largely the result of international agreements aimed at standardizing military cartography (Cantile 2004a). The series is composed of 636 sheets, each covering approximately 600 square kilometers (20′ longitude by 12′ latitude), with Greenwich as the prime meridian. The series was produced in three distinct versions (military, civilian, and classified) and four colors (black, blue, *bistro*, and orange). A new edition, which included administrative boundaries, was introduced in 1974. Starting in 1984, the series was published in eight colors (black, blue, orange, light blue, gray, yellow-orange, green, and magenta). By the end of the century it covered about three-quarters of the country. A related product is the *Spaziocarta* Serie 50/S, published at 1:50,000. Initiated in the early 1990s as a cost-cutting strategy for completing the 1:50,000 series, *Spaziocarta* consists of a series of orthophotos created using SPOT 2 (Système Probatoire d'Observation de la Terre) satellite imagery.

FIG. 564. DETAIL FROM *GROSSETO*, 1993 (F. 331, SEZ. IV), 1:25,000. This is from the recent edition of the 1:25,000 series. The cartographic representation captures the variety of the urban, physical, and agricultural landscape in the vicinity of the city of Grosseto in Tuscany. Note the difference between the level of detail in the urban representation on this map and Milan in 1936 (fig. 563).
Size of the entire original: 58.4 × 84.8 cm; size of detail: 8.4 × 9.9 cm. Reproduced with permission of the Istituto Geografico Militare, Florence (authorization n. 6785 dated 04.06.2014).

The *Carta d'Italia alla scala 1:100.000*, the *Carta topografica d'Italia alla scala 1:25.000*, and the *Carta topografica d'Italia alla scala 1:50.000* are the IGM's three most significant cartographic publications, and together they provide Italy with a basic cartographic framework and foundation. Another important and influential IGM publication is the *Atlante dei tipi geografici*, edited in 1922 by Olinto Marinelli. Marinelli was a true Renaissance man: a geologist, geographer, and cartographer; an explorer of Africa and Tibet in his youth; a professor of geography at the University of Florence; and the editor of the *Rivista Geografica Italiana* for several years. His two most important cartographic works are the *Atlante internazionale* (1929), compiled for the Touring Club Italiano, and the *Atlante dei tipi geografici*, compiled for the IGM. Both atlases had a long-lasting impact on Italian cartography. The beautifully crafted *Atlante dei tipi geografici* consists of a series of maps and descriptions of the most prominent physical geographic features of Italy. A new edition was published in 1948, and a third revised and expanded edition, including an expanded human geography section, was published in 2004 and made available both in print and online (Istituto geografico militare 2004).

In addition to its atlases and map series, the IGM has published books on geographic topics for the general public, technical manuals on cartography and surveying, and two scientific journals (*L'Universo* and the *Bollettino di Geodesia*). Its institutional responsibilities include maintaining a record of Italy's national boundaries, supporting the army's cartographic needs, and developing a national geographic database (including a digital terrain model) derived from the 1:25,000 and 1:50,000 map series and covering the country at a resolution of twenty meters. Responsibilities have also included developing and maintaining the national datum: Italy's first geodetic datum, started in the 1860s and completed in 1919, was followed by the ROMA40 in 1940, by the Italian segment of ED50 in the 1960s and 1970s, and by the IGM95 in the mid-1990s. In addition, the IGM has trained its civilian and military personnel at an in-house cartographic school, founded in 1872. The agency's success in addressing Italy's diverse civilian needs reflects in large measure the central government's recognition of mapping's essential role in national defense.

ALBERTO GIORDANO

SEE ALSO: Geodetic Surveying: Europe; Topographic Mapping: Western Europe; World War I; World War II

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Military Mapping by the Austro-Hungarian Empire. At the beginning of the twentieth century, Austria was part of the large Central European Austro-Hungarian Empire, which dissolved into national states (succession states) after World War I (1914–18). The Republic of Austria became a small country (Treaty of Saint Germain, 1919; fig. 565) but in March 1938 was absorbed by Nazi Germany (Third Reich) and became involved in World War II (1939–45). Following the establishment of the second Republic of Austria (April 1945), an international treaty ensured its independence (1955). The second Republic of Austria, its location bordering the Iron Curtain dividing Europe into East and West, remained neutral during the Cold War. After the Berlin Wall fell in 1989, the borders to its eastern and southeastern neighbors opened, and in January 1995 Austria entered the European Union, followed in May 2004 by several of its

FIG. 565. *MAP SHOWING THE NEW BOUNDARIES OF AUSTRIA BASED ON ARTS. 27 AND 49 OF THE TREATY OF ST. GERMAIN-EN-LAYE, SIGNED SEPT. 10, 1919*. The inset on this map relates the New Republic of Austria established after World War I to the former Austro-Hungarian Monarchy. Size of the original: 21.8 × 41.8 cm. From "The New Boundaries of Austria," *Geographical Review* 8 (1919): 345–59 (pl. VI, facing 348). Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

eastern neighbors—the Czech Republic, Slovakia, Hungary, and Slovenia. Austria entered the Partnership for Peace in 1995, while its eastern neighbors, until 1989 members of the Warsaw Pact, later entered the North Atlantic Treaty Organization (NATO). Such was the context of twentieth-century Austrian military mapping, whose map series served civilian and military purposes.

From the mid-nineteenth into the early twentieth century primary responsibility for Austrian military surveying and mapping lay with the Militärgeographisches Institut in Vienna (founded 1840, disbanded 1920). In 1900 the topographical coverage of the Austro-Hungarian Empire, complete at the metric scales of 1:25,000, 1:75,000, 1:200,000 and largely complete at 1:750,000, was unique in Europe.

The third Austrian survey, surveyed by plane table (1869–87), covered the entire Austro-Hungarian Empire and was based on a new framework of horizontal and vertical control points, which met European level-measurement standards. Reproduction of the multicolored original sheets by black-and-white photolithography began in the early 1900s. Each sheet covered 7.5′ in latitude and 15′ in longitude. Relief symbolization combined hachures, 100-meter contour lines, and schematic rock drawing.

Next the *Spezialkarte der Österrreichisch-ungarischen Monarchie* was derived from the 1:25,000 series and published at 1:75,000 (1873–89). Its 333 draftsmen, who had received special cartographic training, drew 752 sheets in uniform style for reproduction by heliogravure. Compiled on the polyeder (polyhedral) projection, each sheet extended 15′ in latitude and 30′ in longitude. Relief representation included hachures and 100-meter contour lines. The first edition was uncolored, but the second edition showed woodland in green (1887/1888).

Derivation of the *Generalkarte von Mitteleuropa* on the same projection but at 1:200,000 began in 1887, its first sheet appearing in 1889 and publication continuing through 1915. Each sheet covered one degree of latitude and longitude. The 265 multicolored sheets, later increased to 282 sheets, had brown hachures and rock drawing; blue water bodies; black settlements, communication network, and geographical names; and green woodland. Coverage extended east from Switzerland to the Black Sea; south from Central Europe (now Poland) to Greece; southeast to Romania, Bulgaria, and Albania; and southwest to Italy (as far as Rome). It also included the Balkan Peninsula (later sheets with contour lines and hill shading).

The *Übersichtskarte von Mitteleuropa* at 1:750,000 was derived from the 1:200,000 series but on the Albers conic projection (1899–1915). Twelve sheets of the multicolored map series were published, but the series remained incomplete.

The end of the nineteenth century saw demand for large-scale topographic maps increase rapidly along with the growing communication network, settlement, and tourism. Those developments led to the fourth Austrian survey (1896–1915). It introduced precision surveying techniques, such as tacheometric distance measurement and altitude measurements based on trigonometrical observations, to revise the interpolated contour lines. After 1890 the use of photogrammetry for topographical survey in mountainous areas was also introduced. Experiments in 1891 near Vienna led Arthur von Hübl to construct photogrammetric instruments more suitable for field surveying. In 1893–94 photogrammetric surveying was tested in the Tatra Mountains (now Poland). Photogrammetric surveying took place in 1896 on the Dalmatian coast (now Croatia) and in 1897–99 in the Julian Alps and southern Tyrol (now Italy). Hübl recognized the superiority of photogrammetric surveying in mountainous areas, even though transforming the data for drawing was time consuming. Following invention of the optical floating mark by Franz Stolze (1892) and the stereocomparator by Carl Pulfrich (1901), the Militärgeographisches Institut adopted the stereocomparator for drawing contour lines of parts of the south Tyrolean Alps (1902–7). In 1908 the Austrian cartographer Eduard von Orel, based in Vienna, developed a new instrument for stereoscopic evaluation, called the *Autostereograph*, which enabled the direct recording of lines true to scale. After 1910 stereophotogrammetry was permanently adopted in Vienna for topographical surveying (fieldwork was conducted in 1909–11 in the north Tyrolean Alps and 1912–13 in the Hohe Tauern). As early as 1897 Theodor Scheimpflug had investigated the optical transformation of air photos, then taken by balloons, into true-to-scale plane photographs. His invention of the principle of double projection (1899) formed the basis for photogrammetric plotting instruments after 1918. Thus, Austrian photogrammetric innovations, which greatly increased the geometric accuracy of large-scale topographical maps, became internationally known. The first International Congress of Photogrammetry took place in Vienna in 1913.

After 1900 great innovations in map reproduction also occurred. The Militärgeographisches Institut had the first offset lithographic rotary press in Europe. Its output was quadruple that of flatbed mechanical presses. During World War I seven additional rotary presses were mounted, and sixty-five million map sheets were printed.

The fourth survey produced nearly 400 sheets at 1:25,000 that were also published (starting in 1912) as the multicolored *Spezialkarte 1:75,000*. Efforts were also made to update 1:75,000 third survey sheets. In 1918 the fourth survey covered only 6 percent of the new Republic of Austria (parts of Tyrol and Carinthia), because most fieldwork prior to 1915 had occurred in areas that, after the monarchy dissolved in 1918, became other countries.

During World War I large-scale survey was extended to parts of Serbia, Romania, Italy, and Russia. The institution responsible was the Königliche und kaiserliche Kriegsvermessung commanded by Hubert Ginzel. In 1917 the Gauss-Krüger coordinate system (conformal with a 3° longitude zone) was introduced for topographical surveying and mapping. For the Russian theater of operations the *Operationskarte R[ussland]* at 1:400,000 was produced. The Austrian navy produced sea charts of the Adriatic Sea and the eastern Mediterranean Sea until 1918. After the Militärgeographisches Institut was disbanded in 1920, its former staff found employment in surveying and mapping organizations in successor countries of the monarchy and also in Italy, Spain, Turkey, and Brazil.

With the regime change came new institutions responsible for surveying and mapping and reorganization of surveying operations. The geodetic and topographical departments of the former Militärgeographisches Institut were affiliated with the civilian Bundesvermessungsamt (founded 1921, renamed the Bundesamt für Eich- und Vermessungswesen in 1923) located in Vienna. The cartographic and map reproduction departments of the former institute now constituted the Kartographische Institut. Although reorganization meant less-than-satisfactory partition of topographical surveying and mapping after 1920, decisions about needed reorganization of topographical map series covering the new Republic of Austria were made quickly. Besides updating the sheets of the old *Spezialkarte 1:75,000* (begun 1936 with a Gauss-Krüger grid in red; fig. 566), a new multicolored map series at 1:25,000, the *Österreichische Karte 1:25,000*, and a derived series, the *Österreichische*

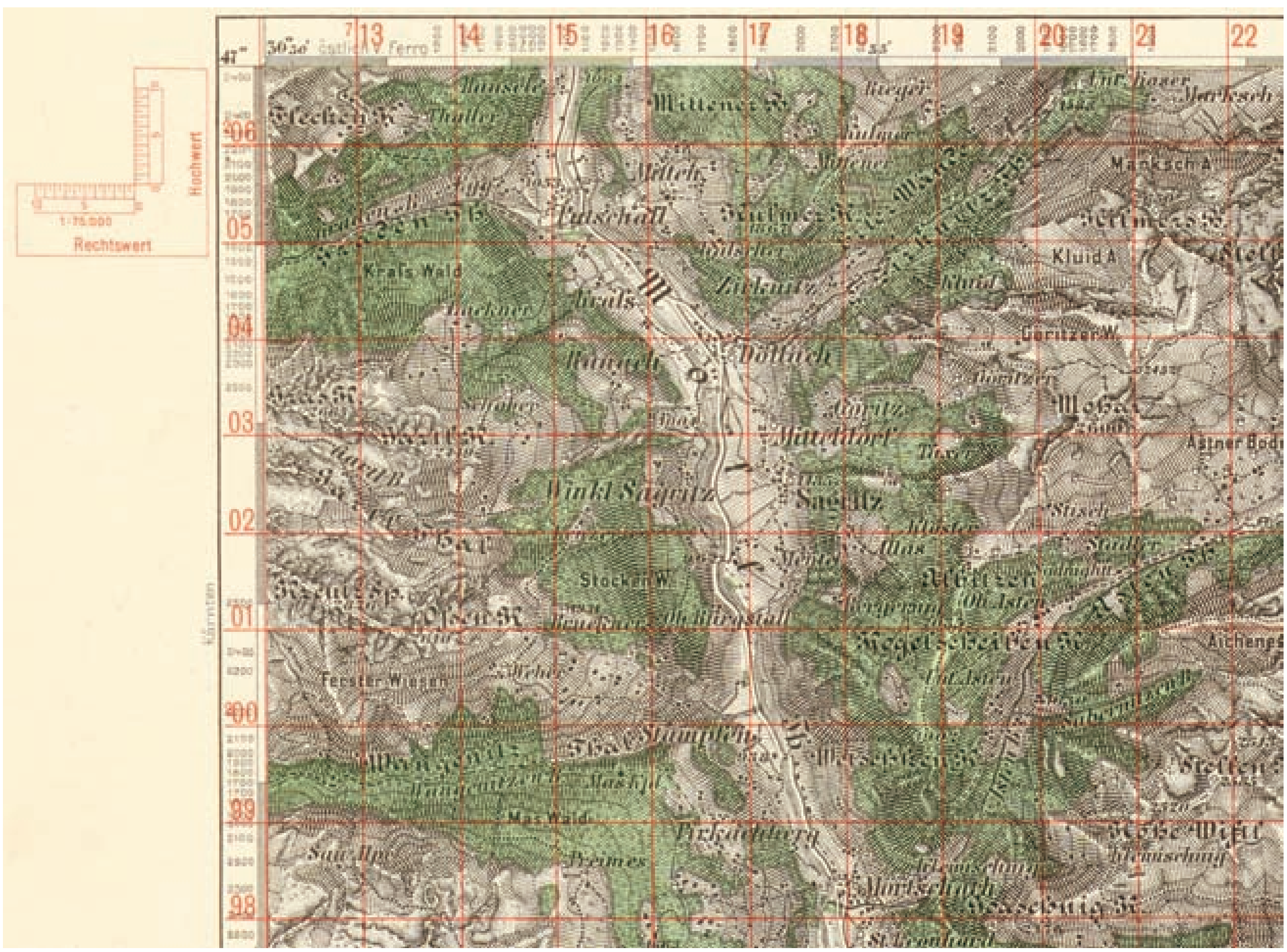

FIG. 566. DETAIL FROM *MÖLL THAL*, SHEET 5250 OF *SPEZIALKARTE 1:75.000*, 1936. The Gauss-Krüger grid is overprinted in red on this military topographic sheet with hachured terrain and green woodland.

Size of the entire original: 42.8 × 56.1 cm; size of detail: 12.9 × 17.5 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

Karte 1:50,000, were produced in 1928. A new index sheet and sheet numbering system introduced in 1933 remained valid until the end of the century. During the mid-1930s terrestrial photogrammetry was concentrated on mountainous areas (mainly the federal territory of Salzburg). Nearly 20 percent of the new Republic of Austria had been mapped before work was interrupted by the absorption of Austria into Nazi Germany (1938). After that the Österreichische Bundesheer was incorporated into the Deutsche Wehrmacht and the Austrian institutions of surveying and mapping into the Reichsamt für Landesaufnahme in Berlin.

In the catastrophic aftermath of World War II all fields of cartographic activity in Austria had to be reorganized. In 1945 the Bundesamt für Eich- und Vermessungswesen was reestablished and became responsible for all types of official cadastral and topographical surveying and mapping in Austria. Rapidly developing technology in the 1950s, especially the introduction of aerophotogrammetry, meant that the incomplete fourth survey had to be entirely reorganized. About 75 percent of the area of Austria was covered only by the third survey, available as a provisional edition of the *Österreichische Karte 1:50,000*. In 1959 work on the *Österreichische Karte 1:25,000* was suspended in order to accelerate surveying for the 1:50,000 scale. Until 1987 priority was given to completing the fourth survey using aerophotogrammetry. By 1989 Austria had completed the new map series at 1:50,000 based on uniform modern aerophotogrammetric data. Using the ellipsoid of F. W. Bessel and the Gauss-Krüger projection each of the 213 sheets at 1:50,000 covered 15′ in longitude and latitude. All sheets had twenty-meter contour lines complemented by hill shading. Between 1963 and 1991 the derived map series *Österreichische Karte 1:200,000* was produced in twenty-three sheets. By 1968 all of Austria was also represented on one map sheet at 1:500,000 using a conformal conic projection (Lambert). In order to extend the range of map scales, photomechanical enlargements without any significant cartographic alterations were made available from 1976. In the mid-1970s Austria started producing orthophotomaps. The first series, the *Österreichische Luftbildkarte 1:10,000* on 3,654 sheets, was finished in the mid-1990s. Work begun in 1976 yielded the first version of a digital relief model in the late 1980s and subsequently continued to advance.

Work on related topographic and military map series had been under way since 1958. The military sheets were equipped with a special grid and enlarged marginal information. Military map series used the scales 1:50,000, 1:200,000, and 1:500,000.

After the political change in Europe in 1989 and the fall of the Iron Curtain, Austria took on a new position in Central Europe. It became necessary to adapt the military map series to international standards by using the World Geodetic System 1984 (WGS84) and the Universal Transverse Mercator (UTM) projection. In 2000 the first military map series of that type was finished. In 1997 the Institut für Militärisches Geowesen was established in Vienna and became responsible for all military map series, including all kinds of military thematic maps and maps for peacekeeping missions abroad.

INGRID KRETSCHMER

SEE ALSO: Coordinate Systems; Military Mapping of Geographic Areas: Europe; Proje-ctions: Projections Used for Military Grids; World War I

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Military Mapping by the Ottoman Empire. Prior to 1895 the Turkish General Staff had confined its mapping activities to Turkey in Europe, where it carried out mapping at a scale of 1:210,000. Following the Ottoman Empire's defeat in the Russo-Turkish War of 1877–78, Prussian staff officers had visited Turkey and been involved in training the Turkish army. Although these Prussian officers carried out some limited mapping themselves, their principal influence was on the Turkish General Staff, which established a mapping section in 1895. Despite the strong influence of the Prussian army, several Turkish officers were sent to Paris, to study at the École militaire. The resulting influence of French methods and design on Turkish military cartography lasted until the outbreak of World War I in 1914.

In 1906, Colonel Mehmet Şevki Paşa, one of the officers originally trained in France, was appointed chief of the military survey department, where he launched a program to map the entire empire. The Bonne projection based on a prime meridian through the dome of the Hagia Sophia Mosque in Constantinople was adopted. It was decided to map European Turkey at 1:25,000, Anatolia at 1;50,000, and Tripolitania, Arabia, and Mesopotamia at 1:100,000. For pragmatic reasons, a reconnaissance or exploration series at 1:200,000 was produced to provide some reliable interim topographic coverage, especially of Anatolia.

Due to the size of the empire, several baselines were measured, at Adrianople (today, Edirne) and near Constantinople in Europe, at Çanakkale to support a survey of the Dardanelles, on the Izmid Peninsula, at Aleppo for the Levant, and near Erzurum, close to the sensitive border with Russia. (A further baseline might have been measured at İzmir as well.) The policy of starting surveys from several baselines led to problems at the junction of map series, such as the 150-meter difference in latitude along the meridian join between the 1:50,000

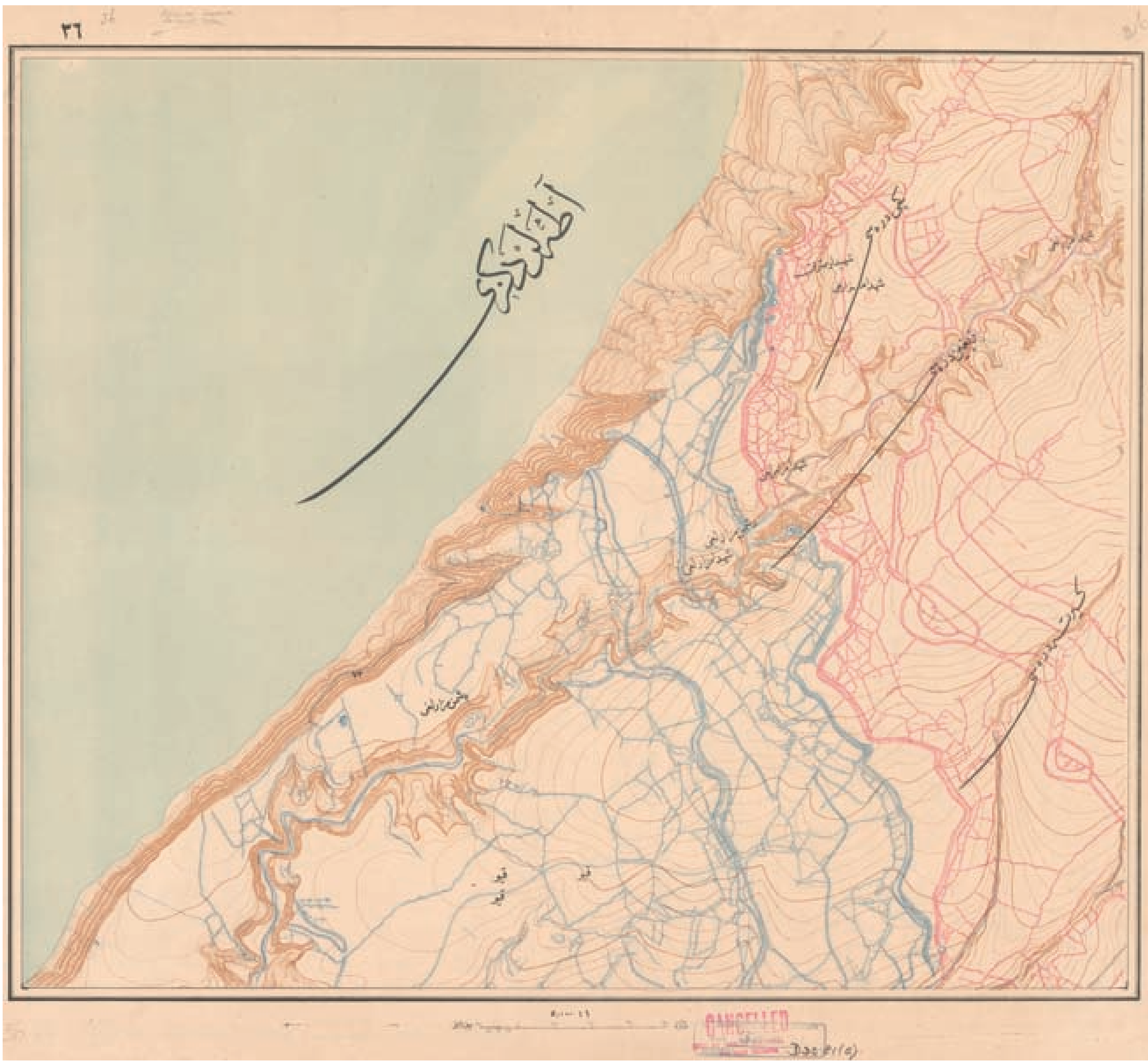

FIG. 567. MAP OF THE WESTERN PORTION OF THE GALLIPOLI PENINSULA, 1:5,000, 1916. Produced by the Ottomans after the Allied evacuation of Gallipoli, the map shows trench lines and barbed wire in addition to topography of the area just to the east of Suvla Bay (sheet 36).

Size of the original: 53.8 × 60.2 cm. Image courtesy of the Bodleian Library, University of Oxford (D30:67[1]).

maps based on Izmid and the 1:25,000 maps around Constantinople.

The triangulation that proceeded from these disparate baselines was effectively a reconnaissance triangulation. Interviewed in 1919, Mehmet Şevki Paşa admitted that there had been no possibility of commencing a regular geodetic survey during the hostilities of the Balkan Wars and World War I (Wood 1919).

The Military Survey Department used plane table techniques for detailed survey work. Despite the limitations imposed by a series of wars between 1906 and 1914, using this technique the Military Survey Department was able to carry out a considerable volume of high-quality work. Ernest MacLeod Dowson (1954, 112), who had directed the Survey of Egypt from 1909 to 1919, praised the "up-to-dateness, accuracy and informativeness [of the] defensive survey of the Gallipoli peninsula" (fig. 567). More than sixty sheets were produced in the years leading up to World War I.

By the end of World War I the 1:200,000 exploration surveys had been completed for several regions of the Ottoman Empire, with the earliest, of western Anatolia, completed by 1911. Relief on these maps was shown by hill shading. When war became imminent, efforts were shifted to the Caucasus and the border area with Russia. Work was carried out in this region in 1911–12 to produce a new-style 1:200,000 series. After completing the mapping of the Russian border region, the military surveyors shifted their focus to the west and southwest and reached the Gulf of Alexandretta in 1916. In response to Allied offensives in Palestine, work was extended southward into the Levant and, in 1918, into Transjordan. In contrast to the exploration surveys' pictorial treatment of relief, the maps in the new-style 1:200,000 series were contoured with a 50-meter contour interval.

Lack of adequate mapping in Palestine put the Ottoman forces at a severe disadvantage against the Allied forces. This deficiency was partly remedied by the work of a German survey unit sent to help, but the maps produced were mainly revised enlargements to 1:50,000 of the inch-to-a-mile (1:63,360) maps that Claude Reignier Conder and Horatio Herbert Kitchener had produced for the Palestine Exploration Fund in the 1870s.

Despite a late start, by the end of World War I systematic military mapping covered much of the Ottoman Empire. The 1:25,000 maps of the Gallipoli Peninsula and the approaches to Constantinople were sufficiently accurate to be adopted and adapted by British and French occupation forces in the 1920s, and the British used the 1:200,000 series as a basis for their own 1:250,000 maps of the region until at least the 1940s.

PETER COLLIER AND MIKE NOLAN

SEE ALSO: Coordinate Systems; Military Mapping of Geographic Areas: Middle East; Projections: Projections Used for Military Grids; World War I

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Military Mapping by Israel. The Holy Land, a transit area between the sea and the desert and between the ancient kingdoms of Mesopotamia and Egypt, has been a war area from the dawn of history. Battles have taken place between Egypt and Persia, Assyria, and Babylon. The area has been conquered by Israelites, by Assyrians, by Babylonians and Persians, by Alexander of Macedonia and the Greeks, by Romans, Byzantines, Arabs, Crusaders, Mamluks, Ottomans, and others, including partially by Napoleon and by the British.

The earliest extant map showing symbols of municipal fortifications is a partially preserved mosaic from the sixth century A.D., discovered in Madaba in Jordan. The first modern military map is the 1799 Jacotin Map, compiled by Pierre Jacotin, Napoleon's mapmaker, in six sheets, at 1:100,000 scale, based on triangulation but of limited accuracy. British Army officers published, under the auspices of the Palestine Exploration Fund (PEF), a map series consisting of twenty-six maps at 1:63,360 scale in the latter part of nineteenth century. These were the most reliable maps available and were used as a principal source for both the British and the Germans during World War I and as infrastructure for the British in Palestine in 1918.

The Survey of Palestine was established in 1920, with land settlement surveys as its main task. A triangulation network was developed, and maps at 1:2,500 and 1:2,000 scale were reduced and combined to create maps at 1:20,000. From 1933 onward, to satisfy growing military demands, the production of maps at 1:100,000 started with enlargements to 1:50,000. The basic map projection was the Cassini-Soldner with the Palestine Grid overlaid. Later, in response to additional military demands a transverse Mercator grid was added (Gavish 2005, 243–45).

During World War II the British charged the Survey of Palestine to produce topographic maps. Data collection was increased and British military survey units, in which Australian, New Zealand, South African, and Polish surveyors served, including a survey and mapping company composed of Eretz Israel volunteers, aided the efforts. Mapping plans were changed. The 1:20,000 scale, sometimes reduced to 1:25,000, was prescribed for topographic maps and the control network was converted from the Palestine Grid to the Palestine Transverse Mercator Military Grid. Toward the end of the war full aerial photography coverage was completed and became an important factor in future mapping.

In the 1940s, mainly around the Jewish settlements, files marked with targets and terrain analysis were created from both 1:5,000 maps enlarged from 1:20,000 scale and smaller and from ground, panoramic, and rectified photographs. After the departure of the British in 1948, aerial photographs from World War II, triangulation, and maps were used. The principal goal of the military Maps and Photography Service was to prepare 1:100,000 maps of the Negev, which was not covered by the British. The maps served the Israel Defense Forces (IDF) for planning and liberation of the Negev during the Arab-Israeli War. At the end of the war the major part of the service was absorbed into the Survey of Israel, which was given the responsibility for military mapping until 1970.

From the beginning, the Survey of Israel continued 1:100,000 and 1:20,000 mapping based on the British maps with appropriate revisions and the introduction of Hebrew names. With modern instrumentation and aerial triangulation applications, precise mapping at 1:50,000 was completed in the late 1960s (Elster 1970). In addition, military mapping and intelligence products for operational purposes were made for areas outside the country with the aid of foreign maps dating from World War II but updated by aerial photographs. The lag between the creation of maps and the intelligence requirements, principally target information, accelerated the use of photographic mosaics and terrain analysis maps. These were found to be particularly valuable during the Six Day War of 1967. Operations were managed through trafficability maps and command and control maps that proved to be operationally efficient as a means of communication between field units (fig. 568).

The requirements increased, particularly after the Six Day War and the occupation of Sinai and Golan Heights, which increased the area to be covered from around 21,000 square kilometers to approximately 90,000 square kilometers. Control surveys and aerial surveys as well as 1:50,000 mapping were undertaken. Some parts of the Sinai had never been mapped at such scale. The considerable increase in area made the Cassini-Solder projection unsuitable and the UTM projection became the basis for military mapping (Adler and Papo 1984). In order to hasten field operations, helicopters were used, and barometers were used for acquiring height data. Super-wide-angle photography was employed, and in areas of minor importance the scale of 1:100,000 replaced 1:50,000. The extended areas made it necessary to use foreign and captured maps in addition to aerial photography, obtained until 1970 without difficulties, for remote operations. A physical presence in distant areas permitted connections of geodetic control networks, including that of Egypt and of the French Levant in Syria and Lebanon.

Beginning in 1970 the top priority for military mapping in the IDF became the location of targets and support to the operational forces. Egypt and Syria obtained Soviet antiaircraft missiles. This put a restriction on the use of vertical aerial photography and resulted in limiting the military mapping applications of the Survey of Israel. It required developing an ability to locate targets and provide operational support in near real time. From 1980, the use of analytical photogrammetry became very important, and from 1990, this action transferred to digital photogrammetry. The constraints led to the development of adjustments to various sensing devices.

The satellite survey activities beginning in 1976 were based on Transit satellites. In parallel with this was the development and use of commercial U.S. and Soviet satellite imagery. The importance of investment in infrastructure such as geospatial databases, and the rapid dissemination of results to users was recognized. Special emphasis was given to direct liaison with the users in specifying their requirements and in determining the effectiveness of results. The most important change in operational procedures, during the 1973 war and after, was the transition from photographic enlargement and mosaics to routine, fast generation of orthophotos and their use as replacements for traditional maps. The use of orthophotos became the infrastructure of artillery, air force, and field intelligence in dealing with targets. The principal scales varied from 1:25,000 to 1:10,000 and were used in parallel with satellite mapping at scales of 1:250,000 and 1:100,000.

Beginning in 1987, the first satellite maps at 1:50,000 and 1:25,000 were produced from SPOT (Système Probatoire d'Observation de la Terre) satellite imagery. A digital infrastructure that included digital terrain models (DTMs) and continuous orthophoto coverage was developed in the 1980s. This permitted spatial and image simulations for planning, navigation, operations, and training. In addition, in the 1980s production lines were established for the continuous output of raster maps, the integration of military information and digital mapping, and geographic information system (GIS) applications.

