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Academic Paradigms in Cartography.

ACADEMIC CARTOGRAPHY IN CANADA AND THE UNITED STATES
ACADEMIC CARTOGRAPHY IN EUROPE

Academic Cartography in Canada and the United States. This entry traces the emergence of the discipline at a handful of geography departments in the first six decades of the twentieth century and the evolution of distinct paradigms, mostly in the last four. It condenses a much longer exploratory essay focused on the United States (McMaster and McMaster 2002) and is enhanced by information on related developments in Canada.

Four major periods can be identified in the development of academic cartography in North America. The incipient period, from the early part of the century to the 1940s, represents what might be called nodal activity because academic cartography was centered at only two to three institutions under the leadership of individuals not necessarily educated in cartography. Outstanding examples were J. Paul Goode at the University of Chicago, John Leighly at the University of California, Berkeley, and Guy-Harold Smith at Ohio State University. A second period, from the 1940s to the 1960s, saw the building of core programs with multiple faculty members, strong graduate programs, and PhD students who ventured off to create their own programs. Three core programs stand out—those at the Universities of Wisconsin, Kansas, and Washington. Other universities, including the University of California, Los Angeles (UCLA), Michigan, and Syracuse, developed cartographic programs in the third period, from the 1960s to the 1980s. This period also witnessed rapid growth in academic cartography in numbers of faculty hired, students trained, and journals started, as well as development within professional societies. Cartography emerged as a true academic discipline, nurtured within geography departments with strong research agenda and well-established graduate programs. In the mid-1980s, when academic cartography in North America reached its maximum growth, the effect of the emerging discipline of geographic information systems/science (GIS/GISci) had not yet been felt. This fourth period was an era of transition, when cartography became increasingly integrated within GIS curricula, the number of academic positions in cartography declined, fewer students were educated as thoroughly in thematic cartography, and what came to be called geovisualization made map reading and analysis highly interactive.

The Incipient Period

The incipient period runs from the very early part of the century to the early 1940s, when much of the cartographic activity in North America was focused on a few individuals with a strong interest in thematic mapping. The most prominent are Goode, Erwin Raisz, and Richard Edes Harrison.

Although basic training in cartography started in North America around 1900, it could be argued that J(ohn) Paul Goode was the first genuine American academic cartographer because he taught courses on map projections and thematic cartography. Although most of his students at the University of Chicago did not devote themselves specifically to cartography, some influenced the course of the field through positions in the private sector, government, and academia.

A Hungarian civil engineer, Erwin Raisz immigrated to the United States after World War I and worked at a map company in New York City. While completing his PhD in geology at Columbia, he studied under geomorphologist Douglas Wilson Johnson, who was a protégé of William Morris Davis at Harvard and had strong interests in the construction of block diagrams and the representation of landscapes. As an instructor at Columbia, Raisz offered the first cartography course there. On the recommendation of Johnson, Davis hired Raisz as a lecturer in cartography in the Institute of Geographical Exploration at Harvard, where he continued to publish and work on his techniques. In 1938, Raisz published the first edition of *General Cartography*, which was to remain the only English general textbook on cartography for fifteen years. Though he never held a regular academic appointment, Raisz promulgated his brand of cartography through his textbooks and his landform maps of various parts of the world.

The son of Ross G. Harrison, one of the most distinguished biologists of his time, Richard Edes Harrison graduated from Yale University in 1930 with a degree in architecture. His interests quickly turned to scientific illustration, and he drew his first map for *Time* magazine in 1932. This initial exposure to mapping piqued his curiosity, and he soon became a freelance cartographer for *Time* and *Fortune* magazines, and one of the first American popular cartographers. In the late 1940s Harrison would fly to Syracuse University once a week to teach the course in cartography, and he also lectured at Clark, Trinity, and Columbia Universities. Although not formally an educator, he nonetheless influenced the discipline of cartography through his specific techniques and intrinsic cartographic abilities. Harrison was active in the professional cartographic community and served as the first map supplement editor of the *Annals of the Association of American Geographers*.

Post–World War II and the Emergence of Centers of Excellence

The period following World War II witnessed a great expansion of geography departments in many U.S. universities and colleges, especially Wisconsin, Kansas, and Washington, as well as a decline at others, such as Harvard, which dissolved its geography program in 1948 (Smith 1987). It was after the war that Raisz and other members of the Association of American Geographers (AAG) sought to establish a more permanent base for cartography within that organization.

A seminal event in the evolution of American academic cartography was the first meeting of the Committee on Cartography, convened by Raisz on 6 April 1950, at Clark University during the AAG's annual convention. Raisz initiated a philosophical discussion of what cartography really was. He divided cartographers into two categories: "geographer-cartographers," who express their ideas with graphs, charts, maps, globes, models, and bird's-eye views, and "cartotechnicians," who help "produce maps, models, and globes by doing the involved technical jobs such as color-separation or cardboard-cutting" (Raisz 1950, 10). His schema also recognized cartologists, cartosophists, toponymists, map compilers, map designers, draftsmen, letterists, engravers, map printers, and cartothecarians (map librarians).

The 1950s witnessed an attempt by cartography to position itself in relation to geography and other disciplines. Although Raisz differentiated the geographic cartographer from the surveyor and described the essence of the modern mapmaker, cartography was seen as atheoretical and largely descriptive. Its significant problems were associated with drafting media and production techniques, and most of the methods for symbolization—including the dot, graduated symbol, isarithmic, choropleth, and even dasymetric methods—had been developed in Europe in the nineteenth century or before. Even so, World War II had accelerated the development of cartographic curricula (Kish 1950) and the 1950s saw the emergence of major programs at the Universities of Wisconsin, Kansas, and Washington as well as smaller, less influential programs.

UNIVERSITY OF WISCONSIN–MADISON. Arthur H. Robinson, who supervised the Map Division of the Office of Strategic Services (OSS) during World War II, was hired by the University of Wisconsin in 1945 and quickly established himself as the unofficial dean of American academic cartographers. He built the cartography program at Madison into the very best in the country during the 1970s and early 1980s. His seminal volume, *The Look of Maps* (1952), was the seed for three decades of cartographic research. He established the first American journal in cartography, the *American Cartographer*, in 1974. His six editions of *Elements of Cartography* and his presidency of the International Cartographic Association attest to his leadership. Robinson also had strong research interests in map projections, map perception, the history and philosophy of cartography, and cartographic symbolization. His 1976 book with Barbara Bartz Petchenik, *The Nature of Maps*, delved deeply into the fundamental principles of cartographic communication. Robinson also influenced several generations of students who ventured off and established their own graduate programs in cartography. Robinson and Randall D. Sale guided the cartography program at Madison and in 1968, Joel L. Morrison, who received his PhD from Robinson, began teaching there. Phillip Muehrcke, who earned his PhD from the University of Michigan under Waldo R. Tobler, joined them in 1973, after working for several years with John Clinton Sherman at the University of Washington. Thus in the mid-1970s, when many geography departments struggled to maintain a cartography program with a single faculty member, Wisconsin had four. By that time, separate BS and MS degrees in cartography existed, and Wisconsin had the very best cartography laboratory within a geography department, as well as a campus laden with faculty talent in the mapping sciences, including positions in surveying, photogrammetry, and remote sensing. Overall, the cartography program at Wisconsin has produced several hundred students with master's degrees in cartography and well over twenty students with doctoral degrees in geography with a specialty in cartography. The first master's degree with a cartography emphasis was awarded in 1949 and the first doctoral degree in 1956 (James John Flannery). Other PhDs from Wisconsin included Norman J. W. Thrower (UCLA), Richard E. Dahlberg (UCLA, Syracuse University, and Northern Illinois University), Henry W. Castner (Queens University), Mei-Ling Hsu (University of Minnesota), George F. McCleary (Clark University and the University of Kansas), David Woodward (Newberry Library and Wisconsin), Petchenik (R. R. Donnelley), Morrison (Wisconsin, U.S. Geological Survey [USGS], the U.S. Bureau of the Census, and the Center for Mapping at Ohio State University), Judy M. Olson (Boston University and Michigan State University), and A. Jon Kimerling (Oregon State University). An important factor in the development of cartographic instruction at Wisconsin was associated with the awarding of several National Defense Education Act Fellowships in the 1960s to support graduate work in cartography.

UNIVERSITY OF KANSAS. The cartography program at Kansas was started by George F. Jenks, who had received his PhD in agricultural geography at Syracuse University, where he also studied with Harrison. After a single year at the University of Arkansas, Jenks arrived in 1949 at a small but talent-laden department. A significant event in his career was an award from the Fund for the Advancement of Science that allowed him to visit all major mapmaking establishments of the federal government as well as a number of quasi-public laboratories in 1951–52. Jenks's objective was to determine what subject matter should be included in a cartographic curriculum. He reported his findings and implemented them in the cartography program at Kansas. This represents a second seminal event in the development of academic cartography from the early 1950s. Jenks's project had identified three key problems for cartographers to address: (1) mass production techniques had to be improved; (2) new inks, papers, and other materials were needed; and (3) additional personnel had to be trained (Jenks 1953, 317). Factors that impeded cartographic training included inexperienced instructors, poorly equipped cartographic facilities and map libraries, limited research and limited access to research, and too little emphasis on the practical application of theory (Jenks 1953, 319).

The importance of this landmark study cannot be overemphasized. Cartography had emerged from World War II as a true discipline, in part due to the great demand for war-effort maps and mapping. Both those who had been practicing before the war, such as Robinson and Raisz, and those who emerged after, such as Jenks and Sherman, realized that comprehensive cartographic curricula could be maintained within geography departments. Jenks's study, in parallel with the previously described efforts by Raisz and the AAG, provided the intellectual infrastructure for those attempting to build cartography as a discipline in universities. Although a few academics (Kish 1950, esp. discussion, 23–24) had called for separate departments of cartography, these proposals were impractical both politically and financially.

Another significant influence on Jenks's early career was his relationship with Sherman of the University of Washington. In the summer of 1956, Sherman came to Kansas to teach, and later Jenks was in residence at Seattle. An important event during the 1960s was the establishment of the National Science Foundation program of Summer Institutes for College Teachers. Summer institutes in cartography, organized under the direction of Sherman and Jenks, were offered first in Seattle in 1963.

The Kansas program experienced rapid growth in the 1970s, when McCleary joined the staff; course offerings expanded with an increased emphasis on map design, and graduate enrollment soared (Jenks 1991). In addition, Robert T. Aangeenbrug, an urban geographer interested in computer cartography, had joined the Kansas faculty in the 1960s, and Thomas R. Smith, who had been hired in 1947, established coursework in the history of cartography during the 1970s and 1980s. Jenks initiated research projects on three-dimensional maps, eye-movement research, thematic map communication, and geostatistics. By the end of the decade, he had turned his attention to cartographic line generalization. Many of Jenks's students accepted academic appointments and continued the "Jenks school" including Richard D. Wright (San Diego State University), Paul V. Crawford (Bowling Green), Michael W. Dobson (SUNY Albany and Rand McNally), Theodore R. Steinke and Patricia P. Gilmartin (University of South Carolina), Carl Youngmann (University of Washington), J. C. Muller (University of Alberta, the International Training Center [ITC] in Enschede, the Netherlands, and the University of Bochum), Barbara Gimla Shortridge (University of Kansas), Terry A. Slocum (University of Kansas), Joseph Poracsky (Portland State University), and Robert B. McMaster (UCLA, Syracuse, and the University of Minnesota). Jenks continued to teach and be engaged in research until his retirement at Kansas in 1986.

UNIVERSITY OF WASHINGTON. Although the first formally identified cartography course at Washington was offered by William Pierson in the geography department during the 1937–38 academic year, it was Sherman who was primarily associated with developing the cartography program at the University of Washington, Seattle. Sherman received his BA from the University of Michigan in 1937, his MA from Clark University in 1944, and his PhD from Washington in 1947. Unlike both Jenks and Robinson, who had received formal training in cartography, Sherman had never had coursework in this field.

In 1968, Sherman developed a proposal to establish a National Institute of Cartography, which had been requested by the National Academy of Sciences/National Research Council (NAS/NRC) Committee on Geography. A panel of prestigious cartographers, including Arch C. Gerlach, Thrower, Dahlberg, Tobler, McCleary, Jenks, and Robinson, assisted Sherman. Unfortunately for the discipline of cartography, the proposed institute was never created. One can hardly help noticing, however, the similarity of the concept to the National Center for Geographic Information and Analysis (NCGIA) established two decades later.

Although Sherman's main research interests were in map design and communication and in tactile mapping, many of his doctoral students pursued dissertation topics related to analytical and computer cartography. They included Tobler (University of Michigan and University of California, Santa Barbara), Richard Taketa (San Jose State), Everett A. Wingert (University of Hawai'i), Jois Child (SUNY Buffalo and Eastern Washington), and Barbara P. Buttenfield (University of California, Santa Barbara, Wisconsin, SUNY Buffalo, and Colorado). Others went into government and industry.

Diffusion of Cartographic Programs in Geography Departments

Thus during the 1970s and 1980s, a series of what might be called secondary programs, many established by scholars with PhDs from Wisconsin, Kansas, and Washington, were created in the United States. Although not exhaustive, one can point to programs at UCLA with Thrower; Michigan with Tobler; South Carolina with Steinke and Gilmartin; SUNY Buffalo with Kurt E. Brassel (Zurich PhD) and Duane F. Marble (Washington PhD); Michigan State with Richard E. Groop (Kansas PhD) and Olson; Northern Illinois University with Dahlberg; Oregon State University with Kimerling; Syracuse University with Mark Monmonier (Penn State PhD); Pennsylvania State University with Alan M. MacEachren (Kansas PhD); and Ohio State University with Harold Moellering (Michigan PhD). Key activities in these departments included Tobler's development of analytical cartography; Thrower's work in animated cartography, the history of cartography, and remote sensing; Moellering's animated cartography and emphasis on a numerical cartography; Monmonier's statistical mapping; and Olson's work in cognitive research. Each of the institutions developed its own area of expertise where, unlike the earlier days when students would pursue a general graduate program in cartography, individual graduate programs were identified for their particular research specialty such as cognitive or analytical cartography.

Canada was similar to the United States in its development of academic cartography, but with fewer noteworthy doctoral programs. A 1995 survey of the source of the graduate degrees of active academic cartographers found twenty-six North American graduate programs that had granted four or more master or doctoral degrees. Only one of the twenty-six was Canadian—the University of Western Ontario (Fryman 1996, 6–7). Canadian geography departments prominent during this era included Carleton University (with D. R. F. Taylor, Edinburgh PhD), Queens University (with Castner, Wisconsin PhD), Simon Fraser University (with Thomas K. Peucker [later Poiker], Heidelberg PhD), and the University of Western Ontario (with Michael F. Goodchild, McMaster PhD who moved to Santa Barbara in 1988 to join the NCGIA). Canadian programs were conspicuously strong in computer-assisted cartography.