The development of image products, the availability of high-resolution and improved-accuracy satellite imagery, and the development of weapon systems requiring high-accuracy target location led to an integration of the mapping and visual intelligence units. Israeli military mapping followed the United States and Great Britain in the improvement of operational intelligence products with an emphasis on applications.

Because of the dominant influence of the military in the dialogs between Israel and its neighbors, there has been a continuing participation of military mapping personnel in the peace process. The armistice agreements in 1949, the joint demarcation of the boundary with Egypt,

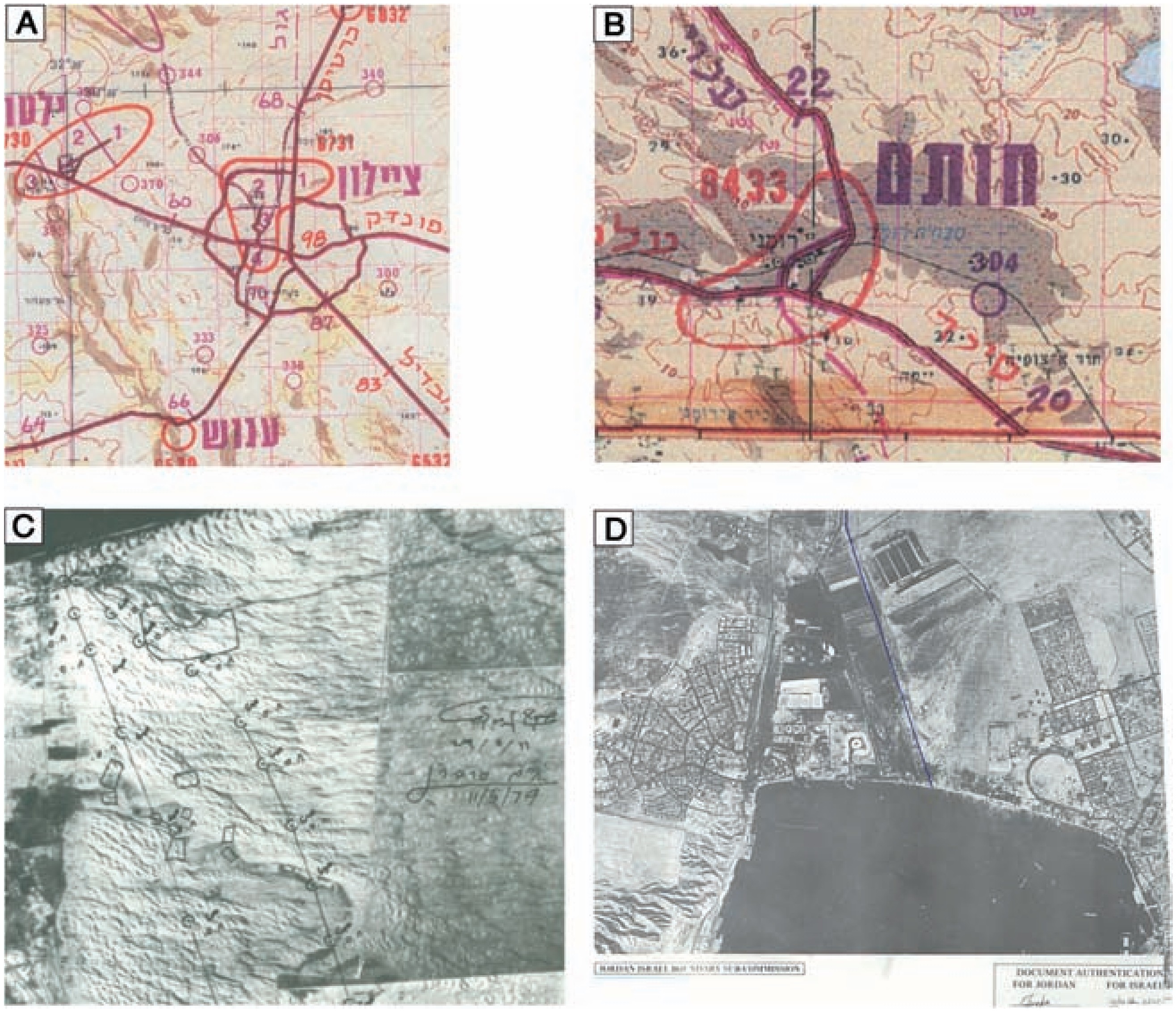

FIG. 568. A COMPOSITE OF ISRAELI MILITARY MAPPING EXAMPLES. (A) 1973 military reference map, (B) 1973 military reference and trafficability map, (C) first use of orthophoto in an implementation of an international peace agreement (the 1979 Israel withdrawal from Sinai), and (D) the first use of orthophoto in an international peace agreement (the 1994 Israeli-Jordanian Treaty of Peace).
Image courtesy of the Survey of Israel, Tel Aviv.

and the delineation and demarcation of the peace agreement between Israel and Jordan were all strengthened by the participation of survey personnel (Srebro 2005, 2012; Srebro, Adler, and Gavish 2009).

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SEE ALSO: Coordinate Systems; Military Mapping of Geographic Areas: Middle East; Projections: Projections Used for Military Grids; Topographic Mapping: Middle East

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Military Mapping by Russia and the Soviet Union. Military mapping in Russia and the Soviet Union has always been bedeviled by excessive secrecy. At the beginning of World War I, when troops were being transferred from the Caucasus to the fronts against Austria and Germany, the topographic store (Sklad topograficheskikh kart) of the Caucasus military-topographic department (Kavkazskiy voyenno-topograficheskiy otdel) in Tiflis (later Tbilisi) had to be reinforced with ten extra men to deal with the inspection and processing of all the maps being returned to stores (Glushkov, Dolgov, and Sharavin 1999). Yet at that time, only maps printed at the scale of survey were secret. The subsequent policy that any topographic map issued must be returned to stores after use makes writing a history difficult. More importantly, the policy has inhibited the use of topographic maps by the Russians themselves. Even officers of the Soviet and Russian forces avoided drawing maps from stores because of the perceived personal danger of being responsible for them. Despite the wide availability of Soviet military maps outside Russia, most remain prohibited to the public within the country.

There are four distinct periods in the twentieth century. Despite the occurrence of two major wars, the period up to the revolutions of 1917 can be seen as a continuation of nineteenth-century Russian practice. The Soviet period from 1917 to the opening in June 1941 of what Russians term the Great Patriotic War forms a second distinct period. In the third period the experience of the Great Patriotic War (1941–45) molded Soviet military cartography through the Cold War until the disintegration of the Soviet Union in 1993. Enforced restructuring then initiated a fourth, post-Soviet period.

Since 1993 the first of these periods has ceased to be regarded as politically sensitive, and has been substantially reassessed (Glushkov 2007a). Biographies of individuals from the period are given by Sergeyev and Dolgov (2001) and Glushkov (2007b). The subsequent periods remain subject to substantial secrecy. Published descriptions have been celebratory in purpose and uncritical in content. Archival material remains largely inaccessible. Accordingly, much remains obscure.

As in most European countries at the beginning of the century, in Imperial Russia topographic surveying and mapping was the prerogative of a corps of military topographers, the Korpus voyennykh topografov (KVT). Its greatest problem in the twentieth century was the same as in the nineteenth century: only a tiny fraction of the huge Russian Empire's territory had been surveyed. Indeed, much was still unexplored. The KVT remained a small body, many of whose officers performed administrative duties within the headquarters staffs of military districts around the country. The number of officers available for geodetic and topographic surveying duties was thus very limited so that prioritization of areas to survey was unavoidable. Nevertheless, by the beginning of the twentieth century a substantial part of the "western border spaces" had been surveyed with contours at 1:21,000 (Glushkov, Dolgov, and Sharavin 1999, 51). Monochrome photographic reductions of the survey sheets to 1:42,000 (one verst to an English inch; a verst is 3,500 ft or 1.0668 km) were prepared for secret issue, but the maps published for routine use were lithographic sheets redrawn in colors at 1:84,000 (two versts to the English inch). However, progress of the surveys was inadequate and in 1907 the decision was made to survey only at 1:42,000. By the outbreak of World War I, modern 1:42,000 contoured maps existed for almost the entire area across which fighting between Germany, Austria, and Russia would take place, although much was still awaiting reduction to 1:84,000 (fig. 569). Mid-nineteenth-century 1:126,000 (three versts to an English inch) hachured maps covered a band east of this and west of a line extending east from St. Petersburg to the headwaters of the Volga, then to the west of Moscow, and south to the River Don and the Sea of Azov. Geodetically, however, this series was weak and revision of the sheets was abandoned in 1903. Although nineteenth-century manuscript surveys existed of some other important areas, most of Russia's deeper interior had not been topographically surveyed at all. The largest scale of mapping covering all of European Russia was the chromolithographed 1:420,000 (ten versts to an English inch) map, compiled from many sources in the 1870s. This had subsequently been extended west and south to include Berlin, Vienna, and the Balkan Peninsula (fig. 570).

Other border areas had also attracted military-topographic attention. In particular, the Caucasus and the frontiers with Turkey and Persia had seen continual military action through the nineteenth century. The Kavkazskiy voyenno-topograficheskiy otdel had thus become a major producer of military surveys and mapping, second in importance only to St. Petersburg. Lithographic stones and other reproduction material in Tiflis were not routinely duplicated in St. Petersburg. A long-established but obsolescent 1:210,000 (five versts to an English inch) series covered southern Russia, the Caucasus, Armenia, and northeastern Anatolia, as well a large part of northern Persia. In addition, modern (post-1872) 1:42,000 maps covered the Crimea and a broad strip south from the Kerch Strait across the Caucasus to Batum, Tiflis, and Yerevan. Shortly before 1914 the Tiflis department extended ten-verst coverage to the eastern half of Anatolia.

In the Russian Far East some topographical surveying of southern Manchuria and the Trans-Siberian Railway had begun in the 1890s. In the Russo-Japanese War of

FIG. 569. DETAIL FROM A WARTIME PROVISIONAL EDITION, 1:84,000 (SHEET XIV-21 OF SMORGON', NOW IN BELARUS). Drawn in 1915, printed in May 1916, and overprinted in red with additional roads, paths, and railways. Trenches are not marked, but the front line passed obliquely across the extract through Smorgon' itself; thus the railway spur marked in red west of Smorgon' was German. Note the key to the overprinted symbols in the west margin.
Size of the entire original: 38.5 × 38 cm; size of detail: ca. 34.7 × 27.7 cm. Image courtesy of John L. Cruickshank.

FIG. 570. DETAIL FROM THE 1:420,000 MAP (SHEET 19, KISHINEV'). Completed in 1886 and reprinted in 1917 with a red overprint indicating additions to the Romanian road and rail networks as of 1914–15. There is a key to the overprint symbols in the east margin (not shown).
Size of the entire original: 55.5 × 68 cm; size of detail: ca. 14.5 × 8.4 cm. Image courtesy of John L. Cruickshank.

1904–5 the mapped areas were soon overrun, and fighting then continued in substantially unmapped territory. Subsequently, a large part of northern Manchuria, the Primorye, and the Amur region was surveyed at 1:84,000 (Glushkov 2005, 2006).

During World War I the developments in Russian mapping and surveying were similar to those of other combatant nations, but they started later and ceased earlier. Warfare between Russia and the Central Powers remained mobile until late 1915. During the first year of war, existing Russian maps sufficed within Russian territory. Within Austro-Hungarian territory good reproductions of the Austrian 1:75,000 sheets were available, but the Latin alphabet and the heavy hachuring in the Carpathians made them difficult to use, and so they were eventually redrawn in three colors with Cyrillic script. More seriously, in the disastrous opening campaign of the war the Russian heliographic copies of the finely engraved 1:100,000 *Reichskarte* of East Prussia proved to have lost much of the detail present in the originals and so were almost useless.

Only in the winter of 1915–16 did large-scale mapping of entrenchments and fortifications begin to be required. Standardized regulations with a system of squaring of maps in versts and half-versts were introduced in August 1916 as part of a reorganization of aerial photographic-intelligence gathering (Glushkov, Dolgov, and Sharavin 1999, 108–17). Artillery targeting using maps and coordinate data alone was not used by Russia, but was introduced on the Russian front by the Germans in September 1917 for the assault on Riga that initiated the final collapse of the Russian war effort.

The official cartographic history of Soviet times, as presented during the 1960s, 1970s, and 1980s (Kudryavtsev 1980; Kudryavtsev, Sergovskiy, and Salyayev 1967; Komkov 1967, 1985; Nikolayev 1970), is clearly incomplete. The extent of the need for revision has been indicated (Postnikov 2002; Filatov 2005); nevertheless, any account continues to rely on Soviet authors. A biographical dictionary covering the early Soviet period (Dolgov and Sergeyev 2005) was an important step forward.

Following the October (Bolshevik) Revolution the Russian army was dissolved, but its Petrograd workshops and storehouses came under Bolshevik control. A Red Army was formed in January 1918, within which a new corps of military topographers was created by May 1918 that was able to attract and retain a nucleus of key personnel from the old corps. However, in February 1918 the map-printing equipment had been evacuated from Petrograd to Nizhniy Novgorod, and the original survey material, reproduction material, and records moved to Omsk. The developing Civil War (1918–21) exhausted existing stocks of maps. Only in December 1918 was a new map-printing facility established at the former Menert Brothers factory in Moscow, where the evacuated machinery and reproduction material were eventually reunited.

Much of the Civil War took place in areas of Russia previously without tactical-scale topographic maps. The new KVT of the Red Army initially used its field capabilities to extend the surveys of western Russia, but in late 1918 all resources were transferred east and subsequently south. In all 138 sheets at 1:42,000 of the Volga region and well over one hundred outline 1:126,000 sheets without relief were eventually produced from old unpublished material with hurried field revision. Some surveying took place in the Urals and Siberia, and eventually mobile lithographic presses were set up in railway wagons there to reproduce locally compiled maps for the campaign against Admiral Aleksandr Vasil'yevich Kolchak. For southern Russia all original material remained in Tiflis, the capital of what was then the independent country of Georgia. The five-verst map thus had to be reproduced from library copies of the printed sheets.

Despite considerable losses of personnel, there was great continuity between the new KVT and the old. The initial leaders were appointed from the existing officers, since only they had the necessary specialist skills in geodesy, topography, and cartography, but military commissars were appointed alongside them. After the end of the Civil War and the death of Vladimir Il'ich Lenin, the KVT was renamed a directorate of the General Staff of the Red Army in 1923, and in 1924 the young military commissar Aleksandr I. Artanov became its head (for details of organizational changes during this period, see Kudryavtsev 1980, 91–97, 120–30). Meanwhile, civil mapping and survey organizations were established alongside the military one (including what became the Glavnoye upravleniye geodezii i kartografii—GUGK). A number of senior figures left the directorate to join these. Throughout the interwar period the relationships between the military organization and successive civil ones remained in flux as Joseph Stalin progressively established his dominance and as new surveys and maps became necessary for the major industrialization projects of the Five-Year Plans, many of which relied on the forced labor of the Gulag. Artanov was replaced by Ivan F. Maksimov in 1929. In October 1938, after returning from service as an "advisor" in the Spanish Civil War, Maksimov was arrested and subsequently shot. Many other senior officers were also purged, leaving young men trained since the Revolution as the remaining officers of the the military-topographic service (Voyenno-topograficheskaya sluzhba, VTS). The thirty-six-year-old M. K. Kudryavtsev became head of the directorate (at that time called the 7th Department of the General Staff). At this point the purges halted, and he remained head of the directorate and service for the following thirty years.

The maps too were in a state of transition throughout the interwar period. In 1918 Lenin decreed the metrication of all measures in the Soviet state. Not only did topographic maps need to be designed at a range of metric scales, but equipment for surveying in metric measures had to be imported or manufactured. Work began in 1919, and a system of sheetlines based on those of the International Map of the World (IMW) was agreed on, but the range of scales was not fixed until 1934, and maps were made to a succession of prototype specifications until standardized regulations for most scales were eventually issued in 1940. For some series, especially at 1:200,000, the easily plotted Prussian Müffling polyhedric projection was used. At this scale the specifications, sheet sizes, and numbering were not standardized until 1942. In the 1920s the nineteenth-century manuscript civil surveys of General Aleksandr Ivanovich Mende were used to produce new 1:100,000 mapping of some interior regions of European Russia. During the 1930s the verst-based surveys of the western border spaces (including the regions that were then in independent countries) were replotted, revised, and reissued at metric scales; however, many other maps at verst scales remained in use, particularly in the Asiatic part of the Soviet Union (fig. 571). The first 1:1,000,000 Soviet maps were produced in 1918, but a campaign to map the entire country at this scale was launched in the late 1930s. At the same time, million-scale mapping of the Near East and Western Europe including Britain was compiled. In addition to the maps on IMW sheetlines, several rectangular-sheet series of Asia and Europe were produced for assembly into large wall maps.

From 1931 Gauss-Krüger rectangular grids (calculated according to the Bessel 1841 spheroid) were applied to new topographic maps at 1:200,000 and larger (fig. 572). But separate geodetic frameworks for different areas within the Soviet Union had yet to be unified. Therefore several distinct coordinate systems (Tashkent 1875, Baku 1927, Pulkovo 1932, Svobodnyy 1935, and others) existed. Discrepancies between grids at points where different geodetic nets eventually met could reach 700 meters.

Map reproduction also changed fundamentally. By the 1940s production printing from stones and intaglio plates had ceased, and maps were printed from lithographic metal plates readily duplicated for use at multiple sites.

Most ground and aerial surveying became the business of the new civil agencies, as did large-scale mapping (1:25,000 and larger), but smaller-scale topographic maps remained military. The details of civil-military interactions remain obscure, but large areas of new topographic mapping were produced, notably in Karelia and the Leningrad oblast. A peculiarity of the mapping of Soviet Karelia was that sheets were left blank beyond the then frontier of the Soviet Union, perhaps contributing to the Soviet failures in the Winter War of 1939–40 (fig. 573). Eastern and northern European Russia remained substantially unsurveyed, as did most of Asiatic Russia.

For the Soviet Union the Great Patriotic War began

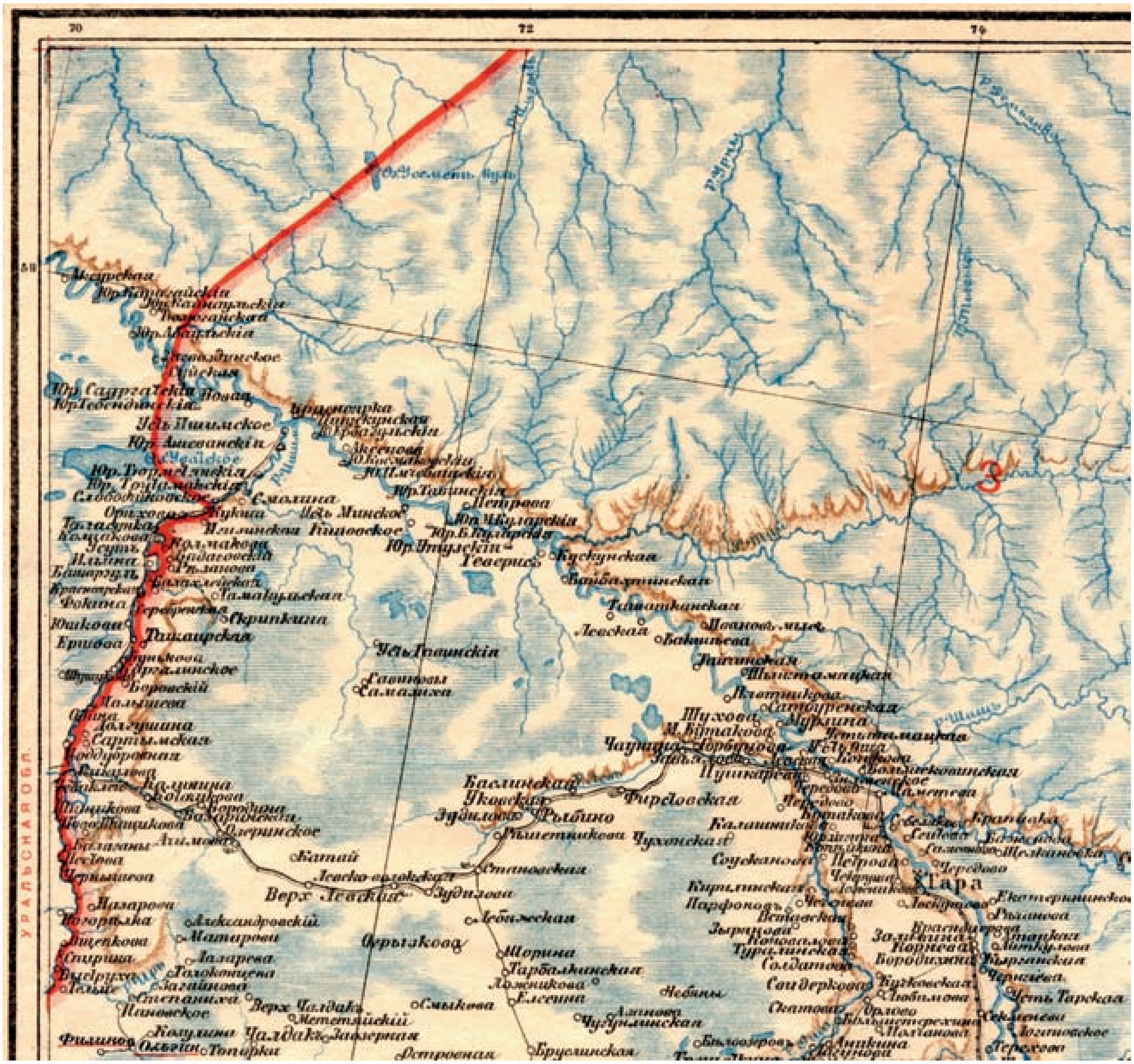

FIG. 571. DETAIL FROM THE 1:1,680,000 (40-VERST) MAP OF THE SOUTHERN BORDER ZONE OF ASIATIC RUSSIA (SHEET IV). Printed in July 1932 with railways revised to 1931–32. The area shown is north of Omsk. The broad red line, shaded to the east, reproduces the line of a Union Republic boundary originally defined on a 1:6,000,000 map issued by the Ministry of the Interior.

Size of the entire original: 56 × 58 cm; size of detail: ca. 16.6 × 17.7 cm. Image courtesy of John L. Cruickshank.

in June 1941. From the beginning there were enormous losses of territory, personnel, stocks of maps, and equipment. The early German capture of the Minsk map factory with its machinery and reproduction material provided a full inventory of current Soviet mapping and transformed the German mapping of Russia. Map factories in Kiev and Kharkov were subsequently also captured, and the factories and other resources in blockaded Leningrad were isolated.

Behind the front lines the initial priority was to complete the 1:100,000 map of Russia west of the Volga (approximately two hundred new sheets). This was done at great cost by the end of 1941. As the Soviet army reformed, an enormous decentralized map production,

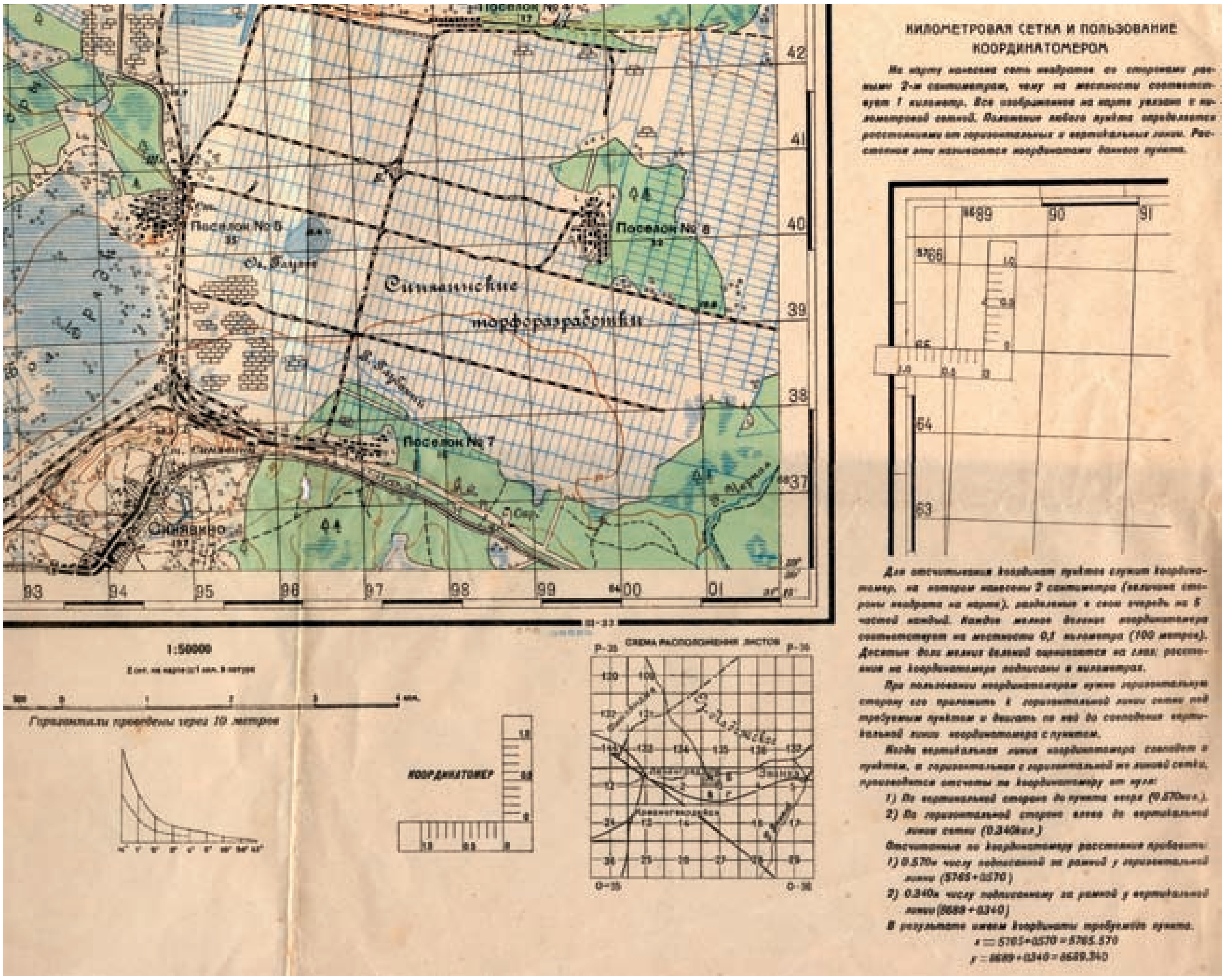

FIG. 572. DETAIL FROM THE 1:50,000 MAP (SHEET O-36-3-A, SHLISSEL'BURG). Surveyed 1923, revised 1931, printed March 1933, one of the early sheets carrying a Gauss-Krüger grid. The instructions given for the use of the grid are closely modeled on the contemporary German model. The peat bogs shown, worked by convict labor, were an essential fuel-supply for Leningrad.
Size of the entire original: 50.5 × 42 cm; size of detail: ca. 24 × 28.7 cm. Image courtesy of John L. Cruickshank.

printing, and supply organization was developed that used all civil and military mapping resources. Within army and front command staffs, there was close cooperation between field intelligence and topographic services; maps were routinely overprinted with local tactical information day to day. Although maps no longer needed should have been returned for destruction, the reverse sides of many were used for letter paper or administrative purposes. Once Soviet troops advanced beyond the former frontiers of Imperial Russia, local maps were redrawn to create Soviet-specification maps (usually at 1:100,000) (fig. 574). Soviet 1:25,000 maps of the approaches through Poland to Berlin had, however, been prepared before the war. Foreign maps were not directly reproduced for issue to Soviet troops.

At the same time in the rear, working groups were reassessing everything about Soviet maps. Instruction manuals were created for making maps and for training in map reading. The geodetic foundations of all Soviet maps were unified and recalculated with a new figure of the earth. Much of this work bore fruit only in 1946 when the unified 1942 geodetic system and substantially redesigned specifications for all topographic maps were introduced (fig. 575). These became the basis of all subsequent Soviet military maps.

Three major themes can be traced in the postwar pe-

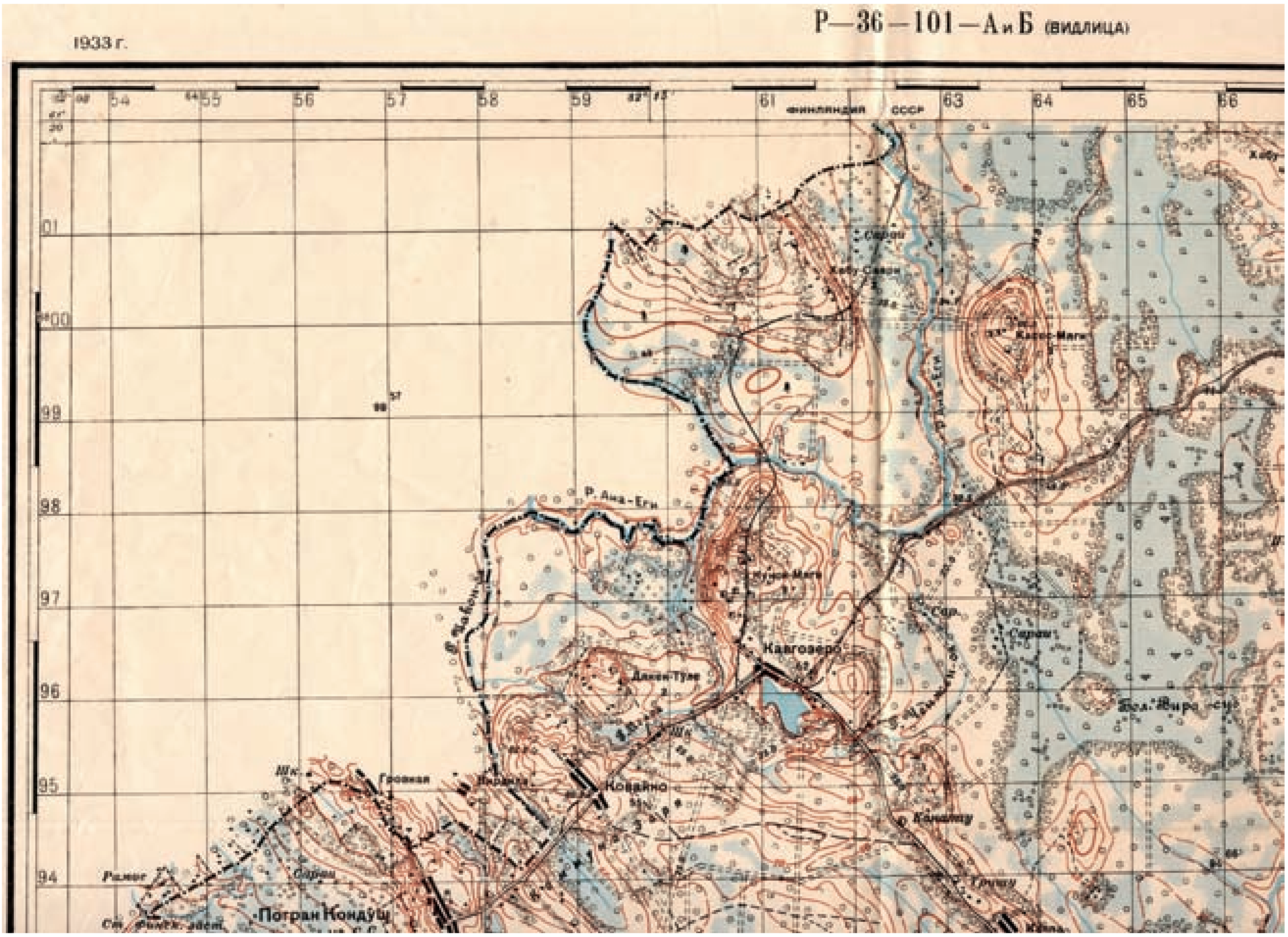

FIG. 573. DETAIL FROM THE 1:50,000 MAP (SHEET P-36-101-A&B, VIDLITSA). Surveyed in 1933 but incorporating the boundary established by the Soviet-Finnish Boundary Commission of 1934 and printed in December 1936. Note that, in contrast to subsequent practice, the topography on the Finnish side of the frontier is left blank.
Size of the entire original: 48 × 43.5 cm; size of detail: ca. 20.2 × 27.8 cm. Image courtesy of John L. Cruickshank.

riod: the completion and improvement of the surveying and mapping of the Soviet Union itself, the integration of the mapping of and by the nations of the Warsaw Pact into the Soviet system, and the extension of Soviet mapping across the world. All three were driven by the demands of the Cold War.