The Transition Period

The intellectual landscape of cartography changed significantly during the 1990s, in large part owing to the rapid growth of geographic information science and systems. In 1985 the prognoses for a new PhD in cartography finding an academic position were excellent whereas in 2000 the job market favored the geographic information scientist. Although one could still study cartography at most major institutions, the number of courses decreased as the number of GIS-related courses increased. Additionally, the term *geographic visualization*, increasingly used by many departments instead of cartography, caused a further erosion of the professional base of cartography. Even so, as GIS was becoming almost ubiquitous within society, a deeper knowledge of maps, cartography, and map symbolization and design remained a crucial skill.

Major changes occurred in the way cartography was taught in American universities during the 1990s. A survey of six universities with a focus on cartography and GIS education confirmed the nature of these changes in cartographic education in general. The most significant changes were: (1) a closer integration with education in GIS; (2) the nearly complete transition to digital methods; (3) a decreasing emphasis on procedural programming (such as FORTRAN and Pascal) and greater emphasis on object-oriented, user interface, and Windows programming; and (4) a greater emphasis on the dynamic aspects of cartography, including animation and multimedia.

Key Paradigms of North American Cartography

In the post–World War II period, academically oriented graduate programs emerged and basic research in cartography accelerated. Although many research paradigms could be documented, some of the more substantial efforts were in communication models, theory of symbolization and design, cartographic design, experimental cartography, analytical cartography, and, in the 1990s, debates in critical and social cartography. Table 1 lists some of the key research activities associated with these paradigms, each of which has a unique and complex history, dissemination, and set of outcomes.

If any single cartographic paradigm was an intellectual leader, it was analytical cartography. Tobler originated the idea of a mathematical, transformational, or analytical approach to the subject in the 1960s and laid out the agenda in his seminal 1976 paper, "Analytical Cartography," which had a profound effect on North American academic cartography. The evolution of this paradigm reflects Tobler's interaction, direct and indirect, with many individuals and institutions, most notably William Louis Garrison at the University of Washington, where Tobler earned his PhD in 1961, and the RAND Corporation in Santa Monica, California, where he worked in the late 1950s and produced some of the first computer-generated maps. After completing his dissertation, Tobler joined the faculty at the University of Michigan and used the meetings of the Michigan Intrauniversity Community of Mathematical Geographers (MICMOG) as a sounding board for his ideas on analytical cartography. His work had a significant influence on both the disciplines of cartography and geography and led to his election to the prestigious National Academy of Sciences, the only geographic cartographer to hold that honor.

Table 1. Paradigms of North American academic cartography

Experimental cartography paradigm
- Psychophysical research
- Eye-movement studies
- Cognitive approaches
Cartographic symbolization paradigm
- Relationship between measurement scales and visual variables
- Formal models of data/symbolization
- Four-dimensional approaches
Cartographic design paradigm
- Establishment of a graphical hierarchy and figure-ground
- Conceptual frameworks for color use
- Knowledge of the visual elements
Analytical cartography paradigm
- Geographic data models
- Terrain modeling
- Spatial interpolation
- Automated generalization
Postmodern-critical paradigm
- Ethical considerations in mapping
- Power of cartographies
- Cartography as a form of state control

What emerged from the concept of analytical cartography was a cadre of individuals working on problems that can be identified as analytical/computational-digital/mathematical in nature. Some were Tobler's own PhD students or those who worked very closely with him, such as Stephen C. Guptill (USGS), Moellering, and Muehrcke. Others were immersed in the paradigm, without necessarily having formal education in it, such as Monmonier, the author of the first textbook on computer cartography, Youngmann, and Muller. Additionally, a large group of individuals educated in the late 1970s through the early 1980s considered themselves computer or analytical cartographers, including Slocum, Keith C. Clarke (University of Michigan PhD), Nicholas R. Chrisman (Bristol PhD), Timothy L. Nyerges (Ohio State University PhD), Marc P. Armstrong (University of Illinois PhD), Buttenfield, and McMaster.

Academic cartography developed in North America through the interaction of pivotal events such as World War II and several key individuals and PhD-granting departments of geography. Four distinct periods are evident, the last of which, starting in the late 1980s and continuing into the following century, witnessed the incorporation of cartography into expanding programs in geographic information science. Although academic cartography never achieved disciplinary independence, it spawned distinctly cartographic paradigms with important roles in the wider research agenda.

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SEE ALSO: Bertin, Jacques; Electronic Cartography: Intellectual Movements in Electronic Cartography; Geographic Information System (GIS): (1) Computational Geography as a New Modality, (2) GIS as an Institutional Revolution; Geography and Cartography; Goode, J(ohn) Paul; Harrison, Richard Edes; Histories of Cartography; Perception and Cognition of Maps: (1) Subject Testing in Cartography, (2) Psychophysics; Public Access to Cartographic Information; Raisz, Erwin (Josephus); Robinson, Arthur H(oward); Social Theory and Cartography

BIBLIOGRAPHY:

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

Harding, George H. 1951. "A Possible Solution to the Problems of Surveying and Mapping Education." *Surveying and Mapping* 11:104–6.

Jenks, George F. 1953. "An Improved Curriculum for Cartographic Training at the College and University Level." *Annals of the Association of American Geographers* 43:317–31.

———. 1987. "Cartographic Education in Today's Geography Departments/Thoughts after Forty Years." In *Studies in Cartography: A Festschrift in Honor of George F. Jenks*, ed. Patricia P. Gilmartin, Monograph 37, *Cartographica* 24, no. 2:112–27.

———. 1991. "The History and Development of Academic Cartography at Kansas: 1920–80." *Cartography and Geographic Information Systems* 18:161–66.

Kent, Robert B. 1980. "Academic Geographer/Cartographers in the United States: Their Training and Professional Activity in Cartography." *American Cartographer* 7:59–66.

Kimerling, A. Jon. 1989. "Cartography." In *Geography in America*, ed. Gary L. Gaile and Cort J. Willmott, 686–718. Columbus: Merrill Publishing.

Kish, George. 1950. "Teaching of Cartography in the United States and Canada." *Professional Geographer* 2, no. 6:20–22 and discussion, 23–24.

McMaster, Robert B., ed. 1991. "U.S. National Report to ICA, 1991—History and Development of Academic Cartography in the United States." *Cartography and Geographic Information Systems* 18:149–216.

McMaster, Robert B., and Susanna A. McMaster. 2002. "A History of Twentieth-Century American Academic Cartography." *Cartography and Geographic Information Science* 29:305–21.

McMaster, Robert B., and Norman J. W. Thrower. 1988. "The Training of Academic Cartographers in the United States: Tracing the Routes." In *Proceedings of the 13th International Cartographic Conference*, 4 vols., 2:345–59. Mexico City: Direccion General de Geografia.

———. 1991. "The Early Years of American Academic Cartography: 1920–45." *Cartography and Geographic Information Systems* 18:151–55.

"News from Cartographic Centers." 1950. *Professional Geographer* 2, no. 6:38–40.

Raisz, Erwin. 1950. "Introduction." *Professional Geographer* 2, no. 6: 9–11.

Robinson, Arthur H. 1979. "Geography and Cartography Then and Now." *Annals of the Association of American Geographers* 69: 97–102.

———. 1991. "The Development of Cartography at the University of Wisconsin–Madison." *Cartography and Geographic Information Systems* 18:156–57.

Sherman, John Clinton. 1991. "The Development of Cartography at the University of Washington." *Cartography and Geographic Information Systems* 18:169–70.

Smith, Neil. 1987. "'Academic War over the Field of Geography': The Elimination of Geography at Harvard, 1947–1951." *Annals of the Association of American Geographers* 77:155–72.

Taylor, D. R. F. 1974. "The Canadian Cartographer and the Computer/Present Trends and Future Challenges." *Canadian Cartographer* 11:35–44.

Tobler, Waldo R. 1976. "Analytical Cartography." *American Cartographer* 3:21–31.

Academic Cartography in Europe. The principal paradigms that emerged in Europe during the twentieth century can be attributed to a handful of intellectuals. Their diverse conceptual frameworks ended an era that was marked by traditional approaches and lacked the clear sense of an academic discipline.

At the start of the century, Germany and Austria were hotspots of cartographic development, with Alfred Hettner, professor of geography at Heidelberg, who first worked out principles of thematic map design (1910), and Karl Peucker, scientific director at Artaria & Co. in Vienna, whose *Schattenplastik und Farbenplastik*, a book on the history and theory of terrain representation, appeared at the turn of the century (1898). Max Eckert, of the Technische Hochschule of Aachen, published his two-volume *Die Kartenwissenschaft*, a monumental collection of facts about specific map themes, in 1921–25. To Eckert, *Kartenwissenschaft* (the science of maps) was the discipline that taught how to produce maps. The first thesis on cartography as a science with viable conclusions about the objectives of the discipline was written in 1963 (a first draft had been published in 1956) by Eduard Imhof, who founded the first academic institute of cartography, Kartographisches Institut der Eidgenössischen Technischen Hochschule in Zurich, in 1925. His artistic talents and practical approach to the subject led Imhof to adhere to the view that theoretical cartography dealt with the critical study of maps, their subject matter, the practical aspects of techniques for constructing them, and the elaboration of standards for map drawing and map compilation. To Imhof, theoretical cartography was an applied science whose subject matter was the representation of the surface of the earth. The final objective was the improvement of this representation, and this could be realized by applying order systematically to the immense number of graphic shapes available. Cartography also contained a strong artistic trend, and in that regard there were strong similarities to architecture. As an artist Imhof emphasized the visual effects, without attaching to them the perceptual characteristics claimed by Jacques Bertin (see below), and Imhof continued to search for better methods for representing terrain. Because of this, he remains an inspiration to cartographers. According to Ingrid Kretschmer, Imhof later developed a system according to which spatial facts, transformed into models, had to be rendered by matching graphic models (Kretschmer 1980). As both were foremost practical cartographers, there are many similarities between Imhof's *Thematische Kartographie* (1972) and Bertin's *Sémiologie graphique* (1967).

Bertin, director of the Laboratoire de Cartographie, École pratique des hautes études, Paris, regarded cartography as a branch of graphic semiology, or the science of sign systems. By identifying the graphic variables, he was the first to systematize the relationships between spatial data and their graphic representation in *Sémiologie graphique*. For him it was the objective of cartography to study and analyze the means, properties, and limits or constraints of the graphic system. In doing so, the contents of the objects to be rendered—that is, the information value of the elements of the graphic system—was deemed irrelevant.

In dealing with the syntactical aspects, i.e., the part of semiology that is only about the interrelationships between the graphic signs, their structure, and the way they have been ordered, Bertin was the first to present a detailed, systematic, and comprehensive analysis of the perceptual properties of graphic elements that could constitute the basis of a graphic language for visual perception. He combined these perceptual properties into a general theory. According to Bertin, visual perception was a universal constant, and once the perceptual properties of the graphic variables were found they could be applied consistently everywhere. By applying them to maps, spatial relationships with internal objects (other elements of the map) or external objects (elements in other maps) are defined.

Bertin did not focus on the semantic aspects, the relationships between the signs and the subjects they symbolize, which were aspects that Imhof and Erik Arnberger had been researching. Bertin also did not study the pragmatic relationships between the signs and their users or viewers, which were analyzed by Arthur H. Robinson and his followers. Bertin claimed (1978) that his theory of graphics was incompatible with information theory, because the latter was linear and used notions that can have multiple meanings (polysemic communication), while Bertin's graphic variables ought to be regarded as unambiguous in their communication characteristics (monosemic communication).

Bertin did not have many followers in cartographic theory. In Austrian reviews of his main work, *Sémiologie graphique*, which was translated into German in 1974, there are alternately references to a "blind alley" and a "soap bubble" (Kretschmer 1980, 145). His work was not translated into English until 1983; his views were slow to penetrate the Anglophone world and had little impact when they did. J. C. Muller in Edmonton thought one of the reasons for the limited Anglo-Saxon attention to Bertin's work was its cookbook-like character. *Sémiologie graphique* provided rules, or rather dictated rules, without convincing demonstrations. Everything had to be taken on the author's authority, as the experiments that could support Bertin's theses were lacking (Muller 1981).

It was Arnberger in Vienna who defined cartography as the discipline of the logic, methodology, and techniques of constructing and interpreting maps. To Arnberger the object of cartographic research was the forms of representation. His conception of cartography therefore was that of a *Formalwissenschaft* (a discipline, like mathematics or statistics, concerned with the forms and not with the contents) as opposed to a discipline such as geography, where it is the contents that matter. For Arnberger the objective of cartography was to work out adequate graphic representations of information whose spatial relationships had to be expressed through cartographic means.

As can be seen from figure 1, Arnberger distinguished between theoretical and practical cartography. The purpose of theoretical cartography was to elaborate the standards according to which practical cartography had to be effected. This was about the development of forms, methods, and rules for a suitable cartographic transformation of the map's contents, matching its structure. The starting point would be the study of graphic forms and the rules regarding their fitness to represent qualitative and quantitative characteristics of the structures, taking into account their relative and absolute position and extent.

Arnberger expressed these views in *Handbuch der thematischen Kartographie* (1966). Similar views were held by Werner Witt in Hannover, which appeared in his *Thematische Kartographie: Methoden und Probleme, Tendenzen und Aufgaben* (1967), but Witt was more practically oriented.

In 1970 Konstantin Alekseyevich Salishchev at Moscow State University (Moskovskiy gosudarstvennyy universitet) found the subject of cartography in the changing spatial aspect of objective reality. For him, the method of cartography consisted of graphic modeling with the help of symbols. Scientific mapping was a modeling process, always aimed at a more thorough understanding of the reality studied and at acquiring new information about it. Salishchev thus regarded cartography as a cognitive science, which he described as "the science of representation and investigation of the spatial distribution, combinations, and interdependence of the phenomena of nature and society (and their changes in time) by means of graphic-symbolic models (cartographic representations) that reproduce these or those aspects of reality" (1970, 83).