As the Great Patriotic War ended, Stalin decreed that the 1:100,000 map of the whole country had to be completed. Postnikov (2002) described the human cost of achieving even minimal ground control for these surveys in remote areas. The devastated areas of the western Soviet Union also had to be retriangulated and resurveyed. All this was done by 1955. In 1940 1:25,000 had become a military scale, and a project to complete 1:25,000 coverage of the country followed. The specifications for all topographic maps were periodically updated to reflect the landscapes now being mapped (Vereshchaka 2002), but there were few fundamental changes. The surveying required for these developments was largely nonmilitary, but the number of military maps to be prepared, printed, stored, and eventually revised was vast.

Military mapping was resumed at different dates in the Soviet-dominated states of Central Europe. It was not until 1954 that they were all required to adopt Soviet standards. However, by 1950 the Polish army (then commanded by a Soviet marshal) was already producing Soviet-style maps in the Polish language. All socialist nations were required to copy the Soviet structures and establish parallel civil and military organizations under close party and security service control (Unverhau 2006). Once established, these organizations could function alongside their Soviet equivalents as elements of a decentralized multinational structure, and their maps could be directly equivalent to Soviet ones. All reproduction material was duplicated and given to the Soviet Union, and from the 1960s if not earlier, the names and

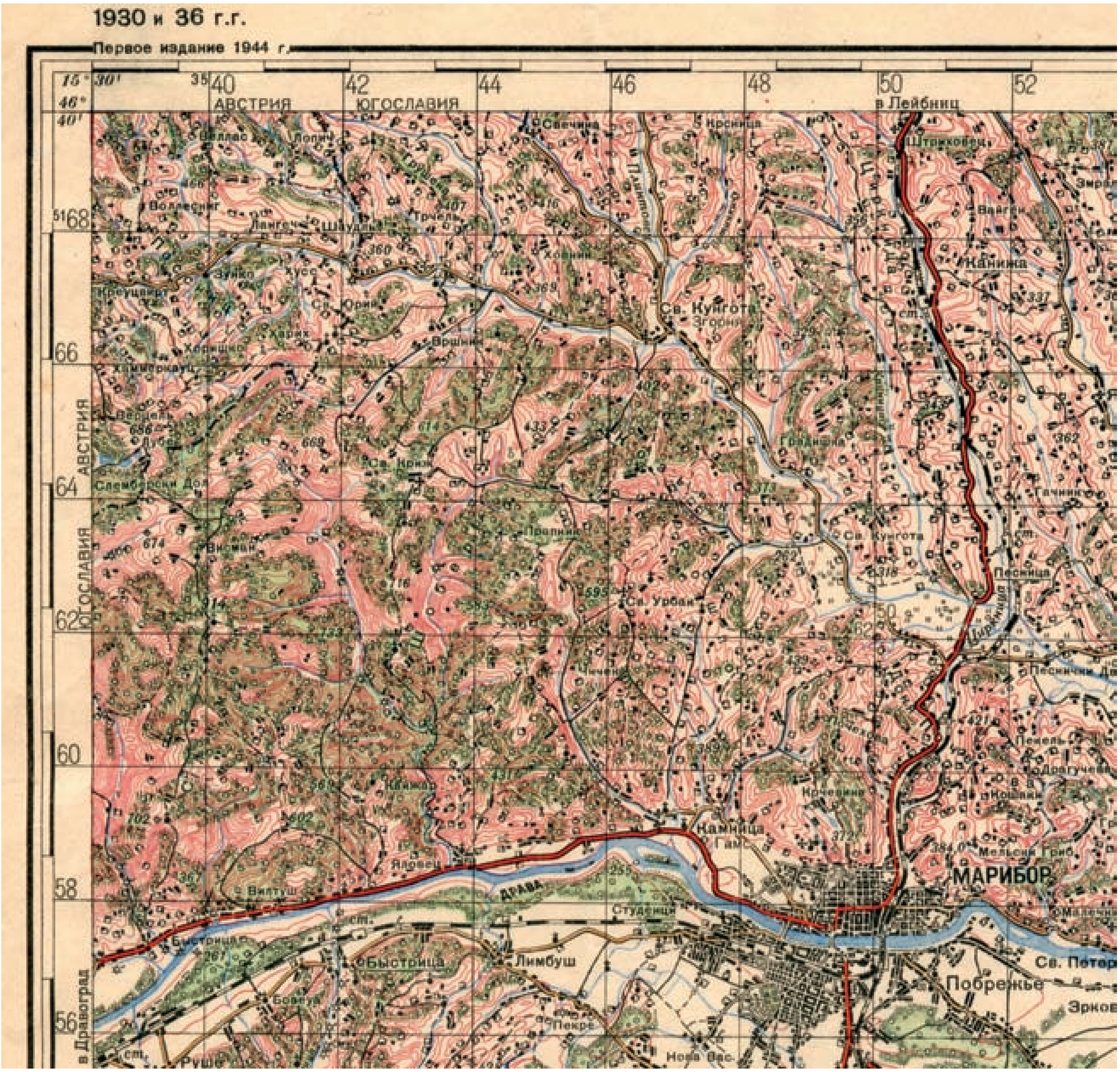

FIG. 574. DETAIL FROM THE FIRST EDITION OF THE 1:100,000 MAP (SHEET L-33–56, MARIBOR). Printed December 1944, it was compiled from the Yugoslav 1:100,000 map of 1932–33 and the Austrian 1:75,000 map of 1937. The dates given at the top of the extract indicate the revision dates of those sources.
Size of the entire original: 41.5 × 41 cm; size of detail: 15.9 × 16.7 cm. Image courtesy of John L. Cruickshank.

marginalia were separated in the reproduction materials so that maps made in one language could readily be reprinted in different languages and alphabets. Thus both Russian and Polish versions exist of many East German military maps. Access to these maps remained strictly compartmentalized, and only the Soviet Union had access to all available material (Fasching 2006).

As a superpower the Soviet Union eventually undertook to map the entire world (Davies 2005). The complex evolution of this enormous project is not completely known, but the 1:1,000,000 mapping of the 1930s and early 1940s was updated after 1946 and extended to include the Americas, Africa, and southern Asia. A number of prototype (or propaganda) sheets at larger scales were produced in the 1940s and 1950s, but the systematic production of tactical-scale maps of Western Europe (in-

FIG. 575. DETAIL FROM THE FIRST EDITION OF THE 1:25,000 MAP (SHEET O-37-135-V-G, ALABUSHEVO). Drawn and printed in 1949 with the 1942-System. It demonstrates that at this scale the introduction of the 1942 coordinate system required more than simply changing the grid printed on maps. The marginal annotation shown indicates that the margins of this sheet had been shifted. It also states that to calculate a (Pulkovo) 1932 system coordinate value, the value of the 1942-System northing should be reduced by 801 meters and the easting reduced by 13 meters. Facsimile reprints of the adjacent sheets (still constructed on the Pulkovo 1932 system) nevertheless continued into the mid-1950s. The area shown includes the Moscow-Leningrad highway to the west of what is now Moscow's Sheremetyevo International Airport.
Size of the entire original: 42.5 × 35 cm; size of detail: ca. 22.4 × 13.5 cm. Image courtesy of John L. Cruickshank.

cluding Britain at 1:100,000) began in the 1960s. Similar mapping of North America dates from the 1970s, and Britain was then remapped at 1:50,000 in the 1980s (fig. 576). Much of this was compiled from existing national map series, but particularly outside Europe some maps were derived from satellite imagery. Parts of this work were delegated to other Warsaw Pact nations including Poland and East Germany. Large-scale plans of an enormous number of towns and cities around the world were also separately produced from the 1950s onward using a complex mixture of sources (fig. 577). Some of these plans have Hungarian versions and may have been produced there (Hegedüs 2008).

Throughout the century the VTS performed educational functions; indeed its Leningradskoye voyenno-topograficheskoye uchilishche (VTU; more recently the A. I. Antonov Institute) was founded in 1822 to train military topographers. Its continuity was maintained through the Revolution by the retention of Vasily Vasil'evich Vitkovskiy and other staff. The service also supplied the vast training needs of the Russian and Soviet armies. The secrecy of Soviet topographic maps prevented their use for teaching map reading, so not all Soviet military maps represented real landscapes. From the 1930s onward, as part of a wide range of textbooks and other teaching materials, increasingly more elaborate sets of training maps portraying falsified landscapes were prepared. For example, teaching set six (issued in 1977) comprised at least twenty-three maps showing sections of one falsified landscape at five different scales. Similar but less elaborate sets of training maps were also prepared by other Warsaw Pact nations.

Research has also been an enduring element within the VTS. A research institute, for many years called the 29-y nauchno-issledovatel'skiy institut (29NII, 29th Scientific Research Institute of the Ministry of Defense), was founded in July 1936. Originally its work concentrated on the development of photogrammetric surveying, and during the Great Patriotic War it developed many fundamental editorial documents. It subsequently focused on geodetic and technical support for the Strategic Missile Forces, on the use of space-based photography for mapping foreign territories, and on the development of the GLONASS (Global'naya Navigatsionnaya Sputnikovaya Sistema) satellite-based navigation system (Filatov 2006). The staff and facilities of the 29NII were substantially enlarged in 1978–81 to develop the digital mapping required for cruise missiles. In association with this the 38th Special Aerophototopographic Detachment (established at Noginsk in the Moscow Military District in 1945) was also expanded to include computing and other facilities and was, as the 38th Central Aerophototopographic Detachment, from 1981 directly subordinated to the chief of the VTU; however, under perestroika further work to automate production of digital mapping was discontinued (Byzov 2003; Rozhenko et al. 2005).

It is still too early for a full assessment of the Russian VTS since the dissolution of the Soviet Union in 1993. Many Soviet mapping facilities ended up in other

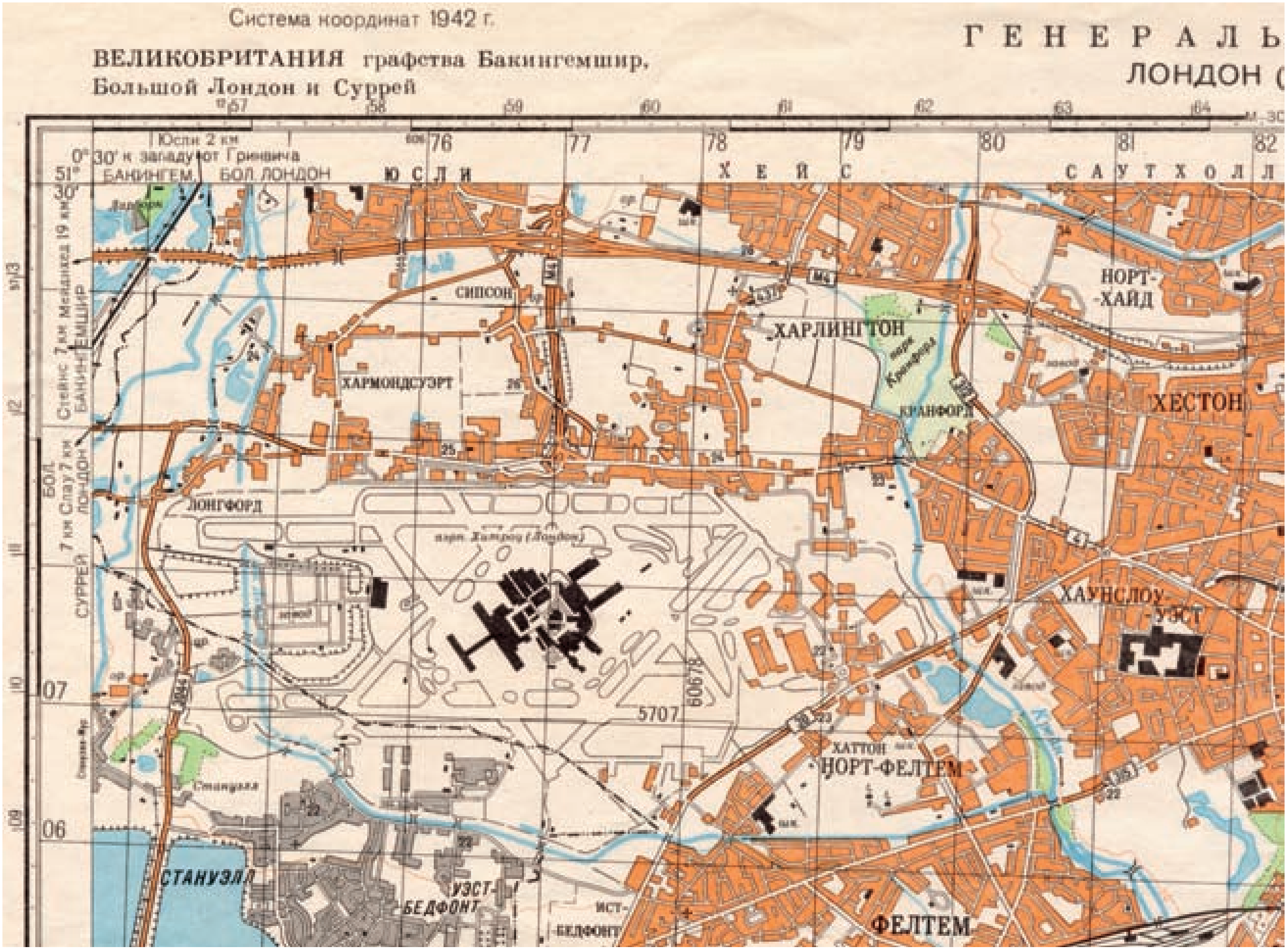

FIG. 576. DETAIL FROM THE 1:50,000 MAP (SHEET M-30-24-V). Compiled from mapping dated 1974 and issued in 1981, showing Heathrow Airport, London. Although the spur from the M4 motorway is shown, the tunnel access to the central terminals is not clearly indicated. Size of the entire original: 43.5 × 41 cm; size of detail: ca. 14 × 18.8 cm. Image courtesy of John L. Cruickshank.

successor states. Within the Russian Federation there was a period of severe retrenchment in the 1990s, and rationalization continued into the twenty-first century. Several military map factories, including those in Moscow and St. Petersburg, became publishers of maps and road atlases for public sale, and marketed their printing and other facilities for commercial use. In this they competed with civilian agencies of Roskartografiya. The secrecy of topographic maps has been partially relaxed after very large numbers were released from storehouses outside Russia, but gridded maps at 1:50,000 and larger scales remain notionally secret. Nevertheless, recent military training texts indicate that new types of maps for warfare in arid and mountainous regions have been developed in the light of experience in Afghanistan and Chechnya (Baranov, Maslak, and Yagodintsev 2006).

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SEE ALSO: Cold War; Coordinate Systems; Military Mapping of Geographic Areas; Projections: Projections Used for Military Grids; World War I; World War II

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FIG. 577. DETAIL FROM THE 1:10,000 PLAN OF LEEDS, ENGLAND (SHEET 1). Compiled in 1971 and issued in 1972. Note that the widths of roads vary abruptly; some major roads are shown at less than true width, while minor roads are enlarged. The z-bend shown in the east-west (orange) main road at a road junction has never existed and is a compilation error. One of the minor roads shown just south of that is fictitious and other errors are identifiable.
Size of the entire original: 88 × 103.5 cm; size of detail: ca. 14.7 × 15.2 cm. Image courtesy of John L. Cruickshank.

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Military Mapping by China. China has an indigenous military mapping tradition going back over 2,100 years. During the Han Dynasty (206 B.C.–A.D. 220), there was a high official post dedicated to surveying and mapping for warfare. However, Western-style military mapping is mainly a product of the twentieth century. The earliest Chinese military surveying and mapping agency with well-integrated Western-style technologies, the Jingshi lujun cehui xuetang 京师陆军测绘学堂 (Military Survey Institute), was set up in 1902 under the Qing Dynasty (Williams 1974). Although a 1:1,000,000 series was planned by the institute and a 1:50,000 series started, little is known about the extent of coverage achieved or its quality. This was a consequence of both the turbulent political situation in the country at the time and a lack of drive by the Qing Dynasty. Following the Revolution of 1911, the new government took a more active interest in mapping, but there was a lack of coordination among the agencies involved (Williams 1974).

Military mapping was put on a firmer basis after Chiang Kai-shek’s Northern Expedition of 1927 and the establishment of a more stable government. In 1928 the Zhongyang guotu cehui ju 中央国土测绘局 (Central Bureau of Land Survey; CBLS) was established under the Zong canmoubu 总参谋部 (Army General Staff). Mapping was carried out at a range of scales, but 1:50,000 was adopted for the standard series. The 1:100,000 series was little more than a reconnaissance map compiled from available sources. From the late 1920s aerial photography was flown for mapping purposes, but it was not until the mid-1930s that photogrammetry became an established method for mapping. The outbreak of the war with Japan in 1937 again disrupted the mapping program, and activities were seriously restricted until 1945.

In Taiwan, which had been under Japanese occupation since 1895, mapping was the responsibility of the Japanese General Staff and the Japanese Imperial Land Survey (Dai Nippon teikoku rikuchi sokuryōbu 大日本帝国陸地測量部). The mapping of Taiwan at 1:25,000 and 1:50,000 scales was commenced in 1895 and continued until 1939. Some partial revision was also carried out in 1944–45 using aerial photography. Smaller-scale derived series were also produced, such as the 1:100,000 series commenced in 1904 (United States, Department of the Army 1963, 131).

The establishment of the People's Republic of China in 1949 substantially intensified and extended the research and education on military surveying and mapping in mainland China. Chinese military topographic maps include a large-scale series at 1:10,000 and 1:25,000, medium-scale series at 1:50,000 and 1:100,000, and small-scale series at 1:250,000, 1:500,000, and 1:1,000,000. Large-scale topographic maps depict detailed planimetric features and relief forms. They include a large number of individual landmarks, settlement features, traffic networks, bridges, hydrologic systems, soil types, vegetation, and classified relief features. The maps include a grid with plane coordinates and a graticule with geographical coordinates. These maps are highly accurate and allow a straightforward measurement of angles, distances, slopes, and areas of map features. With a uniform map sheet system and a Gauss-Krüger projection, they serve as tactical maps for the study of topography, determination of artillery fire parameters, coordination of commanders in the battlefield, and the operation of joint armies. Usually, large-scale topographic maps are created on the basis of military geodetic surveying that establishes the framework for plane coordinates and heights and analytical aerial photogrammetry as the source of mapping contents. Medium- and small-scale topographic maps, or joint operation maps, serve as campaign and strategic maps used by ground forces in combination with other military services and armed forces. With emphasized visualization of large-scope settlements, transportation networks, and maritime and aerial topographic features, they allow various armed forces to study battlefield environments, anticipate operation plans, command joint operations, carry out military maneuvers, and perform other military tasks. The joint operation maps at 1:250,000 and 1:500,000 use a Gauss-Krüger projection, while those at 1:1,000,000 use a conformal conic projection with two standard parallels.

Military aviation charts fall into two categories: general aeronautical charts and special aeronautical charts. General aeronautical charts serve the needs of air pilots and are typically used to determine flight courses, organizing air defense and commanding air-to-air combat. Ferry flights of aviation corps and civil aviation transportation can also rely on general aeronautical charts. The typical map scales are 1:500,000, 1:1,000,000, and 1:2,000,000. The aeronautical charts at 1:500,000 are used for medium-low-level and low-speed flight, hyper-low-level and high-speed flight, and also short-intermediate-range flight. Those at 1:1,000,000 are general-purpose charts for the aviation corps and are widely used for medium-level, medium-speed and intermediate-range flight. Those at 1:2,000,000 are mostly used for high-level, high-speed, and long-distance flight. They generally use a conformal conic projection with two standard parallels for regions between latitudes 80° north and south. For regions beyond 80° north and south, the polar stereographic projection or Mercator projection is used. Aeronautical features, highest regional altitudes, and their reliability are highlighted and annotated in red with large fonts to ensure flight security. Terrain features are depicted using contour lines in combination with layer tints. Residential areas are classified with emphasis on administrative importance and landmark significance. The topological relationships among area, line, and point landmarks are strictly preserved. Moreover, map features are positioned as accurately as possible.

Special aeronautical charts are made to meet the demands of the aviation corps. They specifically highlight features relevant to flight, pilot, and command within a selected battlefield. Their sheet size, contents, scale, and projection are determined on demand. Examples include instrument approach charts, air base training charts, route charts, aerial situation charts, and air corridor charts.

Marine charts are also produced for a number of uses, such as for naval campaigns and the study of the maritime situation, marine positioning, and course determination. Usually they are organized according to purposes and cover regions without fixed scales. The sheet numbers generally consist of region numbers and geographic order numbers aligned, for example, with the trends of coastal geography. Special symbolization and generalization principles are applied to visualize maritime features such as coasts, seafloor relief, navigation obstructions, navigation aids, hydrographical features, and sea boundaries. Whenever nautical broadcasts announce any changes to maritime regions, the corresponding map features are updated directly on the charts. Marine charts are categorized into nautical charts, general sea charts, and thematic sea charts.

Nautical charts depict fundamental marine features relevant for cruising and sailing security. They can be

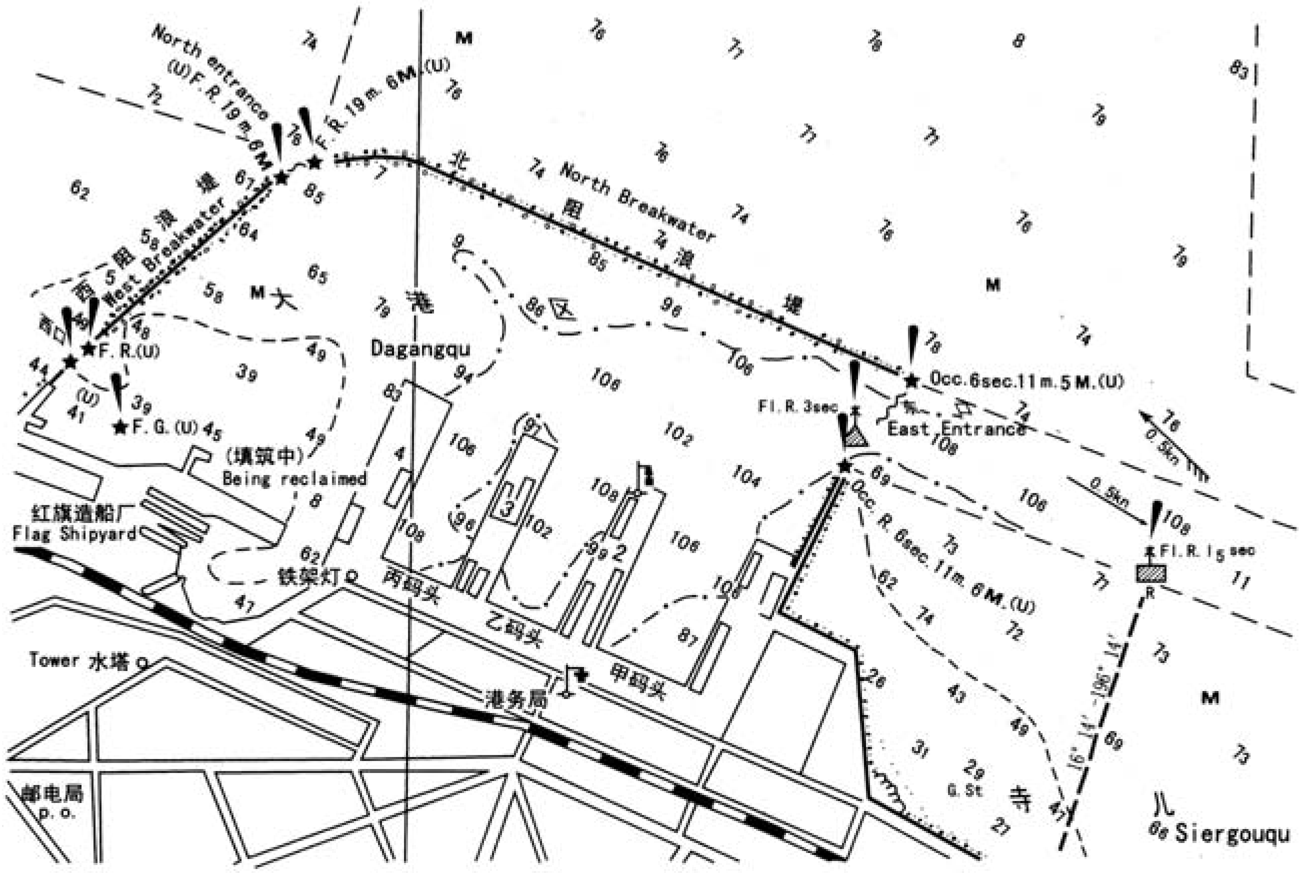

FIG. 578. SAMPLE MAP, A SECTION OF HARBOR CHART 1:45,000. Compare figure 579.

From Wang et al. 2006, 269.

subdivided into general charts of marine zones, sailing charts, and harbor charts (fig. 578). General charts of marine zones, usually at scales smaller than 1:3,000,000, are useful for the study of morphological characteristics of the marine zone, determination of action plans, and sailing courses. Sailing charts at scales ranging from 1:50,000 to 1:3,000,000 include ocean navigation charts, distant sea navigation charts, offshore navigation charts (fig. 579), coastal charts, and channel charts. Harbor charts, at scales larger than 1:100,000, are typically used for ships and vessels to pass in and out of harbors and to select anchorages, for troops to execute landing operations or antilanding operations, as well as for harbor construction.

General sea charts present all kinds of natural and social phenomena of the marine space, their correlations and dynamic changes. They serve all levels of governmental agencies, command departments, and operation branches for the analysis of the marine geographic situation and the determination and deployment of marine operations. General sea charts are subdivided into situation charts and bathymetric charts of the oceans. The former are usually at a smaller scale, depicting the overall situation of an entire marine environment. The latter mainly present marine topography, relief undulation, submarine superficial structure, and natural and cultural features.

Thematic sea charts are used to visualize certain selected natural phenomena or socioeconomic phenomena. Sea charts of natural phenomena include marine hydrological charts, marine biological charts, marine gravimetrical charts, and marine magnetic charts. Sea charts of socioeconomic phenomena include nautical history charts, marine traffic charts, marine aquatic charts, and marine regional charts.

Military thematic maps depict one or several selected military themes in detail and with salient symbols. They can be military geographic maps, military transportation maps, military situation maps, and military target maps. Military geographic maps present a comprehensive overview of the environment of a military region. They include world military geographic maps (1:5,000,000), national military geographic maps (1:3,000,000), and theater geographic maps at different scales. Military transportation maps emphasize presentation of ground

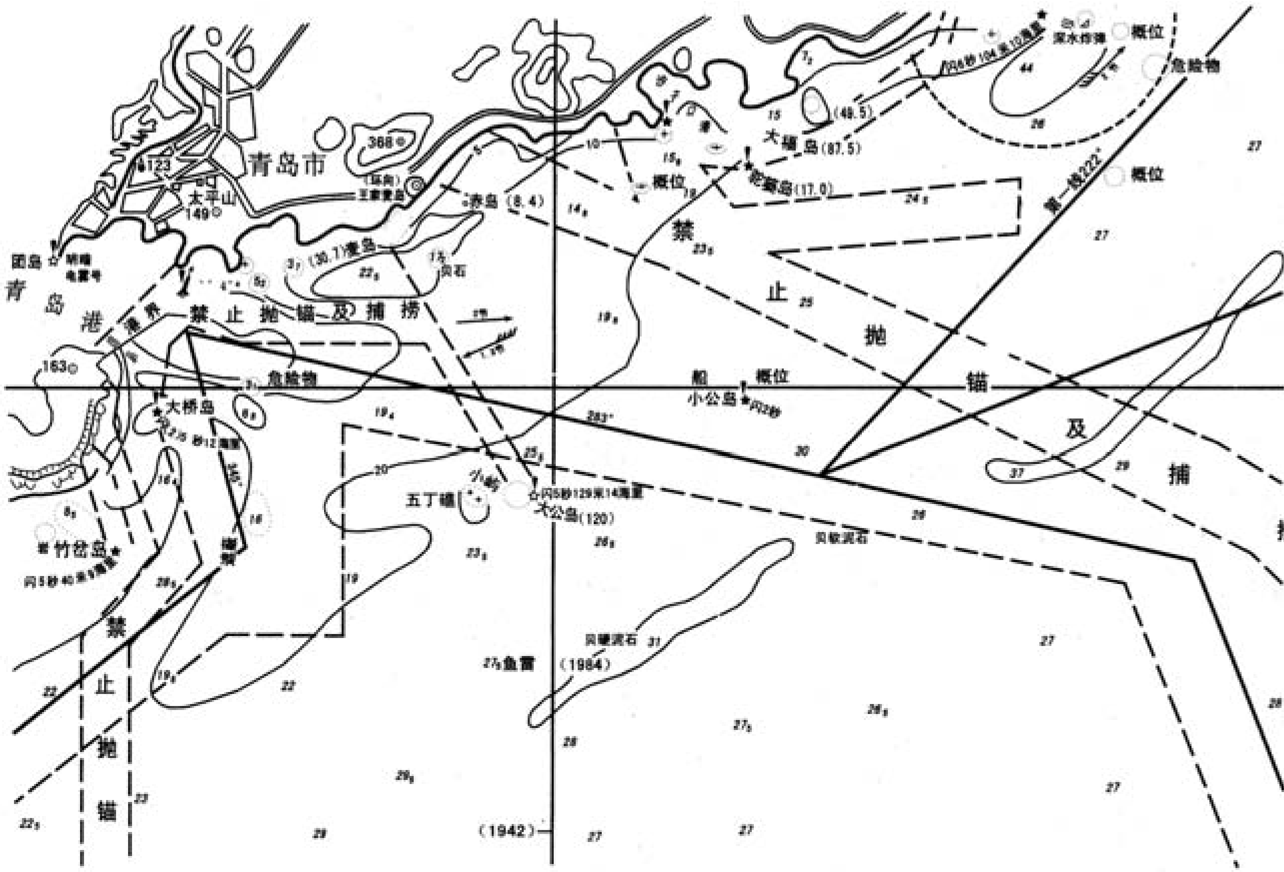

FIG. 579. SAMPLE MAP, A SECTION OF OFFSHORE NAVIGATION CHART 1:250,000. Compare figure 578.

From Wang et al. 2006, 270.

navigational and transportation capacity. They typically use a Gauss-Krüger projection or a conformal conic projection with two standard parallels. There are national military transportation maps, theater military transportation maps, province military transportation maps, and military transportation and logistics maps at scales of 1:500,000, 1:800,000, 1:1,000,000, 1:1,500,000, and 1:2,500,000. Military situation maps highlight up-to-date international and domestic military affairs and important news as well as the evolution of theater military situations. They may cover topics such as military history, examples of battles, military news, the political-military situation, and operational postures. Military target maps emphasize the position, shape, characteristics, and the distribution of strategic, campaign, and tactical targets at scales ranging from 1:5,000 to 1:25,000.

From the 1950s to the 1960s, Chinese military map design was substantially influenced by Soviet cartography, represented by Konstantin Alekseyevich Salishchev. In the late 1970s and early 1980s, Euro-American cartographic theories were gradually introduced into Chinese military cartographic education. Among others, the cartographic communication theories of Antonín Koláčný and Ulrich Freitag, the cartographic model theory of Christopher Board, and the cartographic semiotics and visual perception theories of Jacques Bertin, Arthur H. Robinson, Joel L. Morrison, and others were widely disseminated. A great number of psychophysical experiments on map design, especially visual perception theory, were conducted in 1990s. Gao Jun 高俊 (1986, 1999) developed the cartographic space cognitive theory on the basis of cognitive sciences. Wang Jiayao 王家耀 (1998, 2005) scrutinized the individual processes involved in cartographic space cognition. Cartographic communication theory and cartographic space cognition theory were adopted as the theoretical foundation for map design while cartographic visual perception and cartographic semiotics served as the applied theories for the practice of map design (Chen and Jiang 2000; Wang et al. 2006). A system methodology of map symbolization was successfully implemented in *Zhongguo renmin jiefangjun junguan ditu ji* 中国人民解放军军官地图集 (Chinese people's liberation army officer atlas) by 2000.