In 1978 Salishchev described cartography as a "scientific method of understanding reality by means of geographical maps as graphic-symbolic spatial models of the real world" (93). His critical view of the communication approach persisted, as that approach did not incorporate the necessary task of evaluating the correctness and usefulness of the information rendered through maps. Neither did it incorporate the development of methods to acquire new information. As opposed to the shallow view of persons adept at informatics, scientific mapping as a modeling process was always aimed at a more thorough understanding of the reality studied. For Salishchev the main issue for contemporary cartography was finding new methods of map production and map

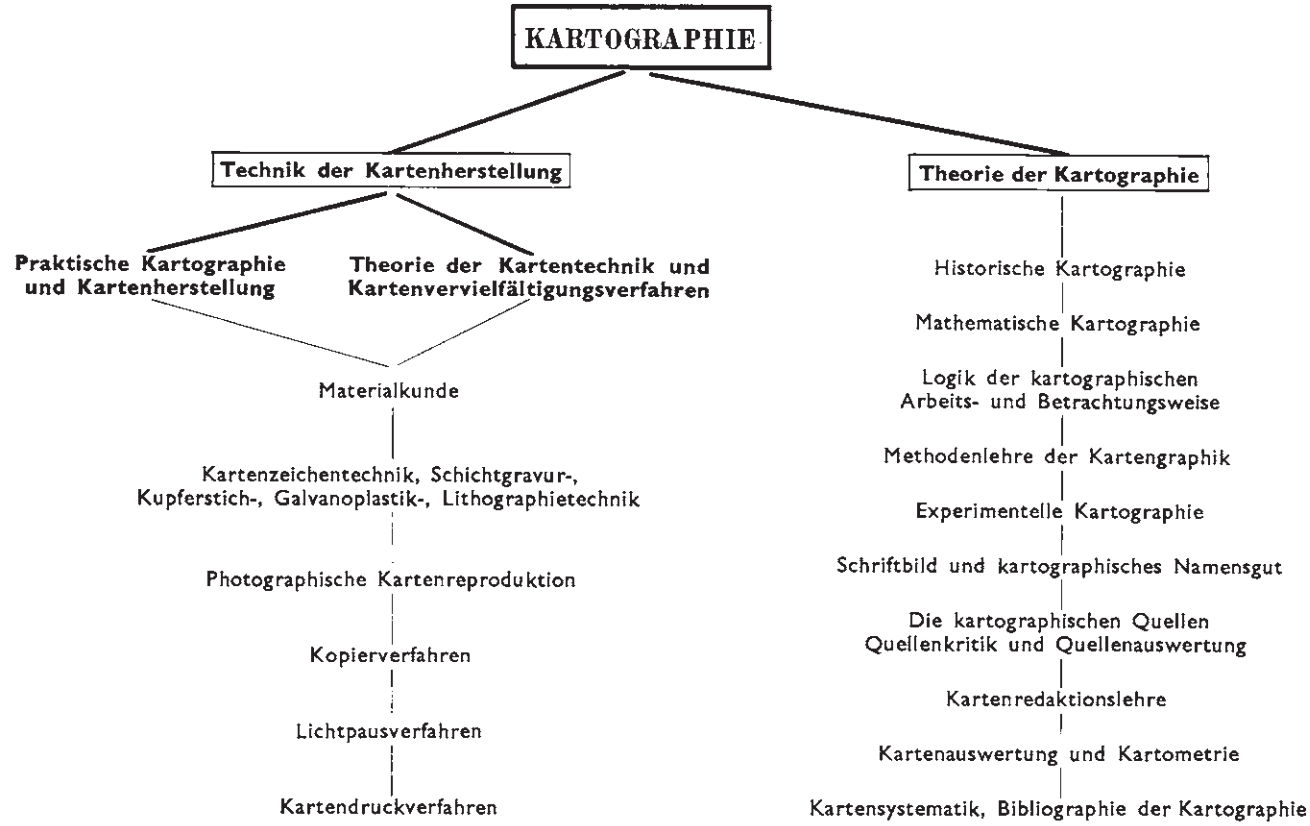

FIG. 1. SUBDIVISION OF THE FIELD OF CARTOGRAPHY ACCORDING TO ERIK ARNBERGER (1966). Size of the original: 11.6 × 18.6 cm. From Erik Arnberger, *Handbuch der thematischen Kartographie* (Vienna: Deuticke, 1966), 18 (fig. 2). Permission courtesy of Hertha Arnberger.

use. Its objective was the representation of and research into spatial systems of varying complexity by cartographic modeling. It is impossible to reach this objective without geographical knowledge. In cartographic education this expressed itself in the emphasis on modeling methods, especially for synthesis maps, but also for typological maps, evaluation maps, and regionalization. In these modeling procedures insufficient account was taken of issues of data quality (Tikunov 1988).

In his later publications Salishchev (1978) allowed semiology and information theory their place in cartographic theory next to his own modeling views. All three form part of cartographic theory, even if Salishchev's primary objection to information theory—that it did not take account of the level of the map user—remained. The amount of information contained in a map is constant, but the amount that can be derived from that map differs according to the level of the map user.

Robinson, at the University of Wisconsin, claimed that cartography is the "conceptual planning and design of the map as a medium for communication or research" (1960, v). This made him the trail blazer for those who regard cartography as the science of communicating spatial information by way of maps. In Europe it was Antonín Koláčný in Prague who was regarded as the scientific initiator of the informatics-induced view of cartography as a communication science. In that sense, Koláčný's lecture at the 1968 International Cartographic Conference (ICC) in New Delhi (published 1969) and the reports of his International Cartographic Association (ICA) Working Group (WG) on Cartographic Information were significant events in cartography. He claimed that map production and map use were not separate processes but had to be integrated. Cartographers had to test the results of their work in order to arrive at an optimal representation. In this whole procedure, the linking thread was cartographic information. The purpose of mapping was communicating this cartographic information.

The impression made by Koláčný on his audience led to the initiation of the ICA WG on Cartographic Information. At its first meeting in Prague (1969) it was decided to change the name to WG on Cartographic Communication (Koláčný 1971, 68). Shortly after the Russian invasion that ended the Prague Spring, Koláčný was no longer allowed to travel abroad or even to publish, and his WG report to the 1970 Stresa ICC had to be presented by others. It was Lech Ratajski at Warsaw University, the leader of the Polish cartographic community, who carried the torch and henceforth chaired the ICA WG and the ICA commission with the same name that was established in 1972. Ratajski's 1973 publication combined the model of cartographic information communication of Christopher Board (1967), which supposed a progressive decrease of the amount of information during the communication process, with that of Koláčný, according to which the information derived by the map user from the map only showed a limited overlap with the information the cartographer inserted in the map (fig. 4 below); moreover he added to C. Koeman's verbal model of cartography "*how* do I say *what* to *whom*" (Koeman 1971, 171) with "what result?" (Ratajski 1973, 220).

Cartology to Ratajski was the discipline that studied the expression and transformation of chorological information by means of maps. Its research area consisted of the source of the chorological information, the processes of information transfer and reception, and the way in which the transmission was expressed (the map). Cartology's methodology described the research methods, the relationships with other areas of science, and the theory of cartographic classification; it also provided definitions for cartographic terminology. The study of cartography could be subdivided into three areas: the theory of cartographic transmission, map knowledge, and cartographic methods. For a schematic view of Ratajski's view of the cartographic science, see figure 2.

The approach to cartography as part of information science developed in its purest form in the United States. Guided by Robinson, this approach provided cartographers with the best perspective for research. Cartography was seen as a communication channel, and study focused on the processes that influence the information transfer. According to Joel L. Morrison, these processes, for the cartographer, were selection, classification, simplification, symbolization, and inductive generalization. For the map user these were the detection, discerning of differences, identification, and estimation of symbolization (Morrison 1976).

With some modifications, such as a greater emphasis

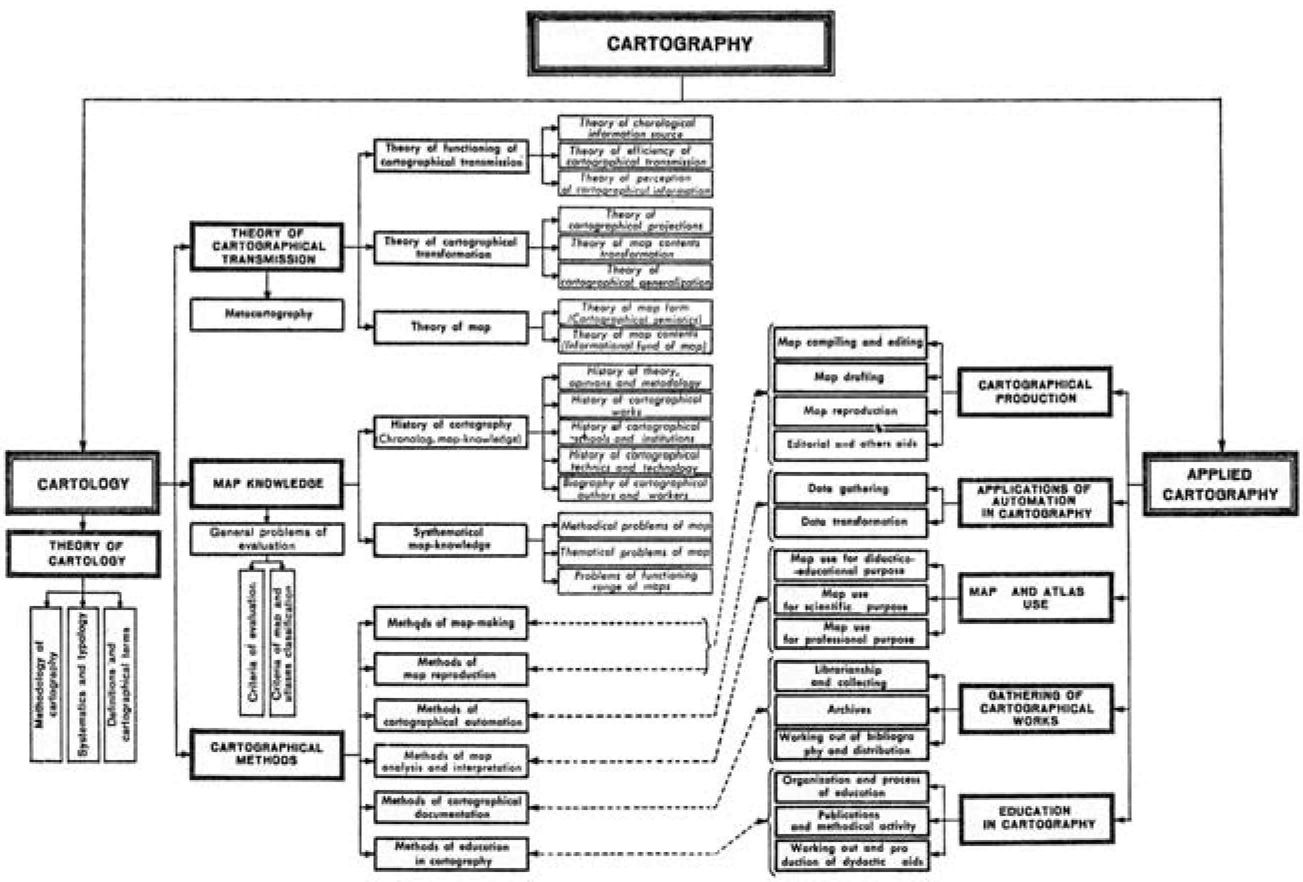

FIG. 2. SCHEME OF CARTOGRAPHY BY LECH RATAJSKI (1973). Size of the original: 12.5 × 18.7 cm. From Ratajski 1973, 226 (fig. 4). Permission courtesy of Bertelsmann AG, Gütersloh.

on the role of geography, this approach to cartography as a part of informatics had the most adherents, even in Europe. That is not to say that it was without its critics. Salishchev (1978) condemned it as too limited. Only when a map is considered as a chorological model of reality are just dues paid to theoretical cartography. The relationships between the map and the reality it portrays should be emphasized, as well as the role of the map in acquiring new information. Bertin's objections were more fundamental: by emphasizing the role of the map as a tool to transfer information, the map's structure and the properties of the graphic language were neglected under the communication approach. According to Bertin (1978), the model of information theory—sender > code > receiver, or more specifically cartographer > map > map reader—was not valid in graphics, as it referred to polysemic and thus ambiguous information, while in graphics it was all about monosemic information.

By the 1970s, the ICA had manifested itself as the major platform for discussions on cartographic theory, through the Commission on Communication in Cartography (later transformed into the Commission on Theoretical Cartography), its meetings (with strong North American input from Morrison, Harold Moellering, and Henry W. Castner), and through its *International Yearbook of Cartography*, which reflected these discussions: its first twenty issues (1961–80) contained over thirty contributions on the theory of cartography from scholars mentioned in this overview.

Like Ratajski, Ulrich Freitag of the Freie Universität Berlin, has integrated Bertin's views into a larger structure (fig. 3), into which information science had also been incorporated. Freitag defined cartography as the "theory and practice of cartographic forms of representation: cartography studies and enables the use of cartographic forms of representation in the process of visual communication" (1979, 35). Like Bertin and Imhof, Freitag started from the graphic elements that can be combined into all kinds of complex structures. However, as the participants in the communication process had not yet been involved, the interrelationships between the graphic elements, between the graphic elements and their meaning, and between the graphic elements and their users were also accommodated in Freitag's approach. Taken together, these different kinds of relationships form the cartographic information transfer. Studying them together allowed the possibility for feedback and for control of the efficiency of cartographic representation in the communication process. The interrelationships between the graphic elements were termed syntactic aspects by Freitag (in fig. 3 this is carto-syntactics); the relationships between the elements and their meaning were termed semantic aspects (carto-semantics), and the relationships between the graphic elements and the map users were termed pragmatic aspects (carto-pragmatics).

At the end of the century none of these approaches to cartography held sway to the exclusion of the others within the global cartographic community. From 1970 onward the theories of both Bertin and Koláčný strongly influenced the cartographic landscape that until then had been almost theory-less. A geography that was turning away from maps did not provide a matrix for an approach like that proposed by Salishchev. The approach to cartography as a *Formalwissenschaft*, emphasizing the methodological aspects of map production, would provide few opportunities for research conducive to further development. Bertin denied the positive input of information science in cartography. The positive climate for psychophysical and map-use research generated by the communication approach was overwhelmed at the end of the century by the onset of digital cartography. It was only at the onset of the twenty-first century that interest in theoretical aspects and cartographic research were resumed, but now with a focus on map use and usability.

One can list the changes that took place in cartographic theory as a series of paradigm changes. The definition of cartography accepted by the United Nations in 1949 was "the science of preparing all types of maps and charts, and includes every operation from original surveys to final printing of copies" (51). This reflected the formalistic approach linked to the views of Eckert and Arnberger. Cartography was seen as the selection of the proper symbols and colors for representing specific themes, without specific regard to their effect. It was Bertin who highlighted the perceptual properties of the graphic variables and built his theory of graphic semiology around it. Thanks to Koláčný it was no longer the production of maps that was central in cartography, and the use of maps became equally important. Cartography became "the art, science and technology of making maps, together with their study as scientific documents and works of art" (ICA 1973, 1).