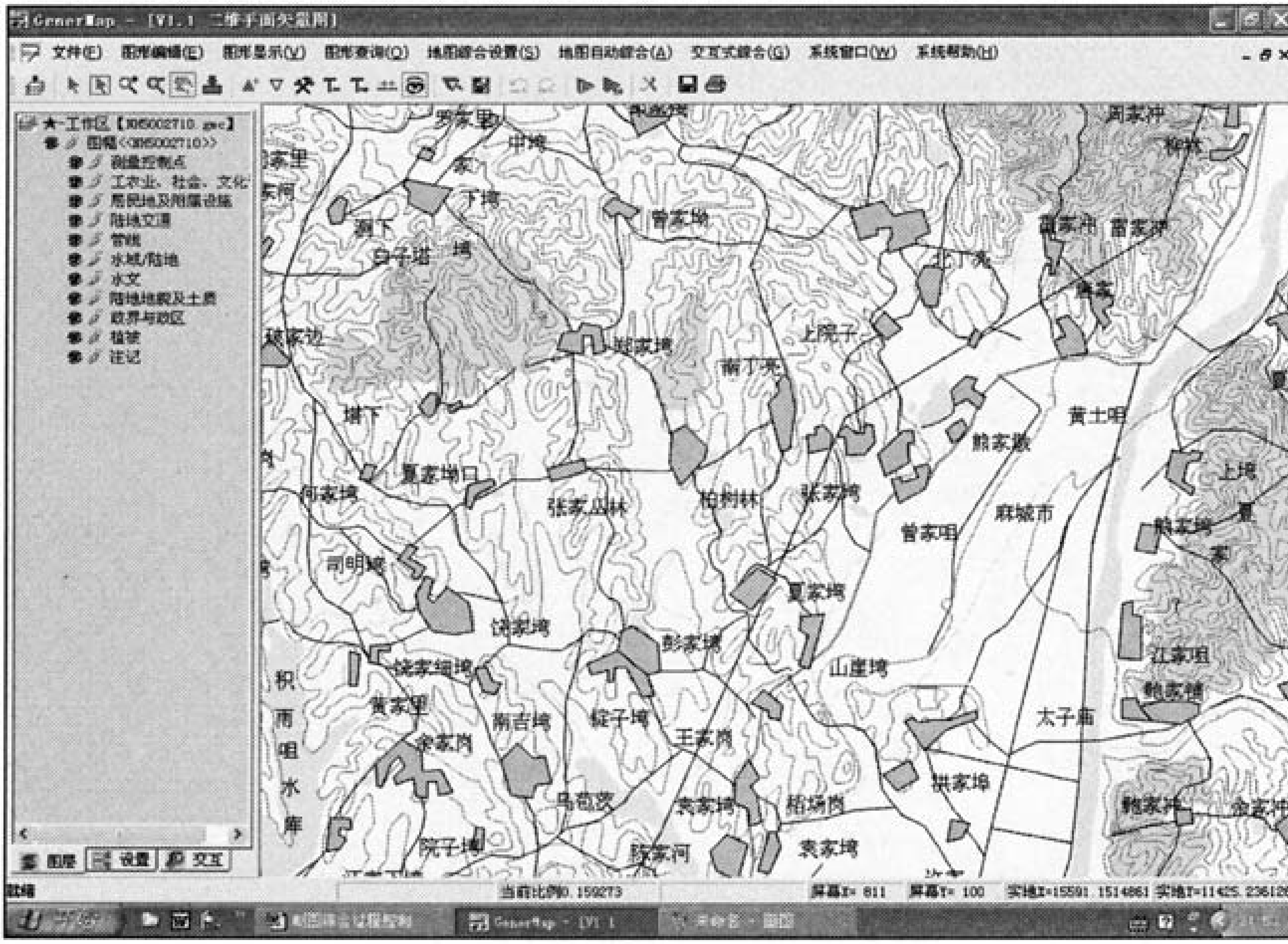

FIG. 580. SCREEN SHOT FROM THE DIGITAL CARTOGRAPHY SYSTEM, SOURCE MAP. Compare figure 581.

From Wu et al. 2008, 333.

In the first four decades after the foundation of People's Republic of China, large-scale topographic maps were produced mainly on the basis of analog aerial photogrammetry along with plane table mapping. Medium- and small-scale joint operation maps were compiled from existing material using manual drawing or scribing and reproduced using photography, plate making, and process-printing technologies. Since the 1990s, large-scale topographic maps have been completely produced from aerial photographs and satellite remote-sensing imagery using digital photogrammetric systems. Joint operation maps are compiled using digital cartographic systems developed in-house. The map originals are then edited using electronic prepress technology and output as color separation films for plate making and printing, or they go through a digital direct plate-making system to obtain the printing plates.

Little is known about Chinese military mapping beyond the national borders. Some Chinese mapping of Korea was produced based on copies of captured Japanese maps for use by Chinese forces during the Korean War (United States, Department of the Army 1963, 123). Mapping must also have been made of Vietnam for use in the brief border war between the two countries in 1979. The border tensions between China and the Soviet Union, which lasted through much of the 1960s, must also have resulted in military mapping of at least the border region.

In the 1980s, military cartography as a fundamental component of military surveying and mapping in China underwent a paradigm change from manual cartography to digital cartography and geographic information engineering. The discipline of military cartography and geographic information engineering addressed modern theories and technologies required to design and produce military maps as well as develop military geographic information systems. While military maps depict the spatial distributions, interrelations, and dynamic changes of natural and social phenomena relevant to military operations, military geographic information

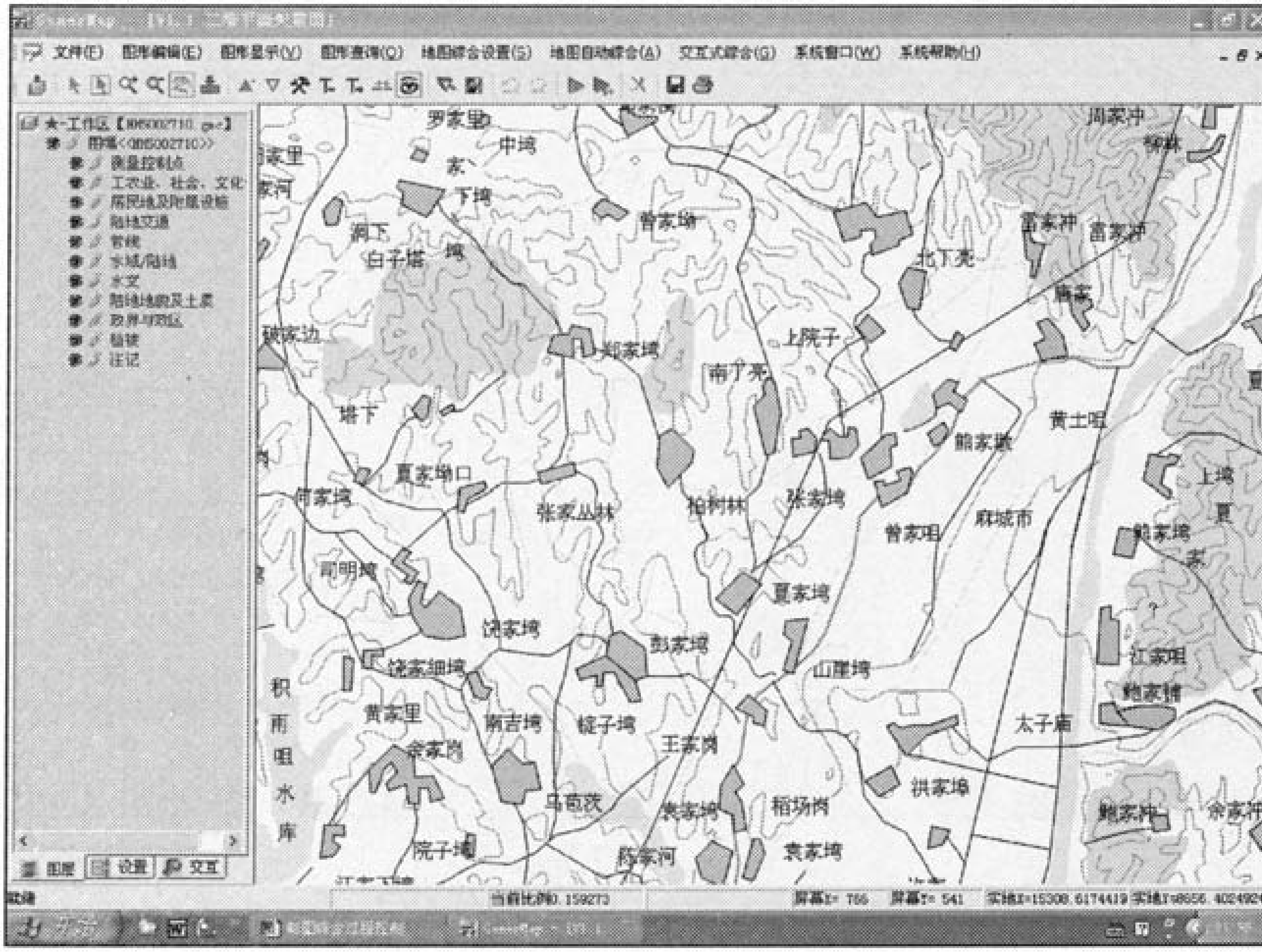

FIG. 581. SCREEN SHOT FROM THE DIGITAL CARTOGRAPHY SYSTEM, GENERALIZED MAP. Compare figure 580.

From Wu et al. 2008, 334.

systems are constructed to capture, abstract, store, manage, analyze, and visualize the military environment and used as working platforms by all-level commanders and headquarters who need up-to-date databases, accurate maps, and technical support for the study of the battlefield and the navigation of airplanes, ships, and land vehicles along with the launch of long-distance weapons, manned space programs, orbit moon plans, and command automation systems. The main topics of this discipline are map projections, map design, map compilation, integrated map production and publication, acquisition and update of multiple geographic data sources, management and retrieval of mass geographic databases, spatial data handling and knowledge discovery, quality control of spatial data, visualization, and virtual geographic environment (Wu 1989; Yang 1990; Gao, Xia, and You 1999).

Automation of map generalization is a core technology in digital military cartography (figs. 580 and 581). Research and experiments allowed cartographers to gain an improved insight into the nature of generalization. The subjective generalization process was converted into a number of objective computer routines supervised by human cartographers. The qualitative criteria used to guide and evaluate the manual generalization process were incrementally transformed into quantitative descriptions in generalization modules. The individual computing models, algorithms, and experiments were integrated in a comprehensive map production system that could conduct iterative generalization processes for all map features at all defined scales and manage the quality of generalization results. This system had been progressively elaborated for the mass production of digital military topographic maps since the end of the century (Wu et al. 2008).

The construction of military map databases in China began in the late 1980s. National map databases were created at 1:50,000, 1:100,000, 1:250,000, 1:500,000, 1:1,000,000, and 1:3,000,000, a world map database at 1:5,000,000, and aviation chart databases and marine chart databases at various scales. The updating of military map databases is supported by three complementary methods: a remote sensing imagery revision system that allows detection of change in land cover and the extraction and vectorization of topographic features; a vehicle-borne GPS system for the actualization and enrichment of a road database; and a map generalization system for the cascaded derivation of multiple topographic map databases at smaller scales from the updated larger-scale map databases.

Military map databases are used for command and operations, weapon systems, moving platforms, military geographic information system, operation training simulation, and map production. In battle command controlling systems, digital maps derived from databases serve as the foundation for the comprehension of the battlefield environment and spatial positioning of posture information. Such functions as the superimposition of friend and foe posture, the dynamic display of changing battlefield situation, the fabrication of electronic sand tables, and queries and spatial analysis of battlefield information are all supported by the map databases. In weapon systems, such as long-distance precision-strike weapon systems, map databases are indispensible for target detection and guidance. For various moving platforms, such as satellites, airplanes, ships and vessels, and land vehicles, map databases provide the information about target orientation, position, and navigation necessary for movement security. In military geographic information systems, map databases are the backbone of a military geographic environment database and support functions such as query, search, spatial analysis, and visualization. In operation and training simulation systems, map databases are again the foundation for the development of virtual reality technologies that can create immersive battlefield environments for commanders to plan the operations and execute maneuvers. Finally, military topographic map databases, aviation chart databases, and marine chart databases are sources from which military maps are derived and updated.

Chinese military cartography made tremendous progress in the second half of the twentieth century. Its theoretical framework is characterized by multiple spatiotemporal cognition models including maps, geographic information systems, and virtual geographic environments. Technically, the traditional manual mapmaking processes have been replaced by digital cartographic systems. The typology of military maps has been diversified from paper maps to digital maps in different formats, media, and access modes. Accordingly, the applications were extended from the use of paper maps to the use of digital maps, electronic maps, web maps, web-based geographic information systems, and virtual geographic environments. Chinese military cartography achieved an internationally advanced level and made a significant contribution to developments in world cartography.

LIQIU MENG

SEE ALSO: Coordinate Systems; Military Mapping of Geographic Areas: Southeast Asia; Projections: Projections Used for Military Grids

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Military Mapping by Japan. The Japanese Imperial Land Survey (Dai Nippon teikoku rikuchi sokuryōbu 大日本帝国陸地測量部) was established under the General Staff office as a part of the Japanese army in 1888. While the navy and its hydrographic service largely followed British models, including the use of imperial units for measurement, the army was initially modeled on the

French army and adopted the metric system for measurements and map scales. However, after the defeat of France in the Franco-Prussian War (1870–71) the Germans started to replace the French as the dominant influence and the General Staff subsequently adopted the Prussian model (Harries and Harries 1991, 31).

While the Japanese Imperial Land Survey was primarily responsible for mapping the Japanese home islands, from the start it was also responsible for mapping territories acquired by Japan as the result of various wars (Hasegawa 2008). The first opportunity to engage in mapping outside of the home islands came during the Sino-Japanese War in 1894, when work was carried out in support of military operations in Korea and northern China. Mapping in Korea was largely under the control of the temporary mapping department. Under the Treaty of Shimonoseki (1895) Taiwan was ceded to Japan, and mapping of the island started at 1:25,000 and 1:50,000, with coverage at the former scale completed in 1934.

The Russo-Japanese War (1904–5) provided the next opportunity for overseas mapping, again with the formation of a temporary mapping department to carry out surveying and mapping in the field. During the course of the war the department surveyed in Manchuria and Mongolia. Southern Sakhalin Island was ceded to Japan at the end of the war under the Treaty of Portsmouth (1905), and a party was sent to survey the boundary demarcation along the 50°N parallel. A triangulation network was subsequently established for the southern half of Sakhalin, and the territory was mapped at scales from 1:25,000 to 1:500,000. Although mapping was extended to cover the whole island, it is not clear whether this was always part of the original mapping program or a subsequent extension of a program set up following Japanese intervention in the Russian Civil War (1917–23) and its occupation of Eastern Siberia.

Koji Hasegawa (2008) claimed that Japan started mapping in Manchuria and Korea in 1907, and began mapping China secretly the following year. However, the Clark University map collection has 1:100,000 maps of parts of Manchuria from 1906, mapping of Korea from 1905, and mapping of China from 1906. It is possible that all the earlier dates relate to mapping carried out during the Russo-Japanese War, and that Hasegawa's later start dates refer to the decision to extend the coverage of surveys carried out during the war. Unfortunately, little research has been carried out on Japanese military mapping and the decision making behind it. At the end of World War II much of the Japanese military mapping and supporting documentation was destroyed to prevent it from falling into Allied hands (Hasegawa 2008, 7). This may be responsible for the uncertainty regarding the dates of different activities. *Foreign Maps* (United States, Department of the Army 1963, 114–15) gives 1896 as the start date for Japanese mapping at 1:25,000 and 1:50,000 for various areas in east China, and 1904 as the start date for 1:100,000 mapping. Despite the discrepancies among sources over the precise dates when mapping programs were commenced, it is clear that in the first decade of the century Japan was mapping parts of the East Asian mainland in anticipation of future military interventions and the expansion of its empire.

Japan annexed Korea in 1910 and began systematic mapping of the country at 1:25,000, 1:50,000, 1:200,000, and 1:500,000. Initially, this was carried out by a combination of the Japanese Korean Provisional Land Survey Bureau (Chōsen Sōtokufu rinji tochi chōsakyoku 朝鮮総督府臨時土地調査局), the Japanese General Staff, and the Japanese Imperial Land Survey, but with the pacification of the country, the mapping became a largely civilian function.

The Japanese intervention in Russia during the Civil War led to renewed mapping activity in Eastern Siberia. Some of the military maps were direct copies of captured Russian 1:84,000 and 1:302,000 maps, but others, such as the 1:25,000 mapping of the Nikolayevsk area and Vladivostok, were based on new surveys. A map at 1:50,000 was also produced for the Ussuri Province. Interest in military mapping of eastern Siberia waned following the withdrawal of Japanese forces at the end of the Russian Civil War and was not renewed until the late 1930s.

During the 1920s Japanese military mapping was largely confined to territories acquired earlier in the century either by conquest or through leasing, such as Kwantung in Manchuria. However, there was some covert mapping of strategically important areas in central Manchuria at 1:25,000 and 1:50,000 during the 1920s and at the start of the 1930s. The covert nature of this mapping meant that it could not be based on high-order triangulation and precise planimetric methods (United States, Department of the Army 1963, 120). The expansionist policies adopted by the Japanese government following the staged 18 September 1931 explosion at Shenyang (also known as the Mukden Incident) led to renewed interest in military mapping, initially in Manchuria itself, but subsequently in China more generally. Following the establishment of the Manchukuo puppet government in 1932, a Manchukuo survey office was established under Japanese control. The Japanese Kantōgun sokuryōtai 関東軍測量隊 (Kwantung army's survey unit) and the Japanese General Staff also published maps of Manchuria at a variety of scales—1:50,000, 1:100,000, 1:200,000, and 1:500,000—with some larger-scale mapping of urban areas. This larger-scale mapping was based on aerial photography and ground surveys, whereas the smaller-scale mapping was initially based on earlier Japanese, Chinese, and Russian surveys.

Japan had been involved in covert mapping of northern China since 1932 as part of its preparations for a war that was widely expected and for which some elements in the army were actively planning (Harries and Harries 1991, 124–28). Part of these preparations included photographic sorties over Chinese territory, one of the earliest uses of aerial photography to create covert mapping during peacetime.

Following the Japanese moves into eastern China in 1937 topographic series were compiled covering major transport and communication lines as well as urban and strategically important areas. These maps were produced at scales between 1:10,000 and 1:100,000. Special-purpose military series were also produced at 1:50,000, 1:100,000, 1:200,000, and 1:500,000 for most of eastern China. This mapping was based on a mixture of photogrammetric methods, field reconnaissance, and earlier Chinese and Japanese mapping (United States, Department of the Army 1963, 110–11). In 1937 a Battlefield Survey Unit was established to carry out mapping in China (Hasegawa 2008).

Japanese military mapping of the Soviet Far East continued during the 1930s, when conflict between them seemed an inevitable consequence of competition for resources (Harries and Harries 1991, 149–50). Indeed, the war in China was initially regarded as a way to secure the Japanese rear in preparation for war with the Soviet Union. When that war broke out in 1939, it rapidly became clear that the Japanese had completely underestimated the fighting potential of the Soviet army and overestimated the impact on the Soviet military of the purges carried out earlier in the decade. The overwhelming defeat of the Japanese army at Nomonhan (20–31 August 1939) convinced the Japanese General Staff that it could not win a war against the Soviet Union and forced the High Command to look elsewhere for opportunities for expansion and the acquisition of natural resources. Trade boycotts of Japan, largely a consequence of its military actions in China, forced Japan to find alternative sources of raw materials and markets for its products.

Japan's initial move was into French Indochina, which it invaded in September 1940 and fully occupied by the following July. The military mapping of Indochina, which was started in 1940, was based entirely on existing French mapping. However, French Indochina was not the only potential target to be mapped by the Japanese. While the army's General Staff had territorial ambitions in Russia and China, the navy followed a policy of expansion toward the south and east into the Pacific. Because expansion in those directions was likely to bring Japan into conflict with the United States, which had military bases in the Philippines, the Japanese began to map the Luzon Island area at 1:200,000 in 1938. Dutch Borneo was also identified as a potential target, and mapping was started there in 1940, based on Dutch originals at 1:100,000 and 1:200,000. The mapping of Borneo was restricted to areas that had been properly mapped by the Dutch, such as around Banjarmasin, because for much of the island the Dutch originals were little more than sketch maps.

Japanese mapping activities accelerated in 1941 with additional mapping of parts of the Philippines at 1:50,000 and 1:100,000. Mapping of British Malaya at 1:50,000 and 1:100,000 and of Thailand at 1:50,000 and 1:200,000 was also initiated in preparation for an expansion toward the south. However, when the war began in December 1941, the mapping available to Japanese forces assigned to the Philippines, the Netherlands East Indies, and British Malaya would have been regarded as inadequate by contemporary Western armies. Good mapping was sporadic and based entirely on colonial mapping that was frequently out-of-date. For the rest of the colonial territories the best available mapping was small-scale sketch maps. Against better-prepared, more heavily armed opponents, these deficiencies in Japanese mapping could have proved decisive.

Following the rapid conquest of Malaya, the Netherlands East Indies, and the Philippines, the Japanese army set up mapping programs in anticipation of counterattacks by the United States and Britain. In 1942 the Battlefield Survey Unit was sent to Southeast Asia to support the ongoing campaign in Burma. Some of the earliest of this mapping was produced in support of the campaigns in New Guinea and the Solomon Islands. In both cases these were offensive campaigns that turned defensive once the Allied counterattacks started, and the mapping was produced to meet an urgent military need. As neither territory had been adequately mapped by the colonial powers, Japan was forced to create new mapping. The difficulties of mapping in these areas and urgent military needs meant that the maps were frequently little better than sketch maps.

In the islands of Micronesia and the Bismarck Archipelago the Japanese had the time and resources to carry out systematic mapping of what were intended as a series of island fortresses to protect the core of the Japanese Empire. Mapping of these islands was mainly carried out in 1943 and 1944, but in the Caroline Islands the Japanese were able to use earlier mapping created after they acquired the islands at the end of World War I.

At the end of World War II most of the organizations responsible for military mapping were disbanded and the Japanese Imperial Land Survey Department became a civilian mapping agency.

PETER COLLIER

SEE ALSO: Coordinate Systems; Military Mapping of Geographic Areas: Korea; Projections: Projections Used for Military Grids; World War I; World War II

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Military Mapping of Geographic Areas.

This composite examines military mapping in areas with substantial activity by colonial powers or by other nation-states operating both within and outside their own borders. When not a part of colonial endeavors, this mapping was typically spurred by major wars, including the Cold War, or by national defense.

Military Mapping of Canada and the Polar North. The first significant twentieth-century event in the military mapping of Canada was the formation of the Mapping Branch in the federal Department of Militia in 1903. Initial projects involved topographic mapping in the Niagara Peninsula and along the border with the United States. This early mapping was done by plane table compilation based on survey control established using prismatic compass, pedometer, and spirit leveling. Five maps per year were produced at the scale of one inch to one mile. Maps were also produced of military bases and training areas. By 1939, when Canada entered World War II, 147 national series maps had been published including Ottawa and areas of Nova Scotia and Manitoba.

Despite experimentation with aerial photography following World War I and photogrammetric plotters in the mid-1930s, Canadian mapping agencies were still basically using mapping methods of the nineteenth century (Sebert 1999, 140). World War II was to dramatically change that. On 26 January 1940, the Canadian First Corps Field Survey Company sailed to England with a complement of 7 officers and 137 sappers (combat engineers). Exposed to the modern instrumentation and methods of the British and American forces, the unit adapted and performed remarkably well (Thomson 1969, 165) and, at war's end, brought their acquired knowledge and skills to military and civilian mapping organizations back in Canada. The military survey organization was reorganized in 1946 as the Army Survey Establishment.

Military influence was instrumental in revamping the specifications for national mapping in Canada to better conform to the standards of the North Atlantic Treaty Organization (NATO) in terms of metrication, content, and terminology (Holmes 1997, 202). Soon after the war, the United States and Canadian military survey and mapping agencies began joint planning of defense mapping under the umbrella of the United States–Canada Basic Security Plan. Recognizing serious deficiencies in mapping for defense, particularly in Canada's north, the first priority was to produce the 918 maps required to cover Canada at the 1:250,000 scale. The civilian federal mapping agency, the Surveys and Mapping Branch, shared production with the military in the priority program to complete the mapping of Canada. Providing ground survey control in Canada's massive and very flat terrain presented a significant problem until the military adapted an American radar navigation system called Shoran (Stretton 1982, 151). The new system proved invaluable, serving well until it was replaced by electronic distance measurement. The Royal Canadian Air Force, using trimetrogon and super-wide-angle-lens camera systems, provided mapping photography of the polar north. At completion in 1970, the military mappers had provided 40 percent of the new maps and had carried out 75 percent of the ground surveying of the mainland Arctic and polar north.

Concurrently with this national mapping project, the military continued production of military training area and base maps, as well as several new products to meet changing defense requirements. One such project was the production of 125 topographic maps at the scale of 1:50,000 to support the Mid-Canada Line, a coast-to-coast string of early-warning radar stations across Canada. A second involved a series of Military Town Plans, intended for reentry operations after a nuclear attack. This 1:25,000-scale series covered potential target cities across the country. The base for this series was subsequently used for Military City Maps in the 1970s in support of internal security operations. Another new product was the Joint Operations Graphic, a NATO series of maps at the 1:250,000 scale, intended for use in joint ground-air operations.

In 1964, the civilian Surveys and Mapping Branch was given sole responsibility for national topographic mapping. The military mapping agency, renamed the Mapping and Charting Establishment in 1966, was limited to mapping in direct support of military requirements with the exception that, to maintain expertise, the unit was permitted to carry out northern survey operations for the Surveys and Mapping Branch. The military unit continued surveying the polar region in support of 1:50,000 mapping until the task was completed in 1987. The trend of increasing demands for dedicated defense mapping continued into the later part of the twentieth century, as new warfare technology significantly changed the nature of survey and mapping requirements, and the military's role in mapping Canada diminished. Despite this trend, military mappers were instrumental in providing rapid geomatics support to national natural disasters such as ice storms, forest fires, floods, and winter storms. Throughout the twentieth century, the mapping carried out by the Canadian military, while contributing to national mapping, has had mapping for defense as its basis.

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SEE ALSO: Coordinate Systems; Military Mapping by Major Powers; Projections: Projections Used for Military Grids

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Military Mapping of North Africa. The French initiated systematic mapping of North Africa in the nineteenth century to support the settlement of French colonists near the coast and to pacify the interior. Although the resulting maps were based originally on the Type 1880 specification in use in metropolitan France, officials decided in 1897–98 to increase the scale from 1:80,000 to 1:50,000, for a hachured monochrome map designed for use by both the military and the civil administration (France, Service géographique de l'armée 1938, 70–71). In addition, interior areas were covered at 1:200,000 (Algeria) or 1:100,000 (Tunisia). While the British had carried out some mapping in support of military operations in Egypt in the late nineteenth century, there had been no systematic mapping elsewhere in North Africa.

Establishment of the Survey of Egypt in 1898 was largely associated with land reform, and its activities were overwhelmingly related to cadastral mapping. Even so, the Survey's presence meant that, in the event of war, the British Army in Egypt would have locally available resources with which to meet some of its mapping needs. Tripolitania, Cyrenaica, and the Fezzan, which were under Ottoman administration, had suffered the same neglect as other Ottoman territories, and there had been little attempt to provide any but the most basic mapping. In 1900 Morocco was still an independent state, but following the occupation of its northern part by the French in 1907 and the establishment of the protectorate under French administration in 1912 (with Spain also administering part of the country), the French mapping programs in Algeria and Tunisia were extended to cover the country.

The first specifically military mapping in North Africa was carried out during the Italo-Turkish War of 1911–12. Neither side had adequate maps when the war began, but the Italian army used its complete freedom in the air to create sketch maps of Turkish positions from vertical aerial photography—the first time vertical photography from aircraft had been used for mapmaking as well as the first time aircraft had been used militarily (Thompson 1966, 10). The Italian army commenced systematic mapping almost as soon as it occupied Tripolitania, Cyrenaica, and the Fezzan, but a local insurgency, which was to continue until 1931, meant that cartographic efforts had to focus on supporting ongoing military operations rather than systematic mapping.

In the unsettled political situation before the outbreak of World War I, Britain was aware of the threat to its strategic supply line through the Suez Canal. A military survey of Sinai was completed in 1913 at a scale of 1:125,000. With Turkey's entry into the war, the British garrison in Egypt was increased, and maps at 1:15,000 were prepared for use in the event of a Turkish attack on the canal. At the same time, the British Army in Egypt was faced with Senussi attacks in western Egypt, where Turkey inspired an expansion of Senussi resistance to the Italian occupation of Cyrenaica. The need to fight the Senussi resulted in the production in Egypt of reconnaissance mapping of the Western Desert but no attempt at systematic mapping (Maule 1919, 2).

During the interwar period the Italians consolidated their hold on Libya, Cyrenaica, and the Fezzan. By the outbreak of World War II, the Istituto geografico militare had produced systematic mapping at scales of 1:25,000 and 1:100,000 for the coastal strip as well as some important oases in the interior. This mapping was based largely on aerial photography and was of a very high quality. Even so, 1:1,000,000 was the largest scale at which the whole country had been mapped. Much of the detail of the interior came from expedition maps compiled by desert explorers, such as Count László Almásy (on whom the novel *The English Patient* was based) and other Britons who later played important roles in World War II (Török 2008). These expedition maps had a significant impact on subsequent military operations because Italian forces were reluctant to operate outside the well-mapped coastal strip, which led to their being outflanked by the British, who were prepared to operate in the poorly mapped desert areas of the interior.

British preparations for fighting in North Africa started early in 1940 with the appointment of a director of surveys and a small staff. In March 1940 they were joined by the 512th Field Survey Company, which was largely responsible for mapping operations in the Mediterranean theater until the end of the war. To supplement his own resources, the director of surveys, as part of the General Headquarters, Middle East Forces (MEF), could draw support from the Survey of Egypt and Survey of Palestine, which proved particularly important because of their reprographics capacity. British work, which initially focused on the anticipated Italian invasion of Egypt, soon included reproducing Italian mapping and extending coverage into the poorly mapped areas away from the coast.

During World War II the British, Italians, and Germans all copied—and overprinted with their own military grids—any maps of enemy territory acquired before the war or captured during military operations. Where possible, this mapping was then revised from aerial photography. A. B. Clough (1952, 52) described how a single copy of the Italian 1:25,000 map of the Tobruk (Tobruch) defenses was captured and reproduced by the British. The British copy was, in turn, captured and copied by the Germans, who were unaware of its Italian origins.

In Europe, most German mapping was produced at the standard scales set by the General Staff of the army (Generalstab des Heeres), even when these adjustments required the photographic enlargement of other countries' maps. In North Africa, medium- and large-scale maps were generally reproduced at the original scale but with sheet sizes and numbering systems changed (United States, Department of the Army 1963). Smaller-scale maps, such as the 1:500,000 series and maps produced for the Luftwaffe, were compiled by the General Staff rather than simply copied from British or French originals.

The British used a combination of ground survey and aerial photography to extend Italian map coverage of Cyrenaica and Tripolitania farther south. Because the Royal Air Force's primary concern was with the defense of Britain, the North African campaign always lacked sufficient equipment, in both numbers and quality, which hampered the acquisition of aerial photography because suitable aircraft and trained crews were frequently not available. The situation was remedied to some extent when South African air force airplanes and crews were transferred to Egypt following the successful conclusion of the East African campaign (fig. 582). However, it was not until early 1943 that the De Havilland Mosquito was made available for photographic missions.