In the United States after World War II, a view of cartography emerged that followed the communication approach; it defined cartography as the "science of communicating information through maps" (Morrison 1976, 97). It introduced concepts like source, sender, receiver, destination, redundancy, and noise. An important contribution of this approach was that it taught cartographers that spatial information transfer, not the production of maps, was the final objective of their work, and that cartographers should check whether the information to be transferred had indeed been received correctly. This need for feedback was best expressed by Koláčný, for whom the objective of cartography was to maximize the overlap between the original spatial information as

GENERAL (SYSTEMATIC) CARTOGRAPHY

Theory of Cartography (System of Cartographic Terms and Statements)

Theory of Signature – Gestalt (Carto-Syntactics, Carto-Graphics)
- Theory of visual apperception
- Theory of syntactic information
- Theory of carto-graphics
  - Theory of graphic elements (variables)
  - Theory of signatures (cartographic figures)
  - Theory of cartographic structures (*Gefüge*)
- Theory of graphic generalization
- Theory of signature transcription (digitalization)

Theory of Signature-Significance (Carto-Semantics)
- Theory of statements (predictions)
- Theory of semantic information
- Theory of general information (encoding, decoding)
- Theory of topologic (spatial) representation (mapping of space)
  - Theory of reduction (map scale)
  - Theory of projection (map projection)
  - Theory of topologic distortion
- Theory of ontologic (topical) representation (mapping of objects)
  - Theory of qualitative representation (signature key)
  - Theory of quantitative representation (signature scale)
  - Theory of ontologic transformation
- Theory of chronologic representation (mapping of time)
- Theory of semantic generalization
  (of topologic, ontologic, chronologic representations)
- Theory of cartographic models

Theory of Signature-Effect (Carto-Pragmatics)
- Theory of visual perception
- Theory of pragmatic information (cognitive mapping)
  - Theory of designative maps
  - Theory of prescriptive maps
  - Theory of appraisive maps
  - Theory of formative maps
- Theory of functional generalization

Theory of Cartographic Communication
- Theory of cartographic vision
- Theory of cartographic representation (symbolization)
- Theory of cartographic generalization
- Theory of cartographic information
- Theory of cartographic behavior (action)
- Theory of cartographic aesthetics
- Theory of cartographic substitution

Methodology of Cartography (System of Rules)

- Methods of sign recognition
- Methods of measurement of syntactic information
- Methods of signature formation (construction)
- Methods of signature combination
- Methods of signature simplification
- Methods of signature production and reproduction
- Methods of signature classification

- Methods of cartographic system analysis
- Methods of cartographic coding
  - Methods of reduction of space
  - Methods of projection of space
  - Methods of typification of objects
  - Methods of grouping of objects
  - Methods of stratification of objects
  - Methods of stage (data) selection
- Methods of cartographic structures
  - Methods of elementary structures
  - Methods of complex structures
- Methods of spatial and topical map classification

- Methods of cartographic teaching
- Methods of functional mapping and map design
- Methods of cartographic standardization
- Methods of functional generalization
- Methods of map use
  (reading, analysis, interpretation, application)
- Methods of functional map classification

- Methods of cartographic organization
- Methods of cartographic training
- Methods of evaluation of cartographic information
  and communication
- Methods of optimization of cartographic communication
- Methods of substitution of cartographic communication

Practice of Cartography (System of Intentional Actions)

Organization of Cartography

Cartographic Editing
- Map preparation
  - Data survey and collection
  - Data storage
  - Data preprocessing
- Map planning
  - Editorial planning
    - Technological planning
    - Financial planning
    - Marketing planning
  - Conceptual planning
    - Planning of map function
    - Planning of map content
    - Planning of map form
    - Coordination of maps and register
- Map drafting
  - Data processing and supplementation
  - Legend draft
  - Map face draft
  - Map compilation
  - Corrections of drafts

Cartographic Production
- Production organization
- Productions of originals by
  - Manual techniques
  - Mechanical techniques
  - Photographic techniques
  - Copy techniques
  - Electronic techniques
  - Combined techniques
- Map reproduction
- Final map preparation

Cartographic Disposition
- Map distribution
- Map storage
  - Documentation (bibliography)
  - Preservation
- Map use
  - Map reading
  - Map analysis (cartometrics)
  - Map interpretation
  - Map processing
  - Map revision

Auxiliary Activities in Cartography

Training in Cartography

Comparative Cartography
- Comparative theory of cartography
- Comparative methodology of cartography
- Comparative practice of cartography

Historical Cartography
- History of theoretical cartography
- History of cartographical methodology
- History of practical cartography

FIG. 3. STRUCTURE OF THE SCIENCE OF CARTOGRAPHY ACCORDING TO ULRICH FREITAG (1979).
After Freitag 1980, 32–33 (fig. 6).

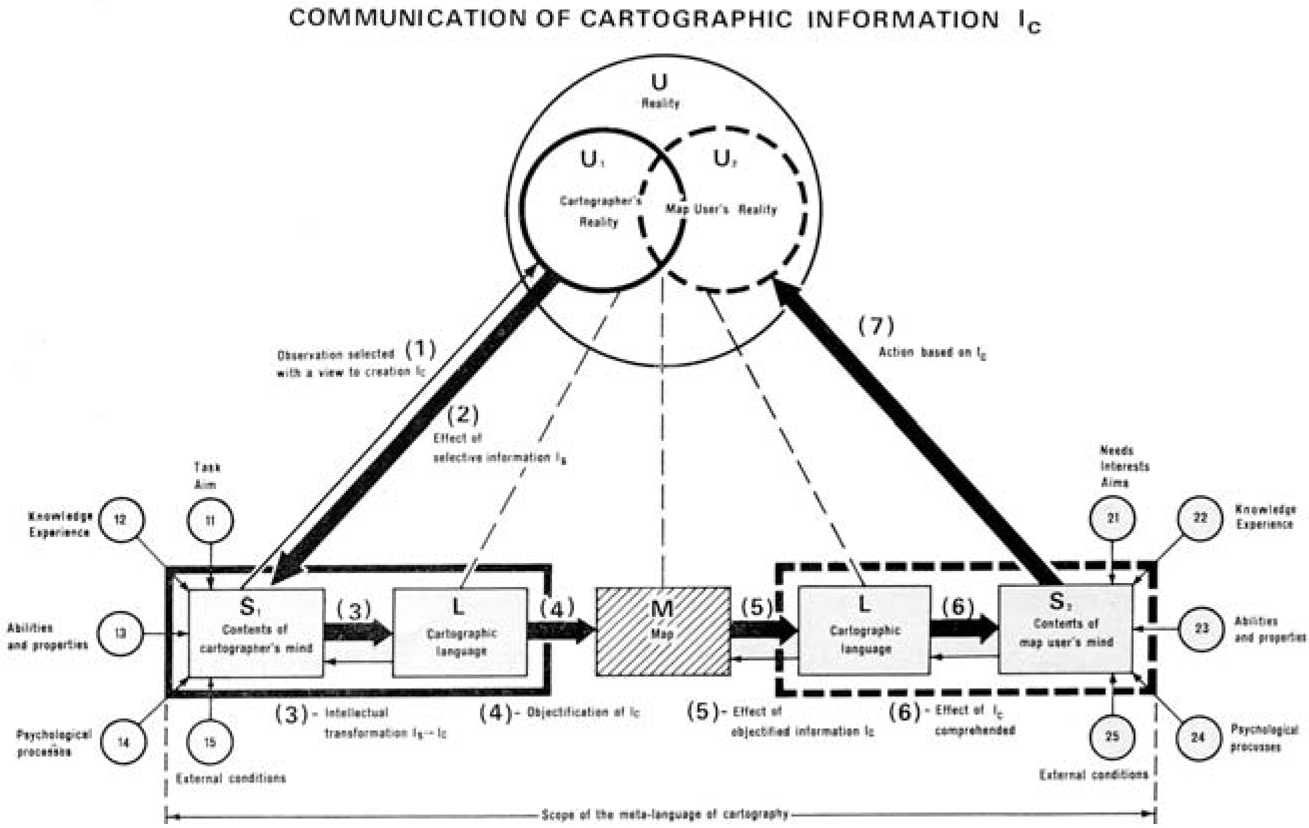

FIG. 4. MODEL OF CARTOGRAPHIC COMMUNICATION BY ANTONÍN KOLÁČNÝ (1969).
Size of the original: 11 × 17.5 cm. From Koláčný 1969, 48.

expressed in the map and the information received by the map user from the map (fig. 4).