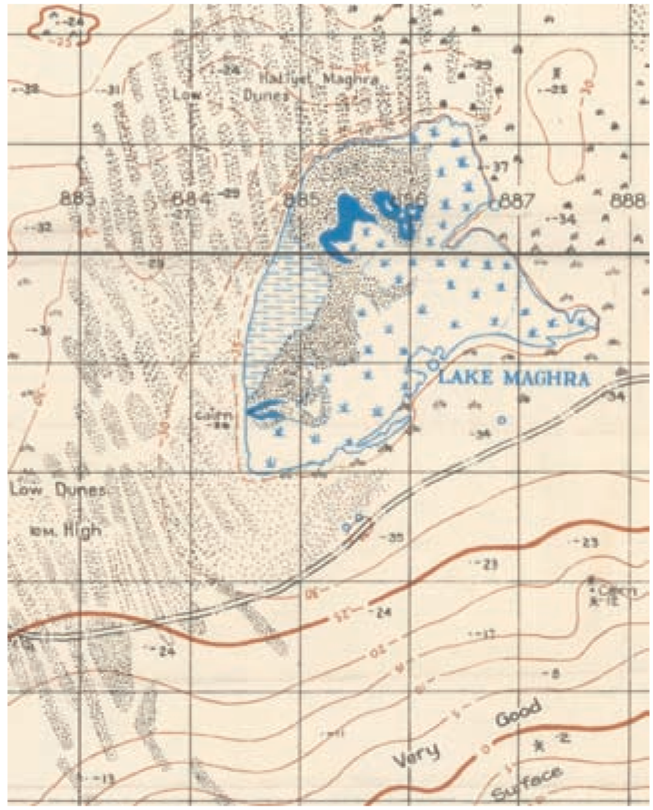

FIG. 582. DETAIL FROM *EL MAGHRA*, 1:50,000, 1942 (1st ED., SHEET 12). Part of the El Alamein position in Egypt, surveyed and drawn by the South African Survey Company in November 1941, it illustrates the difficulty in depicting desert landscapes using conventional line map methods.
Size of the entire original: 57.0 × 42.5 cm; size of detail: 14.6 × 11.7 cm. Image courtesy of Peter Collier.

A major innovation of the British mapping effort was the introduction of the so-called Goings maps, which depicted the suitability of the terrain for different classes of vehicles (fig. 583). The colored maps produced for the Mediterranean theater were quite different from those produced for the invasion of northwest Europe in 1944. Other innovations included the use of block plots for the rapid location of enemy positions. A block plot was a large gridded plotting surface on which the principal points of the existing photography had been located. When mapping personnel received new aerial photography showing newly identified enemy positions, they used the method of intersection to relate these new photographs to those previously plotted on the block plot, and used graphical means to determine enemy positions,

FIG. 583. DETAIL FROM 1:100,000 GOINGS MAP OF *MATRUH EAST* (EGYPT), 1942 (SHEET 3E). The Goings maps were intended to show the suitability of terrain for the movement of mixed mechanized forces.

Size of the entire original: 81.9 × 58.0 cm; size of detail: 11.8 × 17.6 cm. Image courtesy of Peter Collier.

the coordinates of which were then measured and supplied to artillery units (Clough 1952, 64–65).

Prior to Operation Torch, code name for the Allied invasion of northwest Africa in November 1942, the British War Office's Geographical Section, General Staff (GSGS) reproduced all of the available French mapping of Morocco, Tunisia, and Algeria and added the British military grid (fig. 584). These maps were issued to both British and U.S. forces, with reprographic material also sent to Washington, D.C., in case additional production in the United States was needed (Clough 1952, 270–73). Following the occupation of Algiers, the Service géographique undertook a revision on behalf of Allied forces. Because of its limited reprographics capacity, printing was contracted out to civilian printers in Algiers.

An American innovation of the North African campaign was the production, within the North African theater, of photomaps, which were supplied to both U.S. and British forces. However, the British preferred to use available line maps and found little use for the photomaps—a negative attitude toward photomapping that persisted for many years (Clough 1952, 276). The U.S. forces also introduced multiplex plotters into the theater to supplement the British radial line techniques. A British innovation for the Torch campaign was the production of 1:500,000-scale maps with supplementary topographical information supplied by the Inter-Service Topographical Department (ISTD). Established in the School of Geography in the University of Oxford as part of the British Admiralty's Naval Intelligence Division, the ISTD provided expertise in the earth and environmental sciences relevant to military activities.

Even before the defeat of the Axis forces in May 1943, the attention of the Middle East Survey Directorate turned to Sicily and Italy, leaving North Africa relatively neglected. Following the end of World War II the British maintained a military presence in Egypt and Libya, with the latter particular useful for training in desert warfare. Up-to-date military maps were produced to support this presence, but the level of activity was much reduced from that in World War II. The outbreak of the nation-

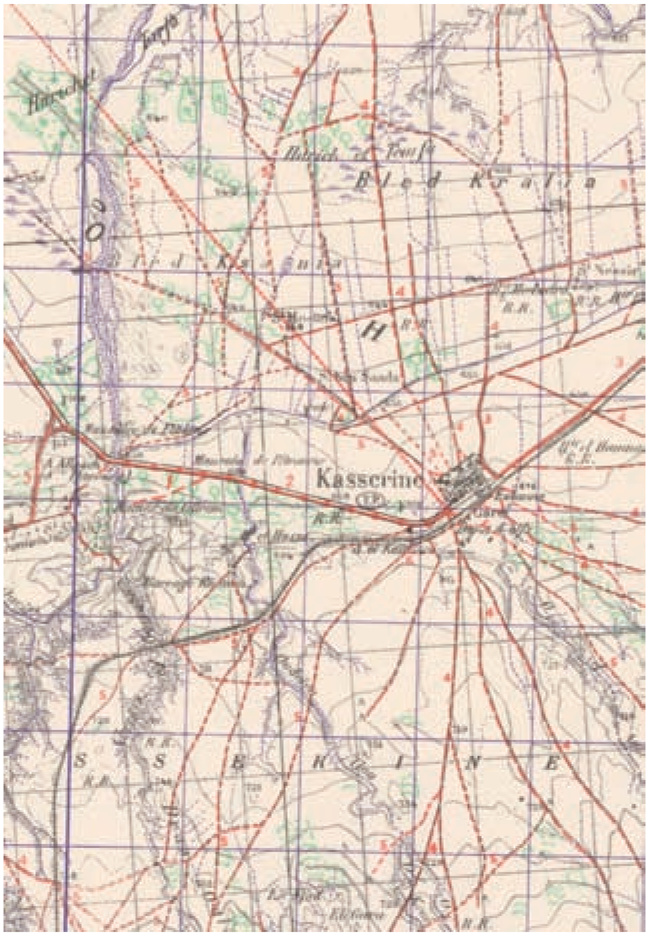

FIG. 584. DETAIL FROM *KASSERINE* (TUNISIA), 1:50,000, 1942 (2d ED., SHEET 84). This map was reproduced by GSGS in 1942 from a French original dated 1937.
Size of the entire original: 52.5 × 77.6 cm; size of detail: 16.1 × 11.1 cm. Image courtesy of Peter Collier.

alist revolt in Algeria gave renewed impetus to French mapping in its colonial territories.

The British maintained a military presence in Tripolitania, Cyrenaica, and Egypt after World War II, and carried out mapping activities in support. In addition, the British Army was also responsible for civil mapping in Tripolitania and Cyrenaica between 1943 and 1951. Much of the activity in Cyrenaica and Tripolitania was limited to the reproduction of existing MEF mapping, with or without minor revisions. The U.S. Army Map Service (AMS) reproduced both the MEF mapping and that produced in Britain by the GSGS, but the AMS reproductions were not always of the latest revised sheets (United States, Department of the Army 1963). In Egypt, British mapping activities were mostly confined to the Suez Canal Zone, where British forces were stationed prior to their withdrawal to Episkopi, Cyprus. British military mapping elsewhere in Egypt was generally limited to the revision, or simple reprinting with a military grid, of Survey of Egypt mapping.

Following Egypt's nationalization of the Suez Canal in 1956, British and French forces invaded Egypt in an attempt to reestablish control of the canal, and—at least on the part of the French—to undermine Arab nationalism and Egyptian support for Algerian nationalists. Maps for the Suez campaign were mainly reprints of earlier British and Survey of Egypt maps, revised to include the "Egyptian Red Grid" (a local grid used for Egypt, although the Universal Transverse Mercator [UTM] grid had been adopted for use more generally) and to reflect changes in communications infrastructure (fig. 585).

In the second half of the century military mapping by the North Atlantic Treaty Organization (NATO) and the Soviet Bloc conformed to the specifications laid down for use globally by these two power blocs and had few, if any, distinguishing features. Local military mapping also continued. In Egypt, this was carried out by the Military Survey Department, which took over responsibility for military mapping from the Survey of Egypt in 1954. However, almost nothing has been published about the military mapping programs of the North African states.

PETER COLLIER

SEE ALSO: Coordinate Systems; Military Mapping by Major Powers; Projections: Projections Used for Military Grids; World War I; World War II

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Military Mapping of Sub-Saharan Africa. During the twentieth century, Africa south of the Sahara was riddled by tribal clashes and civil wars. Fought mainly by indigenous peoples engaged in guerilla warfare, most of these encounters did not require or yield military maps. There were, however, instances of conventional warfare when urgent topographic mapping, often on a makeshift basis, was undertaken to meet the need for maps.

Although not explicitly compiled for use in war, much of the systematic cartography of the continent before

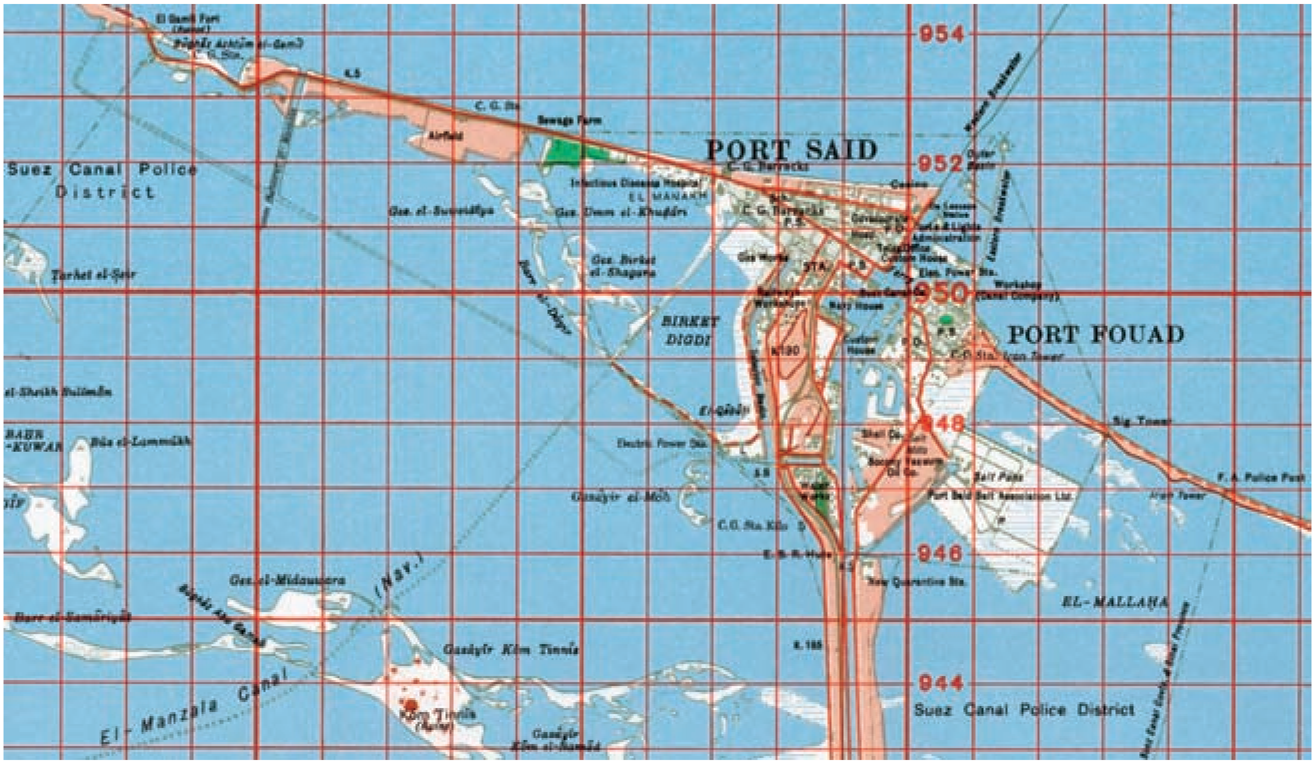


FIG. 585. DETAIL FROM *PORT SAID*, 1:100,000 (GSGS 4Q85, SHEET 92/72, ED. 3). Produced for the Anglo-French invasion of Egypt in 1956. (The scan is taken from a later, 1971, printing.) Size of the entire original: 53.7 × 70.5 cm; size of detail: 11.6 × 20.1 cm. Image courtesy of Peter Collier.

World War II bore a distinct military character. During this period the British War Office played a key role in matters concerning surveying and mapping in British Africa (McGrath 1976), whereas all surveying and cartography in francophone West and Central Africa was done by the Service géographique de l'armée (Finsterwalder and Hueber 1943). Likewise, the mapping of Germany's African colonies by the semi-official Kolonialkartographisches Institut in Berlin was not military, but was nevertheless used for military purposes in both world wars (Demhardt 2000). After World War II, the systematic mapping of Africa by Britain assumed a more civilian character when the Directorate of Colonial (later Overseas) Surveys assumed responsibility for the mapping of the British dependencies, and the work undertaken by the Service géographique de l'armée was transferred to the Institut géographique nationale (IGN) and the Service géographique de l'Afrique occidentale française, based in Dakar, Senegal.

After the partitioning of Africa in the 1880s, the first organized mapping of the continent was undertaken by boundary commissions. The commissioners were usually military surveyors, who mapped boundary zones to illustrate a particular treaty. Apart from these much-needed maps, the survey work of the British boundary commissions also provided the War Office with a framework into which existing topographic information could be fitted. Prior to the execution of topographic surveys based on triangulation, the available topographic material usually consisted of sketches made by travelers, explorers, and military officials while touring on duty or accompanying military expeditions, supplemented by traverses and theodolite and plane table work wherever possible (Great Britain, Colonial Survey Committee 1906). By 1908 the War Office had covered large areas of Gambia, Sierra Leone, the Gold Coast (Ghana), Nigeria, Uganda, the East African Protectorate (Kenya), and Nyasaland (Malawi) by monochrome maps on a scale of 1:250, 000 using this method.

Prior to 1904, maps of the British War Office were numbered according to a single integer sequence prefixed by the acronym IDWO (Intelligence Department, War Office). In 1904, this department was reorganized and the prefix IDWO superseded by TSGS (Topographical Section, General Staff). In April 1907 the Topographical Section was renamed Geographical Section, after which all maps were designated GSGS (Geographical Section, General Staff).

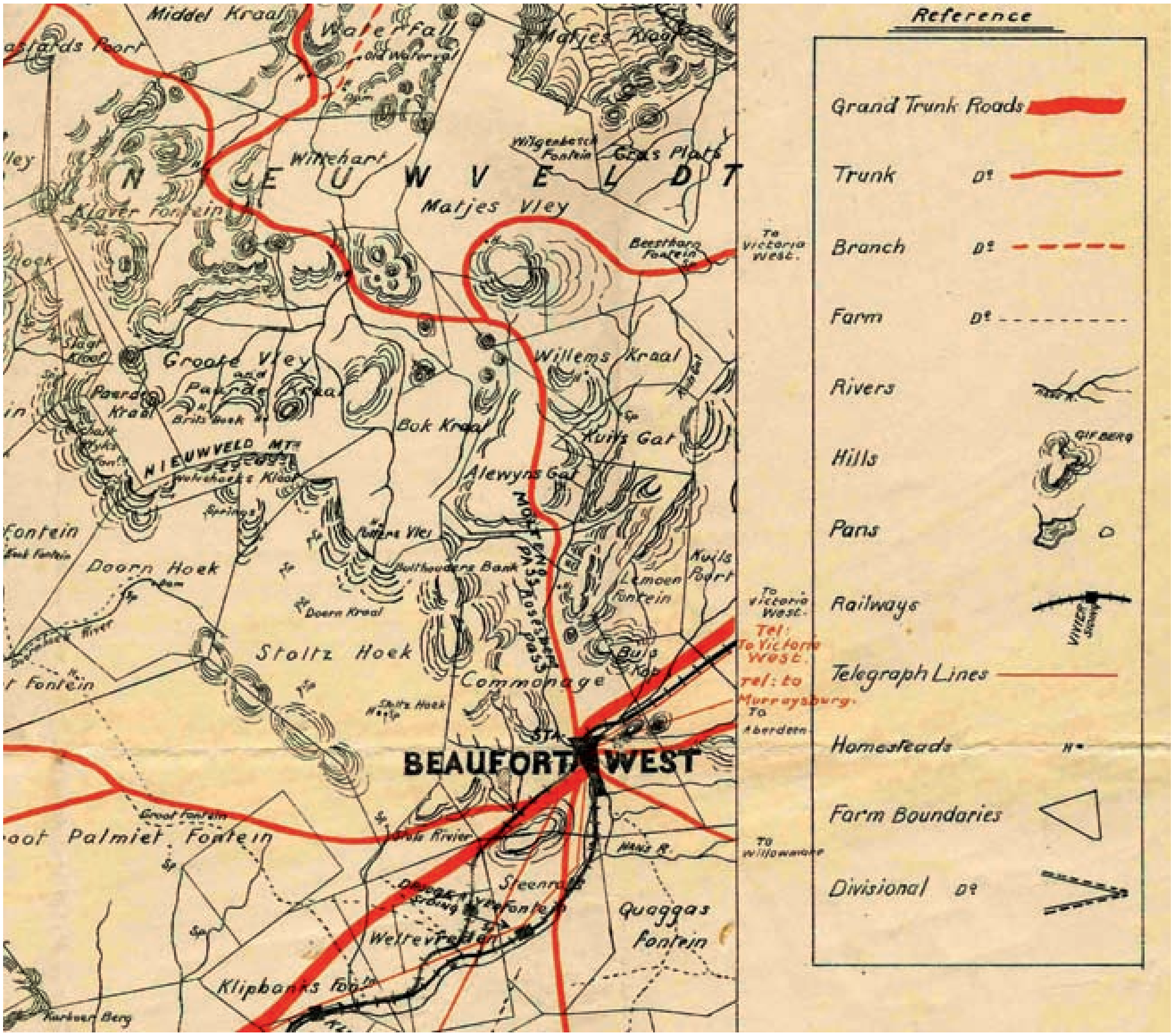


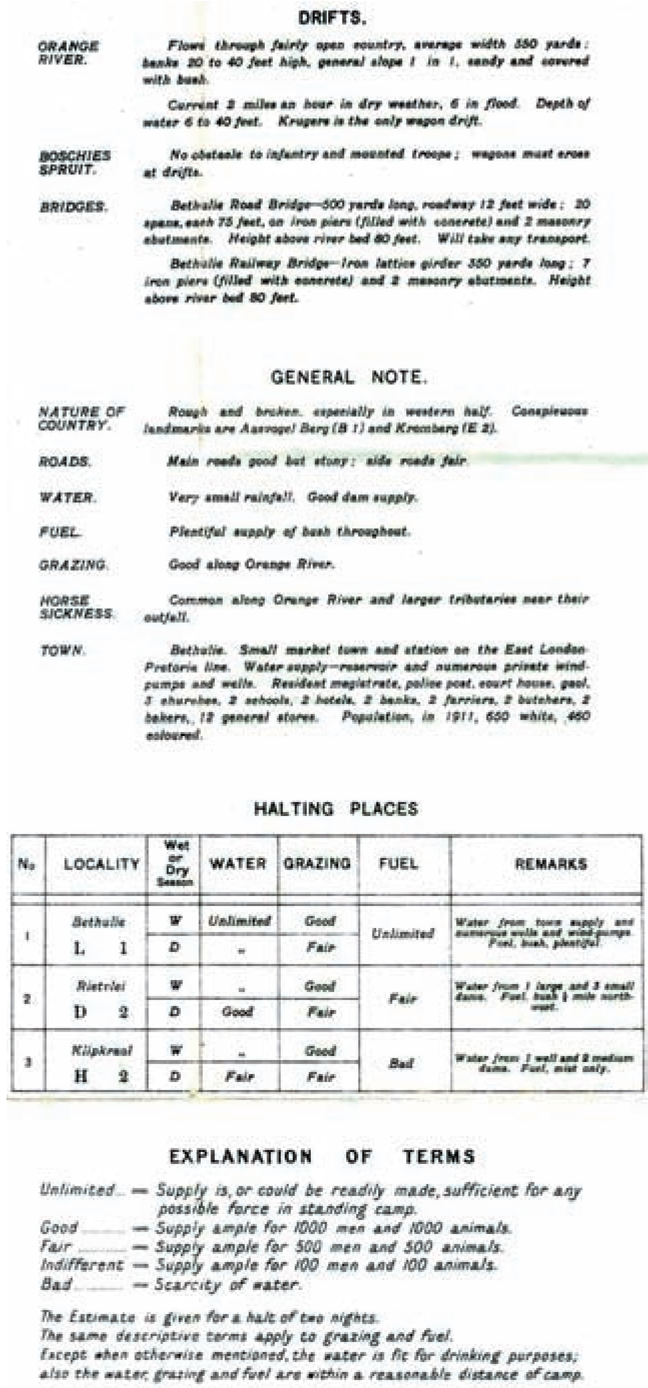
FIG. 586. DETAIL FROM THE *BEAUFORT WEST* SHEET OF THE IMPERIAL MAP SERIES, 1902. Two colors, 1:250,000 (Pretoria: Field Intelligence Department, War Office). This series of compilation maps, which covered the entire country, was compiled during the Anglo-Boer War by fitting together farm diagrams.
Size of the entire original: 64 × 60 cm; size of detail: ca. 18.3 × 20.7 cm. Image courtesy of Elri Liebenberg.

The Anglo-Boer or South African War was fought between the two Boer republics (the Orange Free State and the Transvaal, also known as the South African Republic) and the British Empire from 1899 to 1902. With the advent of hostilities, southern Africa was, as far as large-scale mapping was concerned, still unmapped. The two republics and the Cape Colony and Natal had no tradition of topographic mapping, which meant that the Boers approached the war without maps. The only War Office map series compiled prior to the advent of war was IDWO 2230 (1:63,360) of northern Natal and IDWO 1367 (1:250,000) of the Orange Free State and Transvaal, but both series were inadequate for military purposes. Two survey sections under the command of the Royal Engineers and three mapping sections were sent to South Africa, but under the circumstances mapping by ground surveying could be done only for isolated strategic locations. To meet the huge demand for topographic information, the Field Intelligence Department reverted to unorthodox methods of cartography by fitting together the title diagrams of inaccurate farm surveys that were filed in the offices of the surveyors general (fig. 586). The type of topographic map thus produced was known as a "compilation map." Although maps such as the Imperial Map Series and Major Jackson's Series were crude and inaccurate, they were used extensively throughout the war as they were often the only maps available (Liebenberg 1998).

The war had a lasting effect on British military mapping policy in Africa. The lack of reliable maps had cost the British forces dearly, and Britain realized that if it wanted to retain political supremacy in large areas of the continent, it would have to make provision for the systematic mapping of its dependencies. To obtain reliable maps of southern Africa, three survey map series were compiled in the period following the war (Liebenberg 1972). The most important was GSGS 2230 (1:125,000), which was based on a topographic survey of the Orange Free State by the War Office from 1905 to 1911 (fig. 587). Series GSGS 1764, which was to be part of the general map of British Africa on a scale of 1:250,000, was based on a reconnaissance survey of the northwestern Cape Colony and Basutoland from 1903 to 1911, whereas GSGS 2618 (1:125,000) was a topographic survey of the southern Transvaal executed during 1910–11. In all three cases the survey work was undertaken by teams of Royal Engineers and the maps printed by the Ordnance Survey in Britain.

The way in which the future mapping of Africa had to be conducted, and the degree of responsibility the War Office had to assume, remained a contentious subject. By August 1905 some coordination was effected when the Colonial Survey Committee was established to advise the Foreign Office and the Colonial Office on all matters concerning the survey and exploration of British Africa (Great Britain, Colonial Survey Committee 1906). The Committee consisted of a representative of the Colonial Office, the director general of the Ordnance Survey, and the officer in charge of the TSGS (later GSGS). The latter was to be responsible for the compilation of maps and the Ordnance Survey for the reproduction of all maps except cadastral plans. At its first meeting the Committee laid down specific technical requirements as well as a family of mapping scales for topographic mapping of 1:62,500, 1:125,000, 1:250,000, 1:500,000, and 1:1,000,000. An overriding decision was that each colony or protectorate should be covered at a scale not smaller than 1:250,000.

The Colonial Survey Committee regulated the surveys and mapping of British Africa for forty years. Survey departments had already been established in most colonies and protectorates, and after 1905 parties of Royal Engineers were purposefully sent to Africa to execute topographic surveys, primarily on a scale of 1:250,000, but sometimes also on 1:125,000. Some of the more important map series produced at 1:250,000 were GSGS 1764 (new series) of the northern Cape Colony, Sierra Leone, Nigeria, the Gold Coast, the East African Protectorate,



DRIFTS.

ORANGE RIVER. Flows through fairly open country, average width 350 yards: banks 20 to 40 feet high, general slope 1 in 1, sandy and covered with bush.

Current 2 miles an hour in dry weather, 6 in flood. Depth of water 6 to 40 feet. Krugers is the only wagon drift.

BOSCHIES SPRUIT. No obstacle to infantry and mounted troops; wagons must cross at drifts.

BRIDGES. Bethulie Road Bridge—500 yards long, roadway 12 feet wide; 20 spans, each 75 feet, on iron piers (filled with concrete) and 2 masonry abutments. Height above river bed 80 feet. Will take any transport.

Bethulie Railway Bridge—Iron lattice girder 350 yards long; 7 iron piers (filled with concrete) and 2 masonry abutments. Height above river bed 80 feet.

GENERAL NOTE.

NATURE OF COUNTRY. Rough and broken, especially in western half. Conspicuous landmarks are Aasvogel Berg (B 1) and Kromberg (E 2).

ROADS. Main roads good but stony; side roads fair.

WATER. Very small rainfall. Good dam supply.

FUEL. Plentiful supply of bush throughout.

GRAZING. Good along Orange River.

HORSE SICKNESS. Common along Orange River and larger tributaries near their outfall.

TOWN. Bethulie. Small market town and station on the East London-Pretoria line. Water supply—reservoir and numerous private wind-pumps and wells. Resident magistrate, police post, court house, gaol, 3 churches, 2 schools, 2 hotels, 2 banks, 2 farriers, 2 butchers, 2 bakers, 12 general stores. Population, in 1911, 650 white, 460 coloured.

HALTING PLACES

No	LOCALITY	Wet or Dry Season	WATER	GRAZING	FUEL	REMARKS
1	Bethulie L 1	W	Unlimited	Good	Unlimited	Water from town supply and numerous wells and wind-pumps. Fuel, bush, plentiful.
		D	"	Fair		
2	Rietvlei D 2	W	"	Good	Fair	Water from 1 large and 3 small dams. Fuel, bush ½ mile north-west.
		D	Good	Fair		
3	Klipkraal H 2	W	"	Good	Bad	Water from 1 well and 2 medium dams. Fuel, mist only.
		D	Fair	Fair		

EXPLANATION OF TERMS

Unlimited — Supply is, or could be readily made, sufficient for any possible force in standing camp.
Good — Supply ample for 1000 men and 1000 animals.
Fair — Supply ample for 500 men and 500 animals.
Indifferent — Supply ample for 100 men and 100 animals.
Bad — Scarcity of water.

The Estimate is given for a halt of two nights.
The same descriptive terms apply to grazing and fuel.
Except when otherwise mentioned, the water is fit for drinking purposes; also the water, grazing and fuel are within a reasonable distance of camp.

FIG. 587. MILITARY INFORMATION IN THE MARGIN OF *BETHULIE* SHEET OF THE ORANGE RIVER COLONY, SOUTH AFRICA, 1915. 1:125,000, sheet GSGS 2230. This map was obviously compiled having in mind soldiers on horseback in a dry area.
Size of the entire original: 47 × 60 cm; size of detail: 18.6 × 8.6 cm. Image courtesy of Elri Liebenberg.

Nyassaland, and Somaliland; GSGS 2567 of Basutoland; and GSGS 2571 of Uganda. On a scale of 1:125,000, GSGS 2230 of the Orange River Colony (South Africa) and the East African Protectorate was published. Given this considerable output, it was to be lamented that the surveys were all done in a piecemeal fashion and during the 1920s and 1930s the War Office and Colonial Office spent much time and energy in deciding how to coordinate and finance surveying and mapping in Africa (McGrath 1976). In 1946 central control over civilian mapping was effected by the establishment of the Directorate of Colonial (later Overseas) Surveys.

Before World War I, military mapping was also undertaken in German Southwest Africa, where the Herero and Nama rebellions of 1904 caught Germany by surprise. The task to quickly map the otherwise unmapped protectorate was given to Max Moisel and Paul Sprigade of the semiofficial Kolonialkartographisches Institut in Berlin, which produced a map series (the so-called Kriegskarte) in eight sheets on a scale of 1:800,000. After the rebellion had been crushed, the military Königliche Preußische Landesaufnahme took over the responsibility for the mapping of the protectorate. Three map series were commenced on scales of 1:50,000, 1:100,000, and 1:400,000. Progress was slow, and when South Africa occupied German Southwest Africa in 1914, all three series were still incomplete (Demhardt 2000).

Before World War II the military mapping executed in the Belgian Congo was mostly related to border demarcation. After the war, the Belgian government decided to increase the colony's mining production and expand the existing infrastructure. In 1949 the Institut géographique du Congo Belge (IGCB) was established, and in the same year the Ministry of National Defence agreed to collaboration between the Institut géographique militaire, the air force, and the Service géographique et géologique (SGG) to use aerial photography for the production of a map series on a scale of 1:200,000. Published by the IGCB, these *cartes de territoires* (maps of the territory) covered the entire Belgian Congo. Although partly compiled by military means, these maps have also been available for civilian use.

No new military mapping was undertaken in Africa during World War I. Instead, the available German maps prepared by the Kolonialkartographisches Institut were copied and reissued by Britain and South Africa for the German Southwest Africa and German East Africa campaigns. The 1:400,000 and 1:100,000 sheets of German Southwest Africa were reissued as GSGS 3033 and GSGS 3032, respectively, whereas a German 1:300,000 series of German East Africa was supplemented with English place-names and annotations, and reissued as GSGS 3026. Copies of the German maps of German Southwest Africa and of GSGS 3026 of German East Africa were also reproduced by the South African Government Printer for use by the South African Defense Force.

World War II brought about extensive military mapping in Kenya, British Somaliland, Italian Somaliland, French Somaliland, Abyssinia, and Eritrea. Prior to the war the best maps of Ethiopia and Italian Somaliland were an Italian 1:400,000 series compiled by the Istituto geografico militaire. British maps of this area were either nonexistent or outdated, and in July 1940 the War Office laid down a specific mapping policy, which was closely followed throughout the war (Clough 1952). South of latitude 4°N the standard GSGS 2781 1:2,000,000 series of Africa, covering the whole East African area, was maintained and printed by South Africa, with the area north of 4° being the responsibility of the deputy director of surveys (East Africa). The East African Survey Group undertook the compilation, printing and maintenance of a 1:1,000,000 series (initially GSGS 2465, later GSGS 4646) south of 8°N, whereas a 1:500,000 series covering most of East Africa (GSGS 4355) was compiled from surveys of accessible areas, reconnaissance reports, and any other map material including air photography. Much of the 1:500,000 mapping, as well as the mapping of a 1:250,000 series of more developed areas, was undertaken by the 1st South African Survey Company in collaboration with the East African Survey Group and No. 60 (Photo) Squadron of the South African Air Force (fig. 588).

After the government in Portugal was ousted in a coup d'état in April 1974, war broke out between the three Angolan freedom movements, UNITA (União Nacional para Indepêndencia Total de Angola), the MPLA (Movimento Popular de Libertação de Angola), and the FNLA (Frente Nacional de Libertação de Angola). The Namibian freedom movement SWAPO (South West Africa Peoples' Organization), together with Russia and Cuba, supported the MPLA. The United States supplied UNITA and the FNLA with weapons, and South Africa fought on the side of the latter two movements. From 1965 until the end of the war, 46 and 47 Survey Squadrons, SAEC (South African Engineer Corps) undertook valuable work in Angola and northern Namibia by providing topographic information to the South African forces. For base maps, they used the military edition of the South-West Africa 1:50,000 series produced by South Africa during 1960–70 and the 1:250,000 and 1:100,000 series of Angola published by the Portuguese Ministério do Ultramar.

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SEE ALSO: Coordinate Systems; Military Mapping by Major Powers: (1) Great Britain, (2) Germany; Projections: Projections Used for Military Grids

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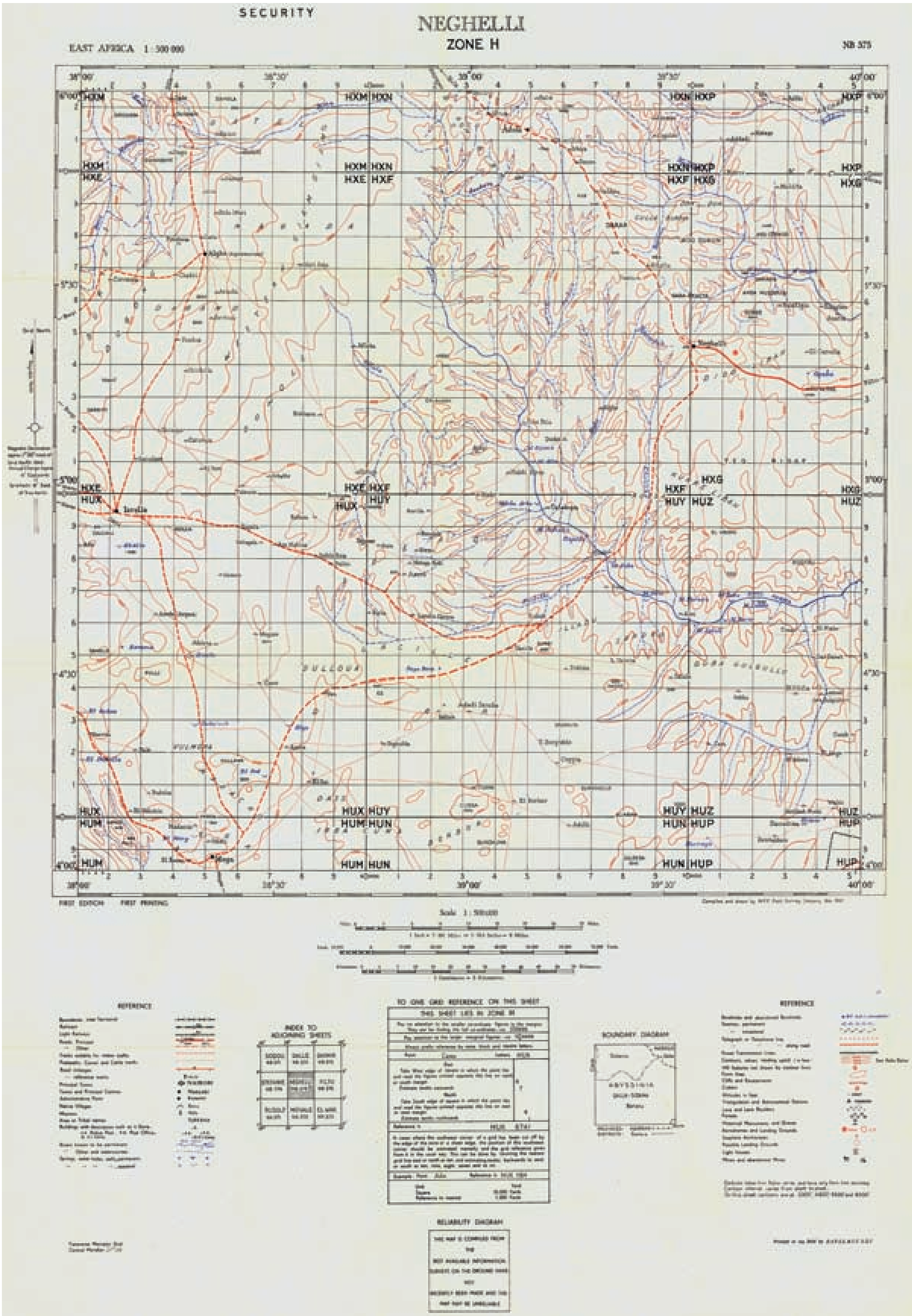
SECURITY
NEGHELLI
ZONE H
EAST AFRICA 1 : 500 000
NB 375
Neghelli
Iavello
Mega
Adola
FIRST EDITION FIRST PRINTING
Scale 1 : 500,000
REFERENCE
INDEX TO ADJOINING SHEETS
TO ONE GRID REFERENCE ON THIS SHEET
THIS SHEET LIES IN ZONE H
BOUNDARY DIAGRAM
ABYSSINIA
RELIABILITY DIAGRAM
THIS MAP IS COMPILED FROM THE BEST AVAILABLE INFORMATION SUBJECT ON THE GROUND HAVE NOT RECENTLY BEEN MADE AND THE MAP MAY BE UNRELIABLE

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Military Mapping of Scandinavia. At the beginning of the century, military maps were the responsibility of the Swedish, Danish, and Norwegian general staffs, in particular their topographical departments. Until its independence from Russia in 1917, Finland's military mapping was the responsibility of the Russian General Staff in St. Petersburg. All four countries also had civilian mapping agencies with the capability to provide the military with basic maps that corresponded to their demands. Over the course of the century these civilian map producers gradually took over the production of basic maps, leaving to the military the task of adapting these maps for military use and producing small numbers of special maps when required. However, at the beginning of the twentieth century, Sweden and Denmark still had both strong military mapping traditions and military organizations capable of producing maps. In both countries the military retained an involvement in topographic mapping during the first decades of the century.

In Sweden, the Rikets allmänna kartverk, an ordnance survey agency formed in 1894, was charged with the production of both military and civilian maps. It was under the head of the General Staff's topographical department until 1937, when the General Staff was abolished. Since then the formal military influence on Swedish mapmaking has been limited. There was, therefore, virtually no purely military production of small-scale topographical maps during the century. However, in Sweden, as in other countries, basic civilian-produced maps were frequently modified for military purposes. This was done in several ways. One of the earliest modifications was to meet the need of the artillery for precise target location. This meant that it was necessary not only to identify the horizontal location of the target but also its height. The maps were therefore provided with a grid and with contours, an innovation that was rapidly transferred to civilian maps.

Other military adjustments of civilian maps included making roads more obvious by coloring them red and specifying road widths. Military objects such as stationary coast artillery batteries or field fortifications that for security reasons were not shown on general maps were included. The boundaries between various kinds of military areas were often added. Normally, these additions were ordered by the military from the civilian map producer, which then printed a special military version of a standard map.

Although not directly involved in World War II, Sweden maintained a high degree of preparedness. A large number of maps were produced for operational planning, maneuvers, and tactical uses. As long as practically possible, the standard map editions were used as basic maps, but numerous large-scale maps had to be produced, many of them hand drawn. Only a very small number of these survive.

In peacetime, military maps were produced for—and during—maneuvers of various kinds. One notable type are the maps prepared for large air force exercises, a standard map to which were added special corridors used by military airplanes and other information necessary for ensuring the safety of civilian air traffic. A large number of maps were also produced for training purposes. For several decades military cadets and potential volunteers were taught mapmaking skills, considered important for officers.

In Denmark, the General Staff's topographical department was merged with its civilian counterpart in 1928 to form the Geodætisk Institut, a civilian organization. The Danish General Staff produced a map series at 1:20,000 and a few maps at 1:10,000, the so-called Maalebordsblad, surveyed in the 1870s and 1880s. Both

(*Facing page*)

FIG. 588. THE *NEGHELLI* SHEET OF EAST AFRICA, 1:500,000. Compiled and drawn by the First South African Field Survey Company. Printed in the field by the Directorate of Army Printing and Stationery Supplies, Union Defence Force, November 1940.

Size of the original: 85 × 57 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.

series served as the basis for the production of another map series at 1:40,000, the so-called Atlasblade.

In 1919 production started on a 1:100,000 series, the so-called Generalstabskort. A few years later contours were added to military editions. The maps were not provided with a military grid but a reference grid was added to some sheets. Smaller-scale maps were also produced including one at 1:1,000,000 from 1926, based on the specification for the International Map of the World (United States, Department of the Army 1963, 152). Military mapping came to an abrupt end in 1928, when the civilian Geodætisk Institut took over.

The Norwegian General Staff had little direct involvement in the production of printed maps, as mapping was the responsibility of the Norges Geografiske Opmåling, the civilian mapping agency. Some officers were involved in producing a 1:50,000 map in 1928–29, but it was published by a private company, Aschehoug. Some printed maps made for military reasons were based on measurements made by officers but printed by the civilian map agency of the Norwegian geodetic survey. The Norwegian General Staff and its topographical department ceased to exist in 1940 following the German occupation of the country. A large number of military maps of Norway were made during World War II, but they were mainly produced by the Germans and the British. After the war Norway became a member of the North Atlantic Treaty Organization (NATO) and used its maps.

In Finland, official mapping was normally performed by the Lantmäteristyrelsen, a civilian institution that also made topographical maps used by the military. An exception occurred in 1918, when the Finnish civil war compelled the Finnish General Staff to produce a rather primitive 1:100,000 map for the area in southern and eastern Finland where fighting took place. The General Staff was also involved in producing the so-called semimilitary district maps, which were explicitly intended for both military and civilian use, and also for a series of maps produced from 1931 to 1951 in cooperation between the General Staff and the Lantmäteristyrelsen and showing areas bordering the Soviet Union.

Finland was, in contrast to the other Scandinavian countries, directly involved in World War II, during the Winter War of 1939–40 and the Continuation War of 1941–44. Good maps were then available when the fighting took place on Finnish territory, but when combat occurred on Soviet territory the Finns had to rely largely on captured Soviet maps, and to some extent on German maps.

Most maps produced by the various Scandinavian mapmaking agencies for long-term use are normally preserved, typically in the Swedish Krigsarkivet. The plethora of maps made for special occasions or training exercises, whether made during war or peace, were only preserved to a very small and seemingly random extent.

BJÖRN GÄFVERT

SEE ALSO: Cold War; Coordinate Systems; Military Mapping by Major Powers; Projections: Projections Used for Military Grids; Topographic Mapping: Western Europe

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United States. Department of the Army. 1963. *Foreign Maps*. Washington, D.C.: Headquarters, Department of the Army.

Military Mapping of Europe. At the start of the century, the military mapping of Europe was an exclusively European endeavor. No non-European country had any interest in producing detailed maps for the entire continent, and most European countries were not concerned with mapping beyond their own borders. The only country involved in mapping extensive areas of the continent was Austria-Hungary, which had been active in mapping large parts of the Balkans in a series of maps at 1:200,000. This mapping was extended to cover northern Italy and parts of France, as well as territory on its eastern borders. Britain had no systematic coverage beyond its own territory, and of its colonial holdings, only Gibraltar had been adequately mapped. The General Staff Map, a series produced by and for most European armies, provided the medium-scale mapping of most European countries. Map sheets were acquired and reproduced by the armies of their country's potential enemies. By contrast, the secrecy policies of some countries, such as Russia, were designed to prevent their maps falling into the hands of potential enemies.

Increasing political tensions in Europe led to an acceleration of mapping programs. By 1909 the British Army knew that mapping of northern France and Belgium would be needed if it were to intervene on the side of the French in a war with Germany. A program was initiated to produce 1:100,000-scale mapping of Belgium based on contoured Belgian originals (fig. 589). In France, where no contour maps existed for the area designated for British operations, the War Office produced copies of the French 1:80,000 series with contours superimposed on the hachured originals. While the future combatant powers typically relied on original surveys for maps of their home territory, cartographic coverage of the territory of potential allies or enemies was derived from existing published maps (fig. 590).

During World War I there was a great expansion not only in the areas being mapped by combatant nations but also the types of maps produced. Before the war, military mapping consisted entirely of medium- and small-scale topographic or geographic maps, but by the war's end a greater range of scales was being used, and a wide range of thematic maps were being produced to support military activities. Scarce water supplies for frontline troops

FIG. 589. DETAIL FROM *OSTEND*, A BRITISH 1:100,000 MAP OF BELGIUM. Prepared in 1911 (GSGS 2364), before the outbreak of World War I, the map was made in anticipation of British intervention on the side of France following a German attack.
Size of the entire original: 72.5 × 42.0 cm; size of detail: 11.4 × 10.6 cm. Image courtesy of Peter Collier.

FIG. 590. DETAIL FROM *BZHEZHANY*, 1917, A RUSSIAN REPRODUCTION OF AN AUSTRIAN 1:75,000 MAP WITH CYRILLIC ADDED. Copying captured enemy maps was very common in wartime. If the map had been acquired prior to the war, it would probably have been redrawn at a Russian map scale.
Size of the entire original: 43 × 56 cm; size of detail: 11.6 × 9.2 cm. Image courtesy of Peter Collier.

led to the production of hydrogeological maps (Rose, Häusler, and Willig 2000), diseases such as malaria led to medical maps, and logistical problems led to transport maps of roads, railroads, and waterways. Toward the war's end planning for the postwar settlement led to the production of ethnographic maps, including versions produced by the American Geographical Society (see fig. 37).

An important new feature introduced during World War I was the use of aerial photography and photogrammetry to create original mapping of enemy-occupied territory. Despite this unprecedented advantage, use of overhead imaging for original mapping was markedly more limited in Europe than in the Middle East.

Following the war there was a scaling back of mapping activities in Western Europe, even though instability in Eastern Europe led to a continuing demand for maps. The newly emerged countries of Central and Eastern Europe started to produce military mapping, usually retaining the scales and styles of their former imperial masters. For example, until World War II Hungarian and Czechoslovakian mapping remained almost identical in both style and scales to that produced by the Habsburg Militärgeographisches Institut. Throughout the 1920s and early 1930s, British, French, and Italian military mapping activities were largely directed toward their colonial territories. For example, the only new maps of Europe initiated by Britain in the 1920s and early 1930s were air navigation charts and a few small-scale maps to accompany reports on various European armies. The exception was the Italian mapping of Albania, which lacked any mapping capacity of its own. Albania's subsequent takeover by Italy revealed the dangers inherent in letting another country map one's territory.

Increased tension in Europe following Adolph Hitler's rise to power led to renewed interest in military mapping programs (figs. 591 and 592). The maps that resulted were often direct reproductions of other states' topographic mapping, with the addition of an appropriate military grid. Original mapping, even in the form of new compilations from existing sources, was rare. However, the first recorded British response was the decision

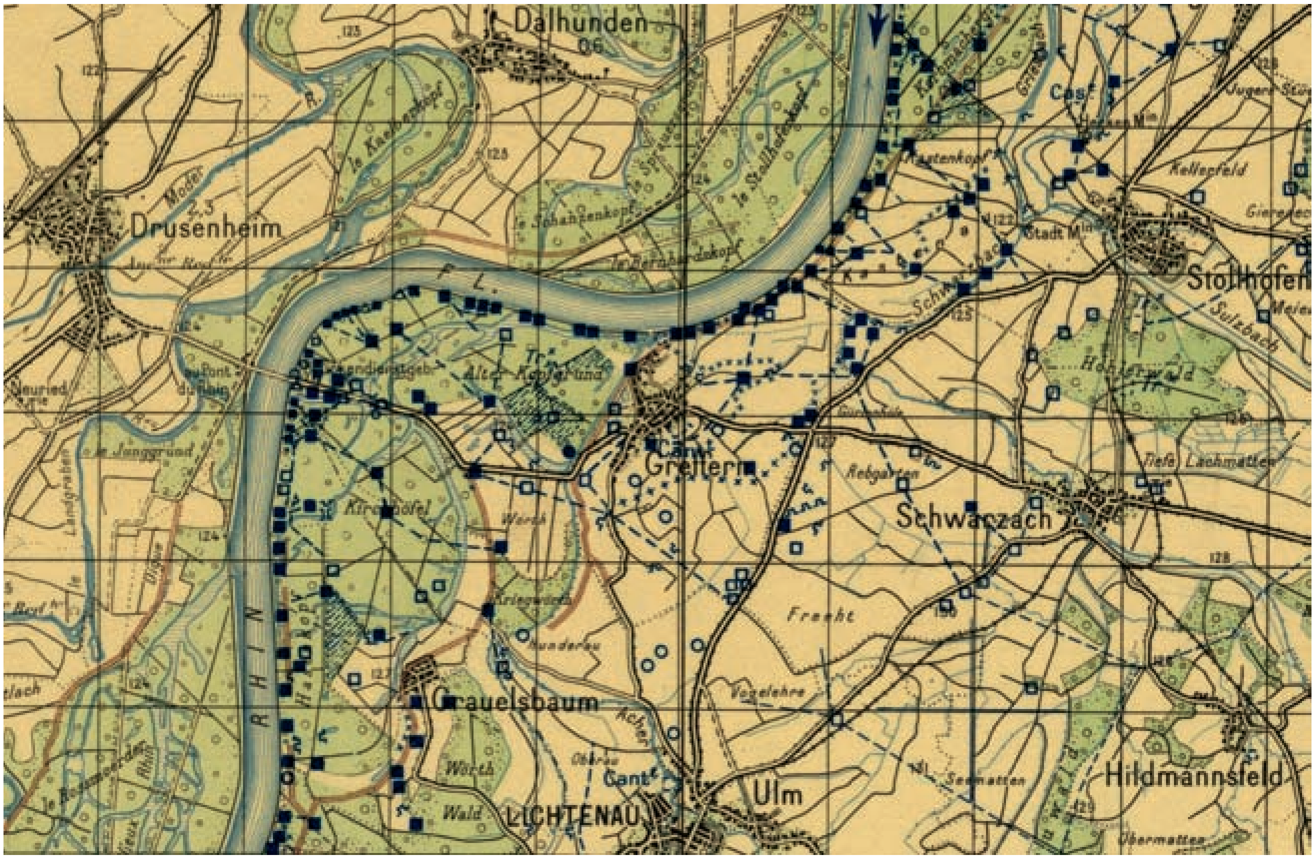

FIG. 591. DETAIL FROM *DRUSENHEIM*, A FRENCH 1:50,000 MAP FROM 1939 SHOWING GERMAN BORDER DEFENSES. Size of the entire original: 52.3 × 61.0 cm; size of detail: 11.7 × 18.0 cm. Image courtesy of Peter Collier. Permission courtesy of the Cartothèque, Institut géographique national.

in July 1936 to produce new compilations at 1:25,000, 1:50,000, and 1:250,000 of northwest France and Belgium. The Munich crisis led to the production of plans of ports in northwest France in mid-September 1938, followed by the reproduction of Czech 1:75,000 mapping at the end of the month (Great Britain, War Office 1929–90).

The German approach was to reproduce foreign mapping at its original scale where the scale was metric, or at the nearest equivalent metric scale where the original had used imperial units. The Ordnance Survey's one-inch (1:63,360) maps were reproduced at 1:50,000 and its half-inch (1:126,720) maps at 1:100,000. Once war broke out in September 1939, Germany started reproducing maps of its allies, such as Italy and Hungary, as well as countries with which it was at war or expected to attack. In contrast to the Western Allies, who rarely reproduced maps at larger than their original scale, the Germans frequently enlarged existing maps, often in monochrome brown, which resulted in maps of doubtful quality and very thick linework. For the war in the east, the Germans reproduced Polish and Russian mapping, frequently producing facsimile 1:100,000 sheets composited from a variety of original sources.

While the Germans made great use of the mapping captured during their conquest of large parts of continental Europe, they seem to have made little use of the mapping organizations in the occupied countries, except as sources of material. For example, the well-equipped Yugoslavian military mapping organization was systematically looted of its equipment and library, with much of the library eventually ending up, after the war, in the library of Britain's Directorate of Military Survey. Some survey organizations, such as the French Service géographique de l'armée (renamed the Institut géographique national), were even allowed to continue working on national mapping programs under German supervision.

After the United States entered the war, there was a huge expansion in Allied mapping activities and the introduction of new techniques of map compilation and reprographics. A key feature of the cooperation between the British and Americans was the Loper-Hotine Agreement of May 1942, which defined the division of re-

FIG. 592. DETAIL FROM *BEFESTIGUNGSKARTE WEST SÜDBLATT*, A GERMAN 1:300,000 MAP FROM EARLY 1940. Map shows the location of French border defenses around Strasbourg.
Size of the entire original: 120 × 101 cm; size of detail: 8.4 × 8.4 cm. Image courtesy of Peter Collier.

sponsibilities between the two powers (Clough 1952, 43). This avoided unnecessary duplication of effort in the compilation of maps and led to the sharing of reprographic material so that maps could, if necessary, be printed simultaneously on both sides of the Atlantic. The agreement also meant that the Allied armies could be supplied with appropriate maps irrespective of which country had produced them. In marked contrast to the practices in World War I, when each country met its own mapping needs, this policy anticipated the cooperation of the Cold War period.

The partition of Germany and Austria into zones under the military control of the four Allied powers created a continuing need for military mapping. The increasing suspicion between the Eastern and Western Blocs also created a need for mapping in anticipation of future conflict. Indeed, the wartime Allies had started acquiring maps of each other's territory even before the end of the war. As the Allied armies advanced into Germany, they systematically seized any surveying and cartographic material found in German map stores and survey departments. Among the material acquired by the U.S. Army was the German geodetic data held in Saalfeld, which covered Central and Eastern Europe as well as large parts of the Soviet Union (Cloud 2002). These data were subsequently used to make an important contribution to U.S. mapping of the Soviet Union during the Cold War.

Increasing tensions in Europe, typified by the Berlin blockade, led to the formation of the North Atlantic Treaty Organization (NATO) in April 1949. This in turn led to a series of agreements on the provision of mapping to NATO forces to ensure that a common pool of mapping would be available to meet the needs of the individual national armies under NATO command. In theory, each participating nation produced maps of its own territory to a common specification, including the use of the Universal Transverse Mercator (UTM) grid. Where a common specification was adopted, it was given a common series designation, such as M745 for 1:50,000 mapping of both West Germany and East Germany (fig. 593). In this case, mapping of East Germany was carried out by the U.S. Army Map Service and the British Directorate of Military Survey using a mixture of prewar mapping, aerial imagery, and ground surveys by soldiers under the Four Power Agreement, which gave the occupying forces access to each other's zones (Geraghty 1997). In practice, the Americans and the British also produced maps of fellow NATO members. For example, in the early 1950s the U.S. Army Map Service produced mapping of Norway and Demark at 1:25,000, 1:50,000, and 1:100,000, based on local sources (United States, Department of the Army 1963; Great Britain, War Office 1929–90).

The large armies maintained in West Germany by the French, the Americans, and the British also required mapping support for their day-to-day activities. To meet some of those needs, both the Americans and the British had large survey, mapping, and printing units based in Germany.

The Soviet Union had in effect taken control of mapping within the Soviet Bloc even before the formation of the Warsaw Pact in 1955. The 1942-System (a single standard for topographic maps) adopted during the war by the Soviets had been imposed on all Warsaw Pact countries, the maps of which now differed mainly in the use of Roman or Cyrillic text. In addition to mapping their own territories, some of the Warsaw Pact countries were also involved in mapping parts of Western Europe. The Soviet mapping program resulted in complete coverage of Europe at 1:1,000,000, 1:500,000, 1:200,000, and 1:100,000, with 1:50,000 coverage of much of the continent (fig. 594). In addition, plans of urban centers were produced at scales of 1:5,000, 1:10,000, or 1:25,000. The urban plans showed all strategically important buildings numbered and colored according to function (military, administrative, and industrial). A list of functions was either printed on the sheet or included in a booklet. In many cases this information was not derived from the published map series of the country

FIG. 593. DETAIL FROM *WISMAR*, 1:50,000 AMERICAN MAP, 1977. Map of an area in East Germany, Series M745, Edition 2-DMATC, sheet L2134. This was the NATO equivalent of the Soviet 1942-System sheets. Size of the entire original: 54.8 × 71.5 cm; size of detail: 13.5 × 22.7 cm. Image courtesy of Texas A&M University Libraries, College Station.

concerned and apparently resulted from ground surveys by Soviet personnel (Davies 2005).

The breakup of the Soviet Bloc in 1989 seemed to reduce the need for military mapping of Europe. However, the fragmentation of Yugoslavia and the resulting wars created an entirely new need. In 1995 mapping support for the intervention by NATO forces to end the conflict in Bosnia was provided by the British Army using its new TACISYS (Tactical Information System) mobile mapping system. A single TACISYS module contained a drum scanner for scanning captured maps, a workstation running GIS (geographic information system) and image processing software, and a plotter capable of producing short print runs. A mobile printing unit accompanying the basic TACISYS module could be used for longer print runs. In a sense, things had come full circle in military mapping as a mobile mapping unit was first deployed at the start of the century, during the Anglo-Boer War, to meet the needs of troops in the field.

PETER COLLIER

SEE ALSO: Coordinate Systems; Military Mapping by Major Powers; Projections: Projections Used for Military Grids; World War I; World War II

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Military Mapping of the Middle East. Francis Richard Maunsell carried out the first explicitly military mapping of the Middle East when he produced mapping at a scale of 1:250,000 of "Eastern Turkey in Asia" (Anatolia) for the British War Office; the first sheets were produced in 1901 (Collier, Fontana, and Pearson 1997). The coverage was extended during World War I into areas of Iraq

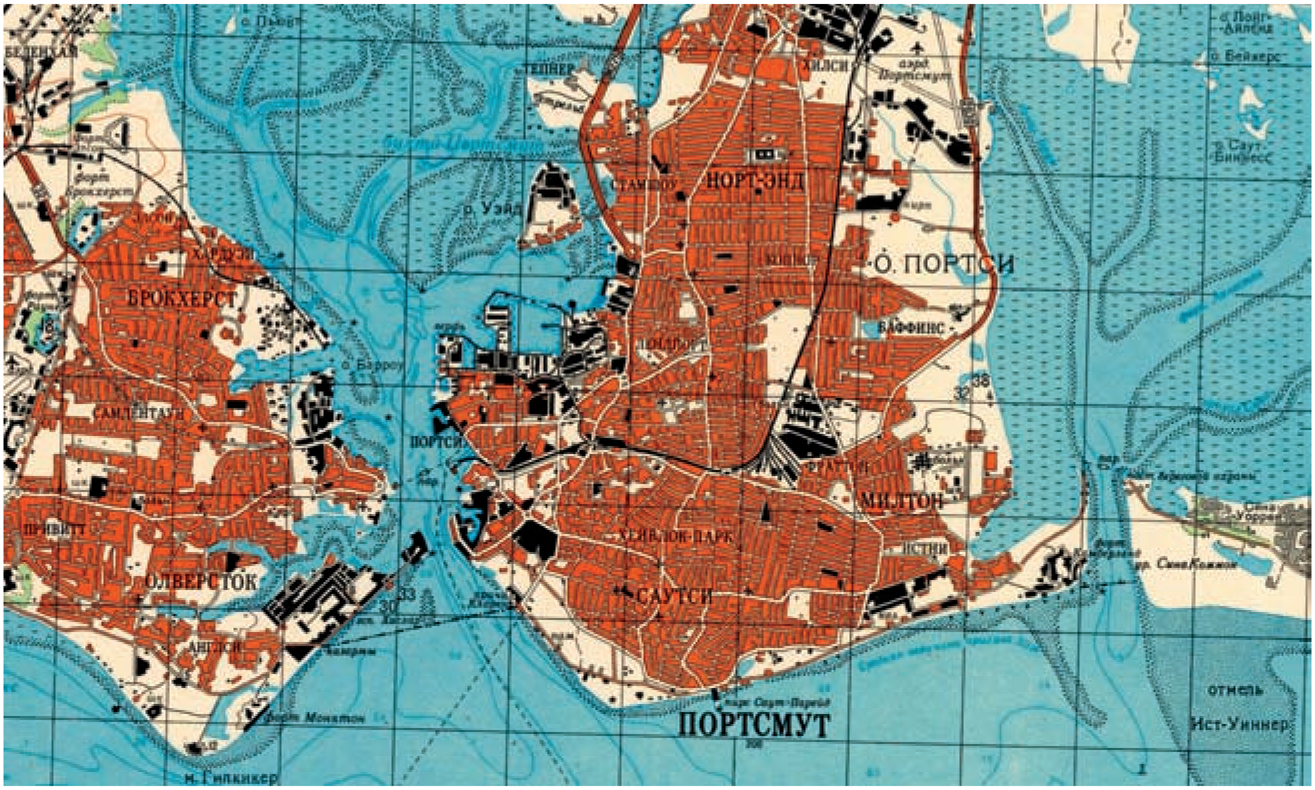

FIG. 594. DETAIL FROM *PORTSMUT*, A SOVIET 1:50,000 MAP OF PORTSMOUTH. This typical 1942-System map is interesting due to the mixture of information shown. Some is out-of-date and was not shown on the Ordnance Survey maps then current.

Size of the entire original: 43.5 × 40.0 cm; size of detail: 13.7 × 23 cm. Image courtesy of Peter Collier.

and Syria. Maunsell's maps were unusual, at the time, in that they were compiled in anticipation of a military need, rather than in response to an existing need.

The governments of Russia and of India both had interests in the region. Russia did some mapping in the Caucasus and northern Turkey, and the Survey of India mapped areas of Afghanistan and some portions of the Afghan/Persian boundary, but there was no systematic attempt to map the region.

British concerns for the security of the Suez Canal led to a survey of northern Sinai by British Army surveyors using plane table techniques just prior to the World War I. However, there remained a gap between the new mapping of the Sinai and Claude Reignier Conder and Horatio Herbert Kitchener's one-inch Survey of Western Palestine, conducted on behalf of the Palestine Exploration Fund (PEF). To fill the gap, British Army surveyors under Stewart Francis Newcombe did a plane table survey under the cover of a PEF archaeological survey of the Wilderness of Zin (Newcombe 1914). At the outbreak of World War I the Survey of Egypt carried out a survey of the Suez Canal approaches, again using plane table techniques.

The lack of any proper mapping when Anglo-French forces landed on the Gallipoli Peninsula in Turkey led to what is believed to be the first attempt to compile a map entirely from aerial photography (Dowson 1921). However, the capture of Turkish maps soon after the landing meant that the aerial photography was mainly used for map revision.

As the British Army advanced into Palestine in 1917 the PEF maps did not meet the needs of modern warfare. In addition, many of the areas for which the army required mapping were behind Turkish lines. This led to a period of experimentation with air survey in which different methods were tried to establish control for the mapping. Where there were identifiable features behind Turkish lines, these could be fixed by triangulation and used to control the mapping. This was the method adopted for the mapping of Gaza, which Dov Gavish and Gideon Biger (1985, 38) claimed to be probably the first town mapped entirely by air survey. Where no such features existed, photo coverage lines were flown parallel to the front line, and additional lines were flown at right angles to the front in an effort to control the mapping.

FIG. 595. DETAIL OF A TIGRIS CORPS MAP PRODUCED FROM AERIAL PHOTOGRAPHY. *Sketch Map of the Country between Sheikh Sa'ad and the Shumran Bend*, 1:126,720 (sheet T.C.4). Made for the attempted relief of the British forces besieged in Kut al Amarna, Iraq, this is believed to be one of the earliest maps produced entirely from aerial photographs. (See fig. 1147 for another detail.)
Size of the entire original: 27 × 45 cm; size of detail: 10.2 × 22.6 cm. Image courtesy of Peter Collier.

While not always successful, the results were regarded as comparable with plane table surveys under active service conditions (Collier and Inkpen 2001, 148). The air survey–derived maps were always regarded as a temporary expedient, and following any advance, plane table survey was used to create new maps of the occupied territory. While the British Army created significant amounts of new mapping from aerial photography, the German army largely restricted itself to revision of the PEF maps enlarged to 1:50,000.

A significant innovation of the Palestine campaign, particularly of the Third Battle of Gaza (1917), was the use of rapidly made position maps. These maps were produced every night during the battle as overprints for existing base maps, utilizing the latest intelligence. Once printed, the maps were rapidly dispatched to the troops (Pirie-Gordon 1919, esp. 88–89).

At the start of the Indian army campaign in Mesopotamia there was even less mapping available than in Palestine. This forced the Survey of India personnel to innovate in similar ways (fig. 595). However, the maps they produced were not regarded as interim sheets, and the surveyors continued to use air survey techniques for areas following their occupation by the Indian army (Collier and Inkpen 2001, 152; Tandy 1925).

Following World War I, both the French and British authorities began systematic topographic surveys of much of the area under their mandates. The mapping was done by French military units in Syria (including Lebanon) and by civilian organizations in areas under British control. At the outbreak of World War II the existing topographic maps were issued in military editions by the simple expedient of overprinting them with a military grid. Due to the number of grids used in the region, and the overlaps between grid zones, some sheets were overprinted with more than one grid.

During the course of World War II the British developed a major mapping capability in the Middle East. Initially based in Cairo, the mapping unit was moved into caves at Tura to avoid Axis bombing. Initially concerned with mapping in support of British operations in North and East Africa, the geographical scope of the mapping work expanded to encompass the whole of the Middle East, the Balkans, parts of Eastern Europe, and Italy. As the demand for maps could not be met solely from military resources, local survey departments were subcontracted to carry out printing. In addition, both the Survey of Egypt and the Survey of Palestine did cartographic work for the British military. This meant that, by the end of the war, reprographic material was held by survey departments in countries that were subsequently to be in conflict.

The British survey units during World War II included surveyors from Great Britain and from Australia, New Zealand, South Africa, and Poland (fig. 596). One survey unit was composed of Jews from Palestine. Their surveys covered the military operational survey require-

FIG. 596. BRITISH ARMY SURVEYOR IN LEBANON. Photographed in 1941 following the invasion by British and Free French Forces.
Image courtesy of the Defence Surveyors' Association, U.K.

ments from Egypt to Syria. The Forces Françaises Libres (FFL) executed a thorough triangulation covering Syria and Lebanon and produced 1:50,000 military maps during World War II, which were in bilingual editions for cooperation with the British.

The varied requirements of military users resulted in maps on a wide range of scales. In most cases smaller-scale maps were simply reductions from existing topographic mapping with additional overprints of military information as required. This practice in the Middle East was little different from military mapping in other theaters of war. The Axis forces were almost entirely dependent on mapping acquired before the war or captured during operations. There is no evidence of any original mapping done by the Axis powers during the war.

Thematic maps of various kinds were also produced. Examples include geological maps, maps designed for logistical support, and recreation maps for troops on leave from the front. Again, in common with other theaters, air navigation charts were produced at a variety of scales to meet the many needs of the users in the Middle East. However, some of the sophisticated navigational aids introduced during the war were not available in the Middle East, and the Gee lattice charts issued in Western Europe were not produced for the region, although Loran charts were issued with coverage as far east as Turkey.

There were a number of mapping innovations by the British during the war that had a wider significance later. One of the most important was the production of Goings (terrain trafficability) maps, designed to show the range of vehicle types that could cross the terrain (Clough 1952). Another important class of maps showed health risks, especially from malaria. These maps pinpointed areas that should be avoided for night exercises.

Prior to World War II the Survey of India was the main provider of mapping for Iran. At the beginning of the twentieth century they produced full coverage at 1:253,440 and partial coverage at 1:100,000. In 1942 an independent Iran military mapping agency was established, which undertook the task of mapping for the Iranian army. The Survey of India also produced early British military maps of Iraq.

At the end of World War II, Syria and Lebanon gained independence from France, but the British maintained a strong military mapping capability in Egypt. Even after the British withdrawal from the Suez Canal Zone, it maintained a small mapping capability in the Middle East. This was very important in support of counterinsurgency operations during the gradual British withdrawal from "East of Suez." It produced maps for various Gulf States and the South Arabian Federation. Britain was also involved in the production of some military mapping that, in retrospect, is hard to justify. This included the production in 1960 of 1:25,000 black-and-white maps of the former Palestine, derived from out-of-date 1:20,000 Survey of Palestine maps.

The Egyptian Military Directorate was established in 1954. Prior to this time, the Egyptian army relied on maps produced by the Survey of Egypt (United States, Department of the Army 1963, 21). This earlier mapping included 1:100,000 reprints of Survey of Palestine maps prepared for the Egyptian invasion of Israel/Palestine in 1948. One set of maps showed the composition of the population in each settlement (fig. 597).

Extensive mapping programs followed World War II, due to both the growth in local military mapping agencies and an increase in American interest in the area. In the 1950s, the U.S. Army Map Service (AMS) produced series mapping of northern and western Iran, western Syria, and Lebanon at 1:50,000 and 1:250,000, along with maps of northeastern Iraq and the mouth of the

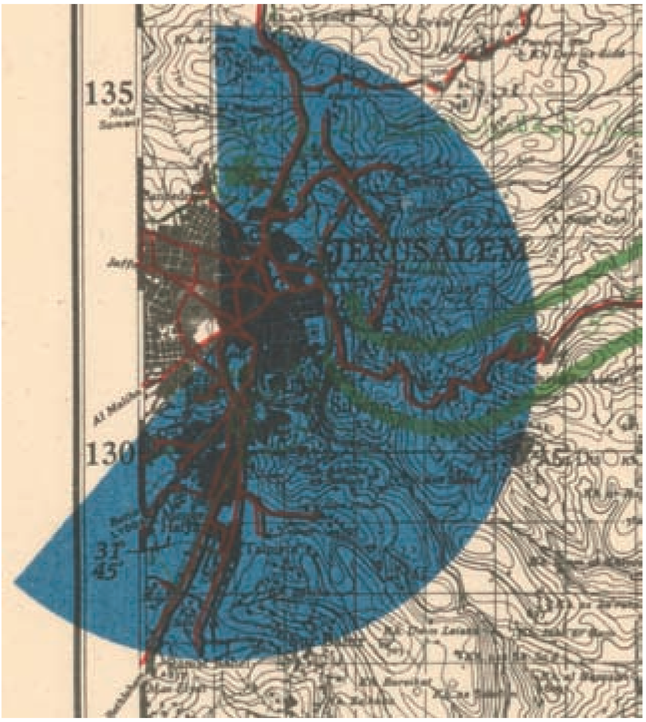

FIG. 597. DETAIL OF A 1:100,000 MAP *JERUSALEM*, 1948. Map by the Survey of Palestine reproduced by the Survey of Egypt (sheet 10, 2d ed.) for the Egyptian invasion of Israel in 1948 following Israel's declaration of independence. The map shows the Jewish proportion of the total population.
Size of the entire original: 46.3 × 53.7 cm; size of detail: 10.1 × 9.1 cm. Image courtesy of Peter Collier.

Tigris at 1:50,000 (United States, Department of the Army 1963, 67–68, 74, 86). Saudi Arabia was partially covered by the AMS at 1:250,000 and larger scales, and since 1975 there has been a systematic effort to provide military topographic mapping of the kingdom.

During the 1980s intensive military mapping of Iraq at scales of 1:50,000, 1:100,000, and 1:250,000 was accomplished. In part this was a response to the Iran-Iraq War. The Israeli attack on the Osiraq nuclear reactor, eighteen kilometers southeast of Baghdad, in June 1981, also drew attention to a possible need for up-to-date mapping. The Iraqi invasion of Kuwait in 1990 and the subsequent First Gulf War in 1991 led to a revival of interest in mapping of the region. A new series of topographic maps was prepared by the U.S. Defense Mapping Agency (DMA) for Iraq and Iran as well as satellite image maps. At the time of writing, the full extent of these mapping programs was still classified.

In the 1960s the United States started to use high-altitude high-resolution aerial photography for mapping in the region. The Soviet Union developed a satellite mapping capability based on small-scale high-resolution frame photography. These data were used for topographic mapping of the countries in the Middle East during the 1980s, mainly at a scale of 1:100,000, but in some areas at 1:50,000. Following the end of the Cold War, this mapping became available and excited considerable interest due to the depiction of militarily sensitive sites.

Starting in the 1970s, various types of image maps were produced in the Middle East. These proved extremely popular due to the speed of production and the relative ease of updating. The Israeli Defense Forces (IDF) began to produce orthophotomaps in the 1970s from aerial photography and, since the end of the 1970s, image maps from satellite imagery. At first these were at small scale (1:250,000) from U.S. Landsat images. By the end of the 1980s image maps at 1:100,000 and 1:50,000 were produced from French SPOT (Système Probatoire d'Observation de la Terre) imagery. In the late 1990s, the launching of high-resolution civilian satellites, with pixels of around one meter and a high level of positional accuracy, created a revolution in both image and topographic military mapping. This revolution was still ongoing at the close of the century.

PETER COLLIER AND HAIM SREBRO

SEE ALSO: Coordinate Systems; Gulf War (1991); Military Mapping by Major Powers; Paris Peace Conference (1919); Projections: Projections Used for Military Grids; World War I

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Military Mapping of Southeast Asia. At the start of the century military mapping as normally understood barely existed for Southeast Asia. For large parts of the region mapping of any kind was almost nonexistent or of very poor quality. As elsewhere, military requirements were largely met by reliance on civil mapping. In the Netherlands East Indies only Java had been mapped, and much of the rest of the colony was still being explored by the Dutch colonial authorities. Burma was in the process of being mapped by the Survey of India, which was to retain responsibility for Burmese mapping up to independence in 1948. A start had been made on mapping in the Federated Malay States and Singapore. Although a survey department had been established in Thailand in 1883 as part of the modernization of the country, little mapping had been carried out by 1900. Mapping for military purposes was found only in French Indochina as the French struggled to pacify the colonies, but even there, systematic medium-scale mapping was wholly a product of the twentieth century. Prior to 1900 the largest scale at which maps were available for the entire territory was 1:500,000.

As in the nineteenth century, British military mapping was focused on surveys of its fortifications at very large scales. British military mapping activities started in 1906 with the mapping of Singapore, as part of a worldwide scheme to review the defenses of naval bases and coaling stations instituted by the Committee of Imperial Defence. Because the Central Powers had no colonies in Southeast Asia, no military mapping activities resulted from the outbreak of World War I. However, the rise of Japan, and its increasing imperial aspirations, caused concern among the European colonial powers in the region. In particular, the British initiated a survey of Johore because of preoccupation with the long-term threat to their new naval base in Singapore.

Following the fall of France and the Netherlands in 1940, Japan put great pressure on the Vichy regime, and eventually took over the whole of French Indochina. In addition, they pressured the Dutch to cede control of the Netherlands East Indies (also known as the Dutch East Indies). The British undertook a mapping program in Southeast Asia to meet the Japanese threat, reproducing revised one-inch-to-the-mile (1:63,360) maps of the Malay Peninsula and reproducing all available Dutch mapping of the Netherlands East Indies in anticipation of the need to intervene militarily. The British also began to revise maps of Burma, initially under the Survey of India, and later under Headquarters India.

With the Japanese conquest of Southeast Asia and the United States' entry into World War II, a division of worldwide mapping responsibilities was negotiated by Martin Hotine, British director of Military Survey, and Herbert B. Loper, chief of the Intelligence Branch of the U.S. Army Corps of Engineers, to avoid duplication of effort. Under the Loper-Hotine Agreement, the mapping of the Netherlands East Indies became a United States responsibility (Clough 1952, 43), although Britain had been reproducing mapping of the Netherlands East Indies since April 1941. Britain retained responsibility for mapping Indochina, Thailand, Malaya, and Burma. By necessity most of this mapping effort was simply a recompilation of available mapping in a military style and with a military grid (fig. 598). Original surveys were impractical because aerial photographic coverage was not available for much of the area until late in the war. This led, for example, to the use of aircraft carrier sorties from Ceylon to obtain aerial coverage for the planned invasion of the Malay Peninsula in 1945. Similarly, Australian and U.S. mapping for the invasion of Tarakan, Balikpapan, and Labuan had to await acquisition of forward airfields on the island of Halmahera in the Moluccas. The one area where considerable original mapping was undertaken was Burma, where an aerial survey program initiated from scratch provided 1:25,000-scale maps needed for the advance from Imphal and Arakan to Mandalay. Lack of adequate ground control led to demands for the use of radar-controlled photographic missions to enable the resection of coordinates of air stations. The first radar-controlled unit was formed in Britain and about to proceed to Southeast Asia when the war ended (Clough 1952, 246).

FIG. 598. DETAIL FROM *MATARAM*, LESSER SUNDA ISLANDS, 1:250,000, 1945. The map (Hind 1120, sheet 1, 2d ed.) was compiled by the U.S. Army Map Service from a variety of earlier Dutch sources. The Dutch had only carried out reconnaissance surveys, hence the use of hatchures for relief portrayal.
Size of the entire original: 58.5 × 47.8 cm; size of detail: 9.3 × 12.3 cm. Image courtesy of Peter Collier.

The Allies were not the only powers to map Southeast Asia during the war. When the Japanese occupied large parts of the region, they undertook some military mapping at 1:50,000 and 1:100,000 in Sumatra, parts of the Celebes, and Halmahera (United States, Department of the Army 1963, 141).

At the end of World War II the British made use of their surplus aerial survey facilities to undertake sub-

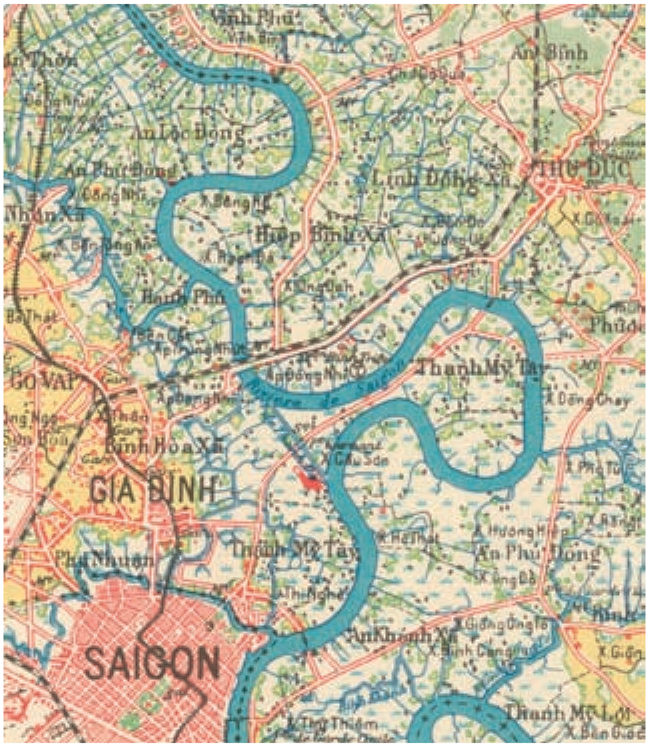

FIG. 599. DETAIL FROM *SAIGON OUEST*, 1:100,000, 1951. Carte de l'Indochine, feuille 221 W. Originally published in 1928, this French map of Saigon was reprinted in 1951 during the First Indochina War.
Size of the entire original: 61.0 × 41.5 cm.; size of detail: 11.7 × 10.1 cm. Image courtesy of Peter Collier. Permission courtesy of the Cartothèque, Institut géographique national.

stantial aerial photography programs covering Burma, Malaya, Thailand, and Indochina. The end of the war was followed by a number of colonial wars as the Vietnamese struggled for independence from France, the Indonesians struggled against the Dutch, and the British were faced with the so-called Malayan Emergency. In Indochina, the French had established the Service géographique de l'Indochine (SGI) in 1899 to provide topographic mapping, but as the security situation deteriorated, the SGI was supplemented in 1949 by the Service cartographique des Forces Terrestres d'Extrême Orient, under the General Staff of the French army in Indochina (fig. 599). In general, the main task of the Service cartographique was to use aerial photography in revising existing map sheets based on ground surveys by the SGI. In the Netherlands East Indies, the Dutch relied on British and U.S. mapping compiled during World War II. During the "emergency" in Malaya, a British survey squadron cooperated with the Survey Department of the Federation of Malaya to revise the one-inch (1:63,360) and other maps.

In the 1960s the British became heavily involved in mapping Sarawak, Sabah, and Brunei in northern Borneo in response to the so-called Indonesian Confrontation. Both 1:250,000 and 1:50,000 mapping were compiled from aerial photography by the Directorate of Military Surveys and the Directorate of Overseas Surveys. In most cases, mapping was based on aerial photography specially flown for this purpose, but some areas were mapped using photography taken by the United States during World War II.

The involvement of the United States in the fighting in Vietnam led to a major mapping effort as well as several important technical innovations. Direct U.S. involvement in mapping started even before the withdrawal of the French and the ceding of independence to North and South Vietnam, Cambodia, and Laos. Between 1953 and 1961 the U.S. Army Map Service (AMS) was engaged in 1:50,000 mapping in parts of Cambodia, Laos, and North and South Vietnam, and between 1954 and 1959 the AMS compiled 1:250,000 maps covering all these countries (United States, Department of the Army 1963, 106).

Having realized that the Vietnamese jungle was not adequately depicted by conventional line maps, the AMS made extensive use of photo mapping in support of U.S. military operations. In many cases these photomaps were hastily created products that lacked contours or other height information. A major technical innovation was the use of radar imagery for mapping areas under perennial cloud cover. Side-looking airborne radar, the early form of radar used in mapping, had poor geometric properties, which made it unsuitable for all but the most extreme cases where no other coverage could be obtained.

Among the other countries known to have carried out military mapping in Southeast Asia are the Soviet Union, China, and Vietnam. The Soviet Union produced military mapping of the region at a variety of scales, 1:100,000 and smaller. Little is known about Vietnamese or Chinese mapping, although it is understood to exist.

MIKE NOLAN AND PETER COLLIER

SEE ALSO: Coordinate Systems; Military Mapping by Major Powers; Projections: Projections Used for Military Grids; World War II

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United States. Department of the Army. 1963. *Foreign Maps*. Washington, D.C.: Headquarters, Department of the Army.

Military Mapping of Korea. Western survey methods were introduced in Korea in the late nineteenth century as part of the Gwangmu Reform, which in terms of mapping were mainly concerned with cadastral work to support reform of land taxation and had no impact on military mapping. The Japanese carried out the earliest military mapping following their annexation of Korea in 1910. By 1926 the Japanese had mapped the whole of Korea at 1:50,000. There were three agencies responsible for this mapping: the Japanese Korean Provisional Land Survey Bureau (Chōsen Sōtokufu rinji tochi chōsakyoku 朝鮮総督府臨時土地調査局), the Japanese Imperial Land Survey (Dai Nippon teikoku rikuchi sokuryōbu 大日本帝国陸地測量部), and the Japanese General Staff. The Japanese Imperial Land Survey was part of the Japanese army under the nested aegis of the General Staff. The maps were monochrome with a twenty-meter contour interval and auxiliary contours at ten meters. Revised by the Japanese until 1942, the series was to form the basis for most post–World War II mapping of the peninsula.

The same three agencies carried out mapping of some strategic areas around major urban centers at 1:25,000. This series was based on plane table surveys carried out between 1911 and 1917, but with some sheets revised as late as 1943. These maps were published in color. Mapping was also produced at 1:200,000 and 1:500,000 by different combinations of the three agencies. The 1:200,000 series was originally produced by the Provisional Land Survey Bureau, with the sheets later revised by the Imperial Land Survey. Some sheets had contours at intervals of 50 or 100 meters, and supplementary contours at 25 meters, but others had form lines or hill shading to depict relief. The 1:500,000 series was contoured at 100- or 500-meter intervals with hypsometric tints. No grids were used on any of the maps made by the Japanese even though grids had become the norm in military mapping elsewhere (United States, Department of the Army 1963, 125).

Following the Japanese surrender in 1945 and the establishment of the governments of North and South Korea, two separate military mapping organizations were established: the General Staff, People's Army (GSPA) in North Korea and the Republic of Korea Army Map Service in South Korea (ROKAMS). Both organizations started by producing direct copies of the various Japanese map series with only minor revisions of names and cultural features, such as roads. The 1:50,000 mapping by the GSPA provided almost complete coverage of the Korean Peninsula, but that by ROKAMS extended only as far north as 40°N. Both map series were overprinted with military grids, the ROKAMS sheets with a Universal Transverse Mercator (UTM) grid and the GSPA sheets with a kilometer grid identical to the Soviet grids of the same period.

Since 1945 the United States has published maps of Korea. As with the maps produced by Koreans, these were initially derived from the existing Japanese mapping, with 1:50,000, 1:250,000, and 1:1,000,000 series produced for the entire peninsula. Following the outbreak of the Korean War the 6204th Photo Mapping Flight was deployed to Korea from the Philippines. The two RB-17 airplanes were modified to fly combat missions, and by late August 1950 started flying photographic missions over Korea. By the end of November 1950 they had flown complete coverage of North Korea at least once. Photographic missions were to continue throughout the Korean War, but most of these missions were for reconnaissance rather than mapping. In addition to conventional line mapping, the U.S. Army Map Service (AMS) produced 1:25,000 photomaps of most of Korea south of 39°20′N (United States, Department of the Army 1963, 123).

The Soviet Union carried out 1:50,000 mapping in Korea following its occupation of the northern part of the peninsula at the end of World War II. These maps were also based on Japanese originals, with the addition of a military grid. Some Soviet mapping had taken place earlier, based on survey work during World Wars I and II. Soviet mapping of the whole Korean Peninsula continued after their withdrawal as part of their wider mapping program. The so-called 1942-System maps were produced at 1:50,000 and 1:200,000 and appear to have been revised periodically until the end of the Soviet era in 1991. Following the entry of China into the Korean War, the Chinese People's Liberation Army made facsimile reproductions of Japanese 1:50,000 maps, but with some modifications for Chinese use. It seems that the Chinese mapping was carried out independently of the GSPA, although the maps are broadly similar (United States, Department of the Army 1963, 123).

Following the Korean War the ROKAMS mapped the area around the Demilitarized Zone at 1:25,000. These maps, produced between 1953 and 1957, were derived from AMS maps at the same scale. A polychrome series at 1:50,000 (L751) was produced between 1950 and 1957 based on Japanese originals, and reflected the distinctive Japanese style of contouring (figs. 600 and 601). Two series of maps were produced at 1:100,000 between 1957 and 1961. One series covered the Korean Peninsula south of 40°N, except for the area around Seoul, which was covered by AMS mapping. The other series covered six towns in the northwestern part of South Korea. A 1:250,000 series, based on AMS originals and covering the whole of Korea, was also produced (United States, Department of the Army 1963, 123).

Little is known about North Korean mapping activities since the Korean War as maps are considered secret documents by the North Korean government. The only examples of North Korean mapping that have been seen by outsiders are those captured during the Korean War. It is not known to what extent new technologies have been applied to map production.

By the end of the twentieth century all of the South Korean map series based on Japanese originals had been superseded by more modern mapping. Procedures called for ROKAMS to add data as required to the topographic bases and other data sets produced by the civilian mapping agency, National Geographic Information Institute

FIG. 600. DETAIL OF AN AMS 1:50,000 MAP, *CHAIN*. Redrawn in Korea in 1950 from a Japanese Imperial Land Survey map of 1937, this early AMS map (L751, sheet 6921 II) has place-names only in the Latin alphabet.
Size of the entire original: 54.7 × 51.0 cm; size of detail: 16.9 × 11.8 cm. Image courtesy of Peter Collier.

FIG. 601. DETAIL OF AN AMS 1:50,000 MAP, *TUKSŎM*. Compiled from 1:25,000 sheets, which were based on photogrammetric surveys, this eighth-edition sheet from 1953 (L751, sheet 6626 IV) has place-names in both the Latin alphabet (black) and Korean characters (red).
Size of the entire original: 52.9 × 51.0 cm; size of detail: 13.6 × 9.5 cm. Image courtesy of Peter Collier.

(NGII). In effect, ROKAMS maintained topographic mapping series parallel those of the NGII. For military purposes there were also various overprints and military layers for both raster and vector data sets.

At century's end the United States still maintained a military presence in South Korea in the form of the army's Second Infantry Division. Some mapping was still being produced by the U.S. National Imagery and Mapping Agency (NIMA) in support of the division's activities such as training.

PETER COLLIER

SEE ALSO: Coordinate Systems; Military Mapping by Major Powers: (1) United States, (2) China, (3) Japan; Projections: Projections Used for Military Grids

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United States. Department of the Army. 1963. *Foreign Maps*. Washington, D.C.: Headquarters, Department of the Army.

Military Mapping of Australia. The Commonwealth of Australia was founded on 1 January 1901. At that time few maps of the territory even existed, and fewer still of military quality. Although the government recognized the seriousness of this deficiency, it was not until 1907 that the country's military assumed responsibility for surveying and mapping.

Initially, the few personnel on hand for surveying and mapping tasks were available only for short periods and were not specifically trained for this technical activity. Consequently, the management of roles and responsibilities remained largely unchanged until 3 July 1915, ten weeks after the Anglo-French landing at Gallipoli, when a notice in the *Commonwealth Gazette* promulgated the decision to form a separate unit of the permanent military forces to be known as the Survey Corps. Until its disestablishment in 1996, the Royal Australian Sur-

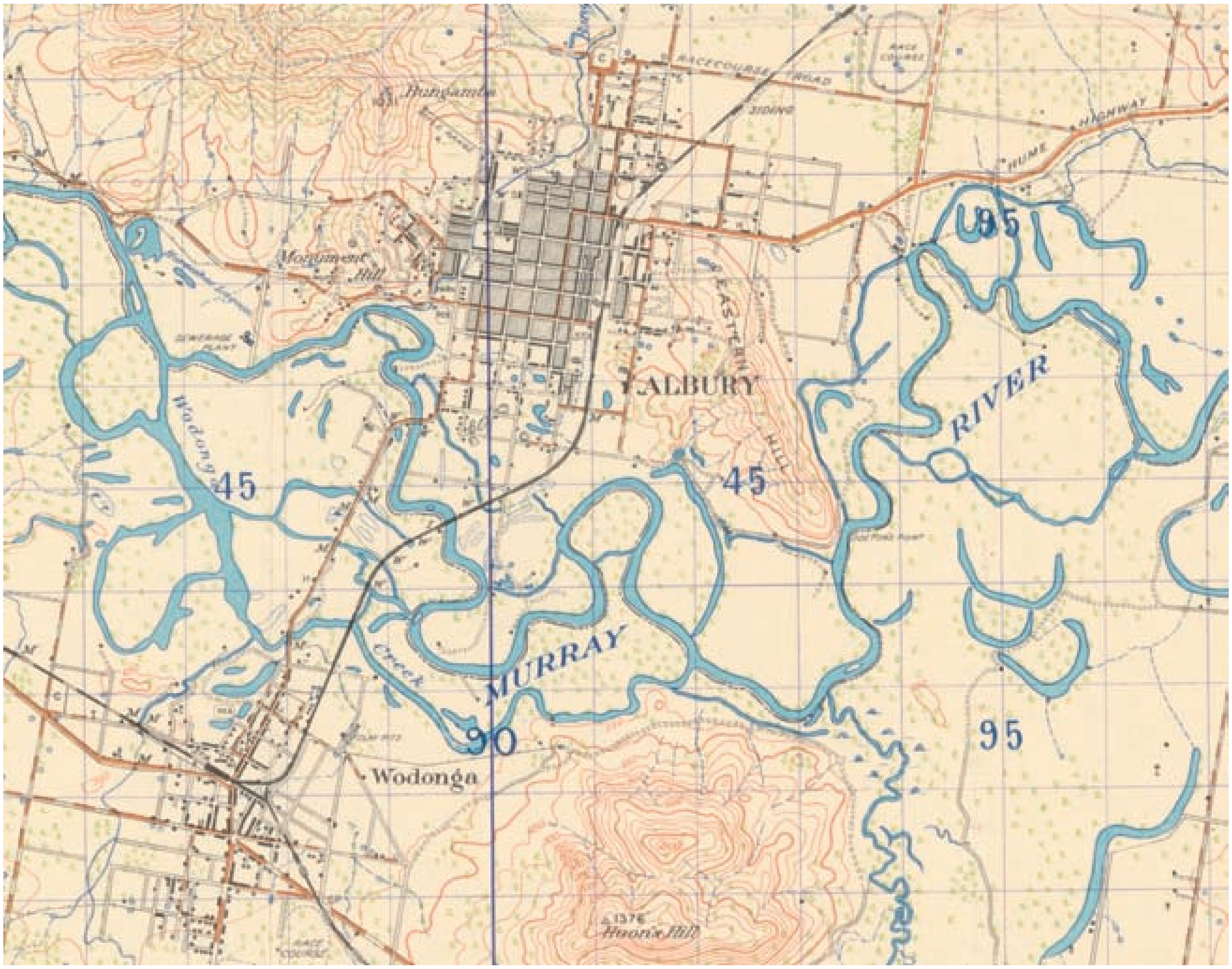

FIG. 602. DETAIL FROM *NEW SOUTH WALES AND VICTORIA: ALBURY*, JUNE 1933. This is the first map by the Australian military to rely heavily on aerial photography. Surveyed by the Australian Survey Corps and Royal Australian Air Force, prepared by the Australian Section Imperial General Staff, scale 1:63,360.

Size of the entire original: 57.3 × 76 cm.; size of detail: 13.6 × 17.3 cm. Image courtesy of the Map Collection, National Library of Australia, Canberra.

vey Corps and its predecessor, the Survey Section, Royal Australian Engineers, contributed greatly to the mammoth task of mapping Australia and other nations in the region (Coulthard-Clark 2000).

At the outbreak of World War I an embargo prohibited surveyors from enlisting in the Australian Imperial Forces. When the embargo was lifted in 1917, mapping operations in Australia came to a virtual standstill as surveyors departed for the Middle East and the Western Front, where some joined the Australian Corps Topographical Section in support of the Anzac Corps, a combined army unit from Australia and New Zealand.

Appreciation of the urgent need for mapping disappeared at the end of World War I, and neglect continued throughout the 1920s. Even so, technological advances and collaboration produced some noteworthy achievements. In 1923, for instance, the Royal Australian Navy's Hydrographic Branch used aerial photographs from the Royal Australian Air Force, supplemented by a trigonometric ground survey, to produce a map of Western Port Bay in Victoria. In 1933 Australia adopted the transverse Mercator projection and with British assistance modified the country's grid system. The prototype Albury map that followed was the first military map produced in Australia to rely heavily on aerial photography (fig. 602).

In 1938, the Australian Department of Defence adopted a Long Range Mapping Program in response to a growing demand for defense mapping. When the outbreak of World War II made the poor condition of Australian mapping painfully apparent, the original program was enhanced and extended as the Strategic Mapping Scheme, which was implemented in conjunction with Australia's state governments.

In 1941 the Survey Corps took on overseas commitments that included surveying and mapping in the Middle East, principally in Palestine, Lebanon, Syrai, and Transjordan. A year later the company returned to Australia, where units were being formed to carry out surveying and mapping in the South West Pacific Area, which included Australia and Papua, the Netherlands (or Dutch) East Indies exclusive of Sumatra, the Netherlands Indies (later Netherlands New Guinea), British Borneo, Portuguese Timor, the Philippines, and Australia's mandated territories, namely, North-East New Guinea, the Bismarck Archipelago, and most of the Solomon Islands. Lawrence FitzGerald, who commanded the survey company in the Middle East and was director of survey from 1942 to 1960, later detailed the surveying and mapping operations (FitzGerald 1980).

By late 1941 Japan had extended its control throughout Indochina, and the threat to the security of establishments in Australia was a cause for alarm. The Army Headquarters Cartographic Company, the major map production unit, was relocated from Melbourne to Fortuna, a rambling old mansion in Bendigo, Victoria. The unit played an important role throughout the war before evolving into the Army Survey Regiment, the mapmaking base of the Australian Army and the largest map production factory in the Southern Hemisphere (Lovejoy 2003).

In the immediate postwar period the Survey Corps undertook several projects that exceeded the capabilities of civilian departments, namely, mapping for a water conservation initiative by the Queensland State Government, an investigative survey to dam and divert the Snowy River in New South Wales, and mapping to assist the Victorian State Government with the 1947 Census. A particularly significant seven-year project with the Long Range Weapons Establishment in South Australia included geodetic surveying as well as extensive mapping for the Woomera Rocket Range and the atomic testing range at Maralinga (Coulthard-Clark 2000; Sargent 1994).

On 31 December 1948 the Army Survey Corps was granted the title "Royal" in "recognition of their services in World War II," and thus became the Royal Australian Survey Corps (RASVY) (Sargent 1994, 283). In August 1954 the RASVY undertook the first of many postwar operations outside the mainland of Australia. The operation in New Guinea was carried out under the terms of a cooperative mapping agreement set up in 1947 between Australia and the United States. Between May 1966 and October 1971 soldiers from the corps were again required for war duties, this time in support of the Australian Task Force in Vietnam (McMillan-Kay 2002, 89–92).

From 1970 to 1986, through Australia's Defence Cooperation Program, the RASVY conducted field surveys and related mapping for Papua New Guinea, the Solomon Islands, Fiji, Tonga, Kiribati, Nauru, Tuvalu, Vanuatu, Western Samoa, and parts of Indonesia. In addition to helping countries in the western part of the South Pacific set up or modernize their mapping programs, these activities established survey control for delineating Exclusive Economic Zones (EEZs) offshore. In addition to surveying and mapping assistance, the RASVY also provided military and civilian personnel in the various countries with on-the-job training as well as specialist training at its School of Military Survey (Coulthard-Clark 2000; Sargent 1994).

In addition to these offshore activities, the RASVY was involved in major surveying and mapping programs from 1958 until the end of the century. The programs involved both Commonwealth and state mapping and surveying organizations. These activities aimed at providing total map coverage of the continent once the continental geodetic network allowed all mapping and surveys to be placed on a single datum. This was a formidable task and the RASVY undertook a major part of it.

Although the RASVY had established itself as a leader in surveying and mapping technology, overseas as well as in Australia, its experience in having adopted analytical photogrammetry in the 1960s, computer-assisted mapping in the 1970s, and numerous innovations in the 1980s was insufficient to cope with uncertainty in the 1990s over technical capability and organizational change. The corps disbanded in 1996, and its topographic squadron was reassigned to the Royal Australian Engineers, while the Army Survey Regiment, after a short period as a commercial support capability, became part of the Defence Imagery and Geospatial Organisation (DIGO), a new organization established on 8 November 2000.

C. D. Coulthard-Clark (2000, 197–98), a prominent Australian military historian, aptly summarized the RASVY's significance and impact: "For a start it was a unique body, since no similar specialist mapping organisation exists or was to be found among other Western armies or national mapping organisations worldwide. In a real sense, its creation was an individually Australian response to a particular Australian problem and set of circumstances. Measured by its output, the corps' achievement was also remarkable, since its achievements transcended a purely military thirst for maps and topographical information."

ROBERT J. WILLIAMS

SEE ALSO: Coordinate Systems; Military Mapping by Major Powers: Military Mapping by Great Britain; Projections: Projections Used for Military Grids

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Sargent, Clem. 1994. "The Royal Australian Survey Corps, 1915–1990." *Australian Surveyor*, December, 275–89.

Miller, O(sborn) M(aitland). Born in Perth, Scotland, on 20 July 1897, Osborn Maitland Miller graduated from the Royal Military Academy, Woolwich, in 1915, and served as an artillery officer with the British Army in France, where he was wounded in 1917. Given a medical discharge, he enrolled in the Royal Geographical Society's (RSG) two-year course in topographic surveying and reconnaissance mapping for explorers. Miller moved to New York in 1922, after the American Geographical Society (AGS) hired him to teach courses in practical and theoretical cartography in its School of Surveying, modeled after the RGS program. The position allowed him to experiment with evolving mapping techniques and contribute to the society's numerous mapping and exploratory projects. Although the AGS downsized the surveying school in 1931, he remained as head of its Department of Technical Training.

After visiting the Wild Instrument Company in Zurich in 1926, Miller became fascinated with photogrammetric mapping, particularly the use of oblique air photos for making small-scale reconnaissance maps. He described his strategy in a 1931 *Geographical Review* article titled "Planetabling from the Air"; refined his technique preparing the cartography for *Northernmost Labrador Mapped from the Air*, a 1938 AGS monograph; and contributed the chapter "Topographic Mapping from High Oblique Air Photographs" to the first *Manual of Photogrammetry*, published in 1944 by the American Society of Photogrammetry, which elected him president the following year.

Miller is best known for the Miller cylindrical projection (fig. 603), developed in the early 1940s at the request of Samuel Whittemore Boggs, chief cartographer at the State Department (Miller 1942). Worried about public misinterpretation of distorted world maps, Boggs commissioned Miller to assess existing cylindrical projections and recommend improvements. Eager for a worldview similar in appearance to the Mercator projection but without extreme areal distortion in poleward regions, Miller repositioned the Mercator map's poles, never shown because they lie at infinity. His strategy, dubbed the "80 percent solution" (Monmonier 2002, 54), finds the projected position for 72°N (80 percent of 90°N) on the Mercator grid and then divides the resulting offset from the equator by 0.8. A similar 80 percent adjustment of other parallels yields a compromise rectangular projection that balances areal and angular distortions and avoids pronounced east-west stretching between 70°N and S. Several American commercial atlas publishers adopted the Miller projection for small-scale world maps, but their European counterparts preferred compromise cylindrical projections developed by Europeans (Snyder 1993, 179–83).

In 1940 Miller and AGS senior cartographer William A. Briesemeister developed a bipolar oblique conformal conic projection as a low-distortion framework for the society's 1:5,000,000 map of the Americas (Snyder 1993, 251–53). After Briesemeister proposed an oblique conic projection for South America, Miller suggested blending a pair of conic projections optimized separately for the two continents, and derived the mathematical formulas for shifting each cone's apex away from earth's axis (Wright 1952, 325). A decade later he devised the Miller oblated stereographic projection for a low-distortion two-continent conformal map of Africa and Europe (Snyder 1993, 244–46).

Miller lived in New York after retiring from the AGS in 1968. He died on 1 August 1979.

MARK MONMONIER

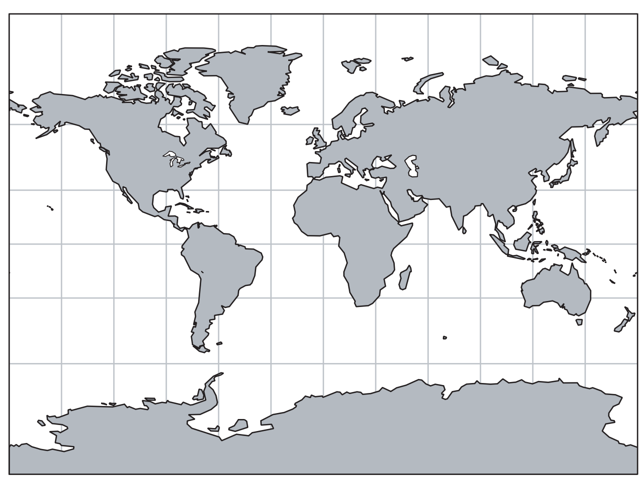

FIG. 603. MILLER CYLINDRICAL PROJECTION. Conceived as a modification of the Mercator projection, the Miller cylindrical projection sacrifices conformality (true angles) for substantially reduced areal distortion in polar regions.

SEE ALSO: American Geographical Society; Mercator Projection; Photogrammetric Mapping: Air Photos and Geographic Analysis; Projections: World Map Projections; Scientific Discovery and Cartography

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Mobility Map. See Wayfinding and Travel Maps: Mobility Map

Modes of Cartographic Practice. Starting in the late nineteenth century, the modern cultural commitment to cartography as an innately progressive endeavor produced, and was reproduced by, traditional histories of cartography. A highly selective canon of early maps enshrined the progressive narrative: by studying the canon, map historians demonstrated how Western mapping had progressed linearly from classical and medieval origins to modern achievements. This historiographic structure was not significantly altered by the development after 1950 of internal histories of cartography. But, after 1978, sociocultural map historians dramatically expanded the field both by reinterpreting the canonical maps and by embracing the variously popular, derivative, ephemeral, non-Western, and indigenous maps previously excluded from study. Sociocultural commentators overwhelmingly rejected the progressive narrative in favor of highly focused, synchronic studies of map texts and contexts. Matthew H. Edney (1993) proposed the study of cartographic modes (i.e., ways of acting) specifically to resurrect the diachronic study of map history without any presumption of the inevitability of progress. The concept of mode necessarily facilitates comparative studies (e.g., Monmonier and Puhl 2000) and has become central to the ongoing development of critical approaches to cartography (Edney 2011b, 338–39). Seeking both comparative and diachronic coverage, volumes 4 through 6 of *The History of Cartography* have all been designed around modern cartographic modes.

The key to understanding cartographic modes is the realization that people understand the world differently for different ends. Several historians have identified such divisions, variously labeling them mapping genres, archives, or discourses depending on the particular criteria used (Edney 2011b, 334). More generally, by empirically tracing the manner in which different kinds of maps circulate socially, geographically, and institutionally, we can discern relatively coherent clusters of interest and activity, which is to say cartographic modes. The identification of modes is thus a process of comparison and discrimination. The core of a mode is a certain conception of spatial significance: for example, the mariner has little interest in continental interiors; the landowner and tax collector are two of several communities that conceive of the world as a mosaic of discrete properties; academics, politicians, and the wider public seek to comprehend the geography of the world by dividing it into a hierarchy of regions. Each spatial conception sustains, and is sustained by, specific discourses employing a variety of representational strategies: marine discourses can feature oral lore, written itineraries, graphic views of headlands, and a variety of harbor, coastal, and oceanic charts; geographical discourses can feature both verbal commentaries, written accounts, and regional maps; discourses of property can feature oral lore, physical marks in the landscape itself, toponyms, verbal descriptions, and graphic plans. The different spatial conceptions imply that each community of map producers and consumers deploys technologies and techniques appropriate to each conception: the assemblage of logs and coastal itineraries, plus astronomical control in the modern era, into sea charts; the direct observation and measurement at a large scale, often ignoring the earth's curvature, of the bounds of each property parcel; the omnivorous compilation of all kinds of source materials into geographical maps of the main features, physical and human, of each region. We can thus start to identify distinct cartographic modes. As discussed here, we can distinguish the modes of marine, property, and geographical mapping. Each mode comprises a more or less coherent suite of spatial conceptions, institutional needs, representational strategies, practices of both map production and map consumption, and groups of individuals among whom the maps circulate.

Diachronic histories of cartography can be written accordingly as the histories of different modes and their interactions (e.g., Edney 2007, 2011a). Modes must not be understood as predefined, idealized, or strictly delimited structures to which mapmaking and map using are fitted. Rather, they are formations through which spatial knowledges and representations evolve together. Modes can possess a great deal of internal variation and they can vary in their degree of cohesion and sophistication. Implicit in this perspective is that modes change over time, through their own internal dynamics as well as through external influences. The historian's task is to delineate each society's cartographic modes and their interconnections by considering all the ways in which a given society construes and represents spatial relationships, whether and how it uses graphic representational strategies, and especially the patterns formed from the

Table 37. The cartographic modes pursued in modern Europe. Modes as applied in volume 4 (*Cartography in the European Enlightenment*), volume 5 (*Cartography in the Nineteenth Century*), and volume 6 (*Cartography in the Twentieth Century*) of *The History of Cartography*. In these descriptions, large-scale is defined as ca. 1:100,000 or larger, small-scale as ca. 1:1,000,000 or smaller, and medium-scale in between.

boundary mapping	medium-scale or small-scale mapping of boundaries between polities such as states and provinces (not properties); in many respects a hybrid of geographical and topographic mapping
celestial mapping	an upward gaze: usually small-scale mapping of the celestial vault and individual planets
dynamic cartography*	mapping phenomena with a temporal dimension, at any scale and including, but not limited to, animated and interactive maps
geodetic mapping	measurement of the size and shape of the earth through high-level triangulations
geographical mapping	generally small-scale mapping of regions or of the entire world, including road maps, generally associated with a wide variety of institutions concerned with knowledge (states, general public, etc.)
marine charting	a seaward gaze: mapping at all scales of seas, coasts, and harbors, undertaken by and for marine institutions; harbor charting pragmatically associated with topographical mapping
overhead imaging*	mapping from airborne and orbital platforms using photography or electronic imaging
property mapping	large-scale mapping of parcels of property for creating, regulating, and preserving property rights and use
thematic mapping	mapping of the distribution of natural or social phenomena at all scales; not the same as special-purpose maps, which are precise manifestations of other modes
topographic mapping	large- to medium-scale mapping of places and by extension of the earth's surface generally, allied to the representation of landscapes by various institutions including engineers (civil and military) and antiquarians
urban mapping	large- to medium-scale mapping of urban places

*Volume 6 only.

circulation of its spatial representations. This is an approach applicable to any society or culture, although in studying non-Western and premodern societies there should be no expectation that their practices of spatial representation and their cartographic modes would be differentiated just like those of modern Western culture (see Meece 2006). Overall, defining and studying modes is very much a bottom-up, empirically driven process.

For the modern Western world, the editors of volumes 4, 5, and 6 of *The History of Cartography* identified eleven specific modes, outlined in table 37. As adapted to the specific periods, these modes have formed the basis of the design of each volume. In particular, they have defined the "conceptual clusters" by which each encyclopedic volume has been organized, as described in each volume's introduction. The benefit of this approach is that it ensures a comprehensive coverage: even as more space has been allotted within each volume to the dominant modes within each period—notably the modes of marine, topographic, and geographical mapping—space is nonetheless reserved for less prominent modes that might otherwise be overlooked. Furthermore, by addressing modes, contributors have been encouraged to consider practices of map consumption as well as map production, thereby supporting the *History*'s avowed intent of promoting the sociocultural study of map history.

As implied above, modes do intersect and overlap. Some intersections are idiosyncratic: a land surveyor who also happens to make regional maps might be an avenue of transmission of new representational strategies and practices between modes. Other intersections can be more pervasive: the habit of geographers to appropriate marine charts and topographic maps for their regional maps stands as a persistent intersection of cartographic significance. Such an intersection does not mean that the modes themselves combine; after all, the regional maps are still circulated and consumed through established geographical discourses, while mariners and engineers continue to work within their own modes. Some intersections are not cartographically significant: individuals can participate in different modes through different aspects of their lives, such as a government official (geographical, topographic, and thematic mapping), who is also a landowner (property mapping), and who is privately interested in astronomy (celestial mapping). But within certain institutional contexts, individuals can produce and consume maps from multiple modes. The commercial map trade, for example, while dominated by the production and sale of geographical, maps can

Table 38. Modern European cartographic endeavors, or institutional groupings, within which multiple cartographic modes are pursued. As applied to volume 4 (*Cartography in the European Enlightenment*), volume 5 (*Cartography in the Nineteenth Century*), and volume 6 (*Cartography in the Twentieth Century*) of *The History of Cartography*.

academic cartography	the scholarly analysis and codification of all mapping practices (volume 6 only)
administrative cartography	the commissioning and use of maps of all sorts within agencies of civil government (central and local)
map publishing	the sale and dissemination of maps through the public marketplace, mostly geographical but also marine, urban, and thematic (called "map trade" in volumes 4 and 5)
map collecting	the conscious effort to collect and consume maps across all modes but generally emphasizing geographical and printed maps whether in small or large quantities
warfare and cartography	the commissioning and use of maps of all sorts within military organizations, not only topographic (tactics) but geographical (logistics, strategics) and marine as well (called "military cartography" in volumes 4 and 5)

nonetheless strongly feature marine charts and urban maps. For this reason, the *History*'s editors have also identified a series of broad institutional endeavors that each brings together a variety of modes (table 38).

The experiences of the *History*'s editors in using cartographic modes to organize diachronic and comparative narratives have highlighted the way in which such study requires a significant shift of the established intellectual perspective of map history. Contributors to the *History* have shaped meaningful narratives, but only after being oriented to the need to distinguish between sets of mapping that map historians have not generally seen as distinct. Perhaps the hardest distinction to accept has been geographical mapping. Usually taken to comprise almost the entirety of the history of cartography, studying geographical mapping as simply the mode *primus inter pares* seems to reduce the status of the entire field. Yet doing so is demonstrably crucial to understanding map history as a social history of cultural production and thereby enhances its significance to scholars across the humanities and social sciences.

Matthew H. Edney

see also: Histories of Cartography; History of Cartography Project; Map: Map Typologies

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Molodenskiy, M(ikhail) S(ergeyevich). Mikhail Sergeyevich Molodenskiy (Molodensky) reformulated the theory of the figure of the earth and made fundamental contributions to the theory of earth rotation. His research provided a theoretical basis for the astronomic-gravimetric network of the Soviet Union, which in turn was the foundation for the geodetic and cartographic survey of the whole country during the presatellite era. Work similar in scope and scientific precision had never been carried out in any other country. His breakthrough mathematic solution (around 1945) to a vexing problem in the correction of geodetic coordinates led to a theory for the direct determination of the earth's topographic surface from measurements of gravity and height. Molodenskiy's theory greatly influenced the development of theoretical geodesy by geodetic scientists in several countries, most notably, Arne Bjerhammar (Sweden), Helmut Moritz (Austria/Germany), Torben Krarup (Denmark), Lars Hörmander (Sweden), and Fernando Sansò (Italy). Because of his work's worldwide significance, Molodenskiy is considered the single most important physical geodesist since World War II.

Born on 15 June 1909 in Epiphan, Tula District, Russia, Molodenskiy was the son of an orthodox priest, a heritage that limited his possibilities for higher education under the Communist regime. Nevertheless, he graduated from the Astronomy Department of the Faculty of Mechanics and Mathematics of Moskovskiy gosudarstvennyy universitet (Moscow State University) in

1931 and was thus eligible for employment as a research worker and lecturer. A few years later he was invited by Feodosiy Nikolayevich Krasovskiy to join the staff of the Tsentral'nyy nauchno-issledovatel'skiy institut geodezii, aeros"yëmki i kartografii (TsNIIGAiK) in Moscow. As the key institution for theoretical and practical geodesy and cartography, TsNIIGAiK was responsible for basic research as well as for issuing all maps of Soviet territory. It was closed to foreigners until the perestroika (literally, "restructuring") initiated by Soviet leader Mikhail Gorbachev in 1987. Krasovskiy was a key figure in the institute and was instrumental in calculating the Krasovskiy ellipsoid, which served as the official reference ellipsoid for all geodetic and cartographic work in the USSR and its European satellite countries (as well as in China) from 1948 into the twenty-first century.

The invitation to join TsNIIGAiK was an enormous honor, quickly justified by Molodenskiy's remarkable work in both theoretical and applied geodesy. He was not only a brilliant mathematician but also a skilled mechanical engineer, who invented or improved gravity pendulums and gravimeters. He was able to foresee the direction of the development of geodesy many years ahead.

In everyday life, Molodenskiy was good-hearted, gentle, and always ready to assist other people. Nevertheless, he was always deeply absorbed by intellectual and highly imaginative pursuits, which made him appear distant and aloof. Even so, those privileged to know him were grateful for the opportunity.

Molodenskiy worked at TsNIIGAiK from 1933 to 1960 while also holding an appointment at the institute of physics—Institut fiziki zemli, a member institution of the Rossiyskaya Akademiya nauk. Responding to persistent pressure—one of the hazards of enormous prestige—he accepted an appointment as director of the Institut. In addition to numerous awards, he was elected a corresponding member of the Akademiya nauk. Although honored by these appointments, Molodenskiy did not like administrative work, which undermined his health, and resigned his administrative position but continued to work for the Institut as a scientist. After 1960, his work focused on the oscillations of an elastic earth, a subject crucial to modeling the planet's irregular rotation. Because of laser measurement of distances to artificial satellites, this new focus was nearly equal in scientific importance to his earlier work on the figure of the earth. Even so, Molodenskiy's theory, a familiar term among earth scientists, is reserved for his classical theory of the figure of the earth and its gravimetric determination.

Molodenskiy spent his last decades in semiretirement, working at home and absorbed by his research. During these years his connection with the outer world was almost entirely through his faithful disciple and assistant M. I. Yurkina. He died in Moscow on 12 November 1991.

HELMUT MORITZ

SEE ALSO: Figure of the Earth; Geodesy: Gravimetric Surveys; Geophysics and Cartography; 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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Moon Map. See Lunar and Planetary Mapping

Moskovskiy institut inzhenerov geodezii, aerofotos"yëmki i kartografii (Moscow Institute of Geodetic Engineering, Aerial Photography, and Cartography; Russia). This institute, known by its acronym MIIGAiK, had its earliest historical roots in the 1767 opening in St. Petersburg of a school to train mapmakers and surveyors for carrying out the general lands survey of the Russian Empire, the General'noye mezhevaniye zemel'. Although that school continued in operation until 1819, another more direct forerunner was the Konstantinian land survey college (*uchilishche*) of the Moscow land survey office (Moskovskaya mezhevaya kantselyariya) established on 14 May 1779 and named for empress Catherine II's second grandson, Konstantin Pavlovich (Kusov 2004, 46).

On 10 May 1835 czar Nikolay I decreed that the land survey college should become an institute—Konstantinovskiy mezhevoy institut—a higher educational establishment financed by the crown treasury. The Institut's graduates were not only engineers competent in geodetic measurement and calculation but also officers of law responsible for verifying estate boundaries by checking historical sources (land descriptions, maps, and legal documents). During the 1840s the Institut's program of study was lengthened from four to six years, and an observatory was opened. On 15 November 1916 czar Nikolay II added "imperial" to the name: Imperatorskiy Konstantinovskiy mezhevoy institut. The eight professors on the staff of the Institut as of 1 January 1917 had expertise in law (V. Ustinov), astronomy (K. A. Tsvetkov), rural hydrotechnical construction (A. Shiryayev), geodesy (Feodosiy Nikolayevich Krasovskiy), analytical geometry (V. M. Lavrov), geodesy and land use planning (S. M. Solov'yev), meteorology and theory of optical instruments (N. M. Kislov), and geodesy and mathematical processing of geodetic measurements (N. Veselovskiy). On 4 August 1917 the Ministry of Justice approved new curricula including twenty-three subjects to be studied in the geodesy division and twenty-two subjects in the land use division. At the end of August 1917 the geodesy division consisted of seven departments (mathematics, physics, study of instruments, geodesy, advanced geodesy and cartography, astronomy, civil engineering), while the land use division consisted of nine departments (government legislation, Russian land legislation, land division [*mezhevaniya*], land use planning, agricultural taxation, forest taxation, pedology, land cultivation, and improvement techniques).

The Russian Revolution of 1917 led to many changes in the Institut's curriculum and structure. The Bolsheviks regarded it as important for the exploration and evaluation of Russia's agricultural lands and forests. In 1918 the influential party functionary, Mikhail Dmitriyevich Bonch-Bruyevich, who had received the Institut's gold medal award when he graduated in 1890, was appointed to the geodesy department. In February 1919 he presented a plan for creating a state survey agency, the Vyssheye geodezicheskoye upravleniye (VGU), to a meeting of land survey engineers. All educational activities of the Institut during the Soviet and post-Soviet periods were henceforth connected with the VGU.

A decree of the Sovet narodnykh komissarov, or Council of People's Commissars, dated 2 February 1930, divided the Institut into two higher educational institutions. The geodesy department of the Institut became the Moskovskiy geodezicheskiy institut (MGI) (later to become MIIGAiK). The land use department became the Moskovskiy institut inzhenerov zemleustroystva (later the Gosudarstvennyy universitet zemleustroystva).

In 1936 the MGI was renamed the Moskovskiy institut inzhenerov geodezii, aerofotos"yëmki i kartografii (MIIGAiK). In 1937 MIIGAiK consisted of four departments: geodesy, cartography, aerial photography in geodesy, and the study of geodetic instruments (the latter later renamed the department of optics and mechanics and, more recently, the department of optical instrument construction).

Krasovskiy, chair of the VGU, designed a basic geodetic control network for the Soviet Union, as well as the chief methods creating it. He worked until 1936 on preliminary calculations of the parameters of the new ellipsoid, basing his work on all available high-precision geodetic measurements. Continuing to work on the ellipsoid with A. A. Izotov until 1940, he improved the ellipsoid, and in 1946 by law it became the standard (known as the Krasovskiy reference ellipsoid) for all Soviet maps. That model and the accompanying system of rectangular coordinates (SK-42) remained in use until 2002, when they were replaced by the new model (PZ-90) and system of coordinates (SK-95).

During the decade 1957 to 1967 the chair of the air survey photography department, Boris N. Rodionov, also the chief designer of a number of Soviet space research projects, developed methods for photogrammetric processing of scanned panoramas, making it possible to compile large-scale plans for some areas of the moon's surface.

On 11 March 1993 the Institut was reorganized into the Moskovskiy gosudarstvennyy universitet geodezii i kartografii, although the historical acronym MIIGAiK continued in official usage. Thereafter MIIGAiK became the main center of higher geodetic and cartographic education in Russia and the largest educational institution of its kind in Europe. Thousands of MIIGAiK graduates took part in exploring the territory and natural resources of Russia; compilation of its maps; and construction of its cities, roads, and industrial enterprises.

By the early twenty-first century, MIIGAiK was actively participating in the exploration of earth and outer space and in applying the results in science, economics, agriculture, geological prospecting and ecology. MIIGAiK rendered assistance to other countries of the world by training their national scientific and engineering staff in geodesy and cartography. During the first decade of the century more than 2,000 foreign graduates of the university were working in eighty-five countries around the world. The national geodetic and topographic services of different countries had close and mutually advantageous economic and scientific relations with MIIGAiK. Its highly qualified teachers, long experience in training specialists and researchers, modern laboratories and field stations, and wide contacts with various scientific institutions guaranteed a high level of theoretical and practical training for students at the university.

In order to support the graduate programs offered by MIIGAiK, eight specialized academic councils were established to evaluate scientific theses and dissertations. Research by graduate students at MIIGAiK covered a wide range of problems in geodesy, cartography, and cadastre, as well as selected other fields, including precision instrumentmaking, geoinformatics, ecology, and remote sensing. Some 5,000 graduate and postgraduate students from Russia, the Commonwealth of Independent States, and some other countries received their education at MIIGAiK. Every year 750 new students were admitted.

MIIGAiK's faculty consisted of 68 professors and 230 associate and assistant professors. The scientific programs employed 100 research fellows. Research activities were developed in close cooperation with Tsentral'nyy nauchno-issledovatel'skiy institut geodezii, aeros"yëmki i kartografii (TsNIIGAiK), the Gostsentr Priroda, the Nauchno-redaktsionnaya kartosostavitel'skaya chast' (later renamed PKO "Kartografiya"), different survey and processing units of the Glavnoye upravleniye geodezii i kartografii (GUGK; later called Roskartografiya), and the Rossiyskaya Akademiya nauk institutes specializing in geography, geology, oceanography, etc.

The scientific-technical school of MIIGAiK had been formed with the participation of Russian scientists, starting in the nineteenth century with astronomer F. G. W. Struve (V. Ya. Struve) and physicist and designer of the Russian standard measures of length and weight Adolf Theodor Kupffer (Adol'f Ya. Kupfer). Those active in MIIGAiK during the twentieth century included geophysicist V. A. Magnitskiy, geodesist and astronomer Yu. D. Bulanzhe, geodesist Krasovskiy, geodesist and geophysicist M. S. Molodenskiy, geodesist A. S. Chebotarev, cartographer Konstantin Alekseyevich Salishchev, social geographer and cartographer A. I. Preobrazhenskiy, cartographer and geographer N. S. Podobedov, cartographer V. I. Sukhov, cartographer M. I. Nikishov, and geodesist V. D. Bol'shakov.

The MIIGAiK's directors during the twentieth century are listed in table 39. The frequent changes of directors 1925–34 indicate a difficult period for MIIGAiK. The rectors during that time were Bolsheviks of high standing but without any connections with geodesy or cartography. They were installed in the Institut to monitor its prerevolutionary professors and to enforce the class consciousness and interests in the Institut's policy regarding enlistment and cleansing of personnel and students.

TABLE 39. Twentieth-century directors of MIIGAiK

1917–19	N. M. Kislov
1919–24	Feodosiy Nikolayevich Krasovskiy
1924–25	P. A. Kobozev
1926	Feodosiy Nikolayevich Krasovskiy
1927–28	M. I. Latsis
1928–29	R. I. Berzin
1930–34	D. S. Bazanov
1934–43	A. I. Mazmishvili
1944–48	I. M. Semin
1948–57	M. S. Murav'yev
1957–63	P. S. Zakatov
1963–88	V. D. Bol'shakov
1988–2007	V. P. Savinykh

From Kusov 2004, 284–328.

Before the 1930s the geodetic department of MIIGAiK trained cartographers, who received the diploma of geodesist-cartographer. In 1936, at Krasovskiy's initiative, the cartographic department began to teach students who would graduate as cartographers. The department began to take shape in the early 1930s, and its main features were established during the 1940s. The founders of the department, including P. V. Denzin, Krasovskiy, and Salishchev, shaped the department's curriculum and placed the emphasis on training future leaders of basic large-scale surveying and mapping of the Soviet Union. Throughout its history MIIGAiK remained closely involved with actual field survey and geographical description.

Professor Petr Alekseyevich Skvortsov founded and led MIIGAiK's research and education school of artistic landscape mapping. Skvortsov was dedicated to developing design methods for natural, geographically precise, and artistically beautiful landscapes. Traveling the Soviet Union with easel and paints, he drew regions at sunrise, daytime, and sunset. He was the main author, along with others, of the mosaic map of the Soviet Union titled *Industriya sotsialisma,* which won a Grand Prix in the 1937 Paris Exposition Internationale des Arts et Techniques dans la Vie Moderne and was shown at the 1939 New York World's Fair. Skvortsov inspired his students, and they compiled many *zhivopisnyye karty* (map-pictures), the most outstanding of them being huge wall maps (figs. 604 and 605).

The "old guard" cartography professors, both at the Moskovskiy gosudarstvennyy universitet (MGU, Moscow State University) and MIIGAiK, had "graduated" from the difficult and demanding "field school" of the Gosudarstvennykh topograficheskikh s"yëmok i kartografirvaniya. The most outstanding of those geographer-cartographers would create the Soviet scientific school of geographical cartography. Salishchev, after having surveyed Arctic Siberia, developed the geographical aspects of cartography first at MIIGAiK and then at MGU. As chief editor of GUGK's topographic-geodetic service, Topografo-geodezicheskoy sluzhby, Podobedov was responsible for the geographical content of Soviet topographic maps at the scale of 1:100,000 (1946–54). He later became the chair of the field cartography and geography department at MIIGAiK.

In the early twentieth century the intensive experimental and theoretical work of TsNIIGAiK, MIIGAiK, and the field units of GUGK on cartographic applications of geographical exploration had led to changes in higher

FIG. 604. WALL MAP PAINTING, *LANDSHAFTNAYA KARTA*, 1953. This large wall map of the European part of Russia looking north from the Black, Caspian, and Aral Seas was painted under Petr Alekseyevich Skvortsov's direction at MIIGAiK and hangs in the reading room. Size of the original: 3.5 × 4.6 m. Image courtesy of the Moskovskiy institut inzhenerov geodezii, aerofotos"yëmki i kartografii and Alexey V. Postnikov.

education for cartographers. In 1936 the Soviet government considerably strengthened training in geographical subjects for the specialty of geodesist-cartographer, emphasizing thorough training in physical, social, and regional geography. That ruling required the inclusion of the following geography courses in the curriculum: dynamic geology, oceanography, hydrology, meteorology, edaphology, botanical geography, zoological geography, geochemistry, geomorphology, application of physical geography to cartography, geomorphological mapping, methods of geographical-cartographic field investigations, methodology of social geography, general and economic statistics, elements of demography, ethnology, social geography of the capitalistic world, geography of the international division of labor, methodology of regional geography (*kraevedenie*), social geographical mapping, and the history of geography. The curriculum changed and developed over time. At the MGU, geographical subjects and their mapping applications continued to be the core of cartographers' training. The importance of geography at MIIGAiK varied, but its teaching continued and gained acceptance, especially due to the adoption of remote sensing for studying the earth's resources (Postnikov 2002, 253–54).

Through the late 1940s training of cartographers at MIIGAiK was provided by five departments led by the following chairs: mathematical cartography (M. D. Solov'yev), map compiling and editing (G. N. Cherdantsev), drawing and design of maps (V. L. Chusov), map publishing (V. V. Pus'kov), and physical geography

FIG. 605. LANDSCAPE DRAWING BY SKVORTSOV'S STUDENTS. This detail shows the terrain of a small portion of the Caucasus Mountains northeast of Ochamchire, a city on the east coast of the Black Sea.
Image courtesy of the Moskovskiy institut inzhenerov geodezii, aerofotos"yëmki i kartografii and Alexey V. Postnikov.

(G. D. Rikhter). The last department had been founded in 1926 at the initiative of Krasovskiy and Aleksandr A. Borzov.

The particular significance of geographical training for cartography students was due to the requirement for its graduates to be specialists in field cartography, that is, compilers, editors, and revisers of topographical maps. From the mid 1940s onward, the cartography department allowed its graduate students to specialize in map projection and compilation or in map publishing. In 1993 a third specialty, digital cartography and geographical information systems, was introduced (Kusov 2004, 336–37).

ALEXEY V. POSTNIKOV

SEE ALSO: Geodetic Surveying: Geodetic Surveying in 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; Tsentral'nyi nauchno-issledovatel'skiy institut geodezii, aeros"yëmki i kartografii (Central Research Institute of Geodesy, Air Survey, and Cartography; Russia)

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