The American approach to cartography as a communication science was unsatisfactory insofar as it saw cartographers only as technicians who passed on information without influencing it. However, this information has to be adapted to the target group, to the objectives, to the medium, to the scale, etc., in order for the map to be effective. The Russian approach to cartography as a cognitive science provided important contributions: cartography is the science of getting to know reality by mapping it. This presupposed an iterative modeling approach that had to be repeated until the map was a suitable model of reality. It is possible to see parallels with portrait painters, who can render persons properly on their canvas only after they have gotten to know them, and are thus able to portray the essence of their personalities.

Prior to the 1980s maps had to serve multiple functions simultaneously: storage, navigation, and communication. The onslaught of the computer meant another change of paradigm. Since the 1980s the data model has the storage function, and from this data model multiple cartographic products may be derived, each adapted to specific communication objectives.

The second contribution of automation was the availability of all map elements in the data model. This allowed the application of techniques of explorative cartography (alternatively called analytical cartography or scientific visualization); it created the possibility of experimenting with aggregation levels, classification levels, and representation methods, and of relating map space to data space in brushing techniques and a host of other analytical possibilities.

The abundance of information led to yet another view of the cartographic profession. As a vast majority of information needed was available from the World Wide Web, the function of cartography changed to adapting available spatial information into a form that allowed for interactive decision making: cartography had become the science of making spatial information accessible and manageable and transferring it, with the aim of solving spatial issues.

FERJAN ORMELING

SEE ALSO: Bertin, Jacques; Eckert, Max; Electronic Cartography: Intellectual Movements in Electronic Cartography; Geography and

Cartography; Imhof, Eduard; International Cartographic Association; Koeman, Cornelis; Koláčný, Antonín; Kretschmer, Ingrid; Peucker, Karl; Public Access to Cartographic Information; Ratajski, Lech; Salishchev, Konstantin Alekseyevich; Societies, Cartographic: (1) Western Europe, (2) Eastern Europe

BIBLIOGRAPHY:

Bertin, Jacques. 1978. "Theory of Communication and Theory of 'The Graphic.'" *International Yearbook of Cartography* 18:118–26.

Board, Christopher. 1967. "Maps as Models." In *Models in Geography*, ed. Richard J. Chorley and Peter Haggett, 671–725. London: Methuen.

———. 1981. "Cartographic Communication." In *Maps in Modern Geography: Geographical Perspectives on the New Cartography*, ed. Leonard Guelke, Monograph 27, *Cartographica* 18, no. 2:42–78.

Fabrikant, Sara Irina. 2003. "Commentary on 'A History of Twentieth-Century American Academic Cartography' by Robert McMaster and Susanna McMaster." *Cartography and Geographic Information Science* 30:81–84.

Freitag, Ulrich. 1979. "Grundlagen, Aufbau und zukünftige Aufgaben der kartographischen Wissenschaft." In *Kartographische Aspekte in der Zukunft*, ed. Heinz Bosse, 31–58. Bielefeld: Deutsche Gesellschaft für Kartographie.

———. 1980. "Can Communication Theory Form the Basis of a General Theory of Cartography?" *Informations Relative to Cartography and Geodesy, Series II: Translations* 38:17–35.

Hettner, Alfred. 1910. "Die Eigenschaften und Methoden der kartographischen Darstellung." *Geographische Zeitschrift* 16:12–28 and 73–82. An edited version appeared under the same title in the *International Yearbook of Cartography* 2 (1962):13–35.

Imhof, Eduard. 1963. "Tasks and Methods of Theoretical Cartography." *International Yearbook of Cartography* 3:13–25.

International Cartographic Association (ICA). 1973. *Multilingual Dictionary of Technical Terms in Cartography*. Ed. Emil Meyen. Wiesbaden: Franz Steiner.

Koeman, C. 1971. "The Principle of Communication in Cartography." *International Yearbook of Cartography* 11:169–76.

Koláčný, Antonín. 1969a. "Cartographic Information—A Fundamental Concept and Term in Modern Cartography." *Cartographic Journal* 6:47–49.

———. 1969b. *Utilitarian Cartography—the Road towards the Optimal Effect of Cartographic Information*. Prague: Research Institute for Geodesy and Cartography.

———. 1971. "Cartographic Information: Report of the Working Group." *International Yearbook of Cartography* 11:65–68.

Kretschmer, Ingrid. 1980. "Theoretical Cartography: Position and Tasks." *International Yearbook of Cartography* 20:142–55.

Morrison, Joel L. 1976. "The Science of Cartography and Its Essential Processes." *International Yearbook of Cartography* 16:84–97.

Muller, J. C. 1981. "Bertin's Theory of Graphics/A Challenge to North American Thematic Cartography." *Cartographica* 18, no. 3:1–8.

Ratajski, Lech. 1973. "The Research Structure of Theoretical Cartography." *International Yearbook of Cartography* 13:217–28. Reprinted in *The Nature of Cartographic Communication*, ed. Leonard Guelke, Monograph 19, *Cartographica*, 46–57. Toronto: B. V. Gutsell, 1977.

Robinson, Arthur H. 1960. *Elements of Cartography*. 2d ed. New York: John Wiley & Sons.

Salishchev, Konstantin Alekseyevich. 1970. "The Subject and Method of Cartography: Contemporary Views." *Canadian Cartographer* 7:77–87.

———. 1978. "Cartographic Communication/Its Place in the Theory of Science." *Canadian Cartographer* 15:93–99.

Tikunov, Vladimir S. 1988. "Theoretische Entwicklungsrichtungen der Modellierungsmethoden thematischer Karteninhalte." *Petermanns Geographische Mitteilungen* 132:41–45.

United Nations, Department of Social Affairs. 1949. *Modern Cartography: Base Maps for World Needs*. Lake Success, N.Y.

Academy for Spatial Research and Planning (Germany). See Akademie für Raumforschung und Landesplanung

Access. See Public Access to Cartographic Information

Accuracy in Mapping. The processes by which maps are produced are inevitably prone to error and uncertainty. Latitudes and longitudes measured using a Global Positioning System (GPS) inherit the errors inherent in that system, which can amount to as much as seconds of arc in some circumstances. In a different vein, maps printed on paper stretch and shrink with folding and with changes in humidity. In general the accuracy of a map can be defined as a measure of the degree to which it departs from a correct representation of reality.

This notion of the map as a representation, or as a compilation of measurements, embodies a scientific perspective on cartography that is at odds with many alternatives, and implies that all aspects of the mapmaking process can be defined to rigorous standards of objectivity. Thus while topographic map production by agencies such as the U.S. Geological Survey has been subject since the mid-twentieth century to well-defined standards of accuracy that resemble measurement standards in other branches of science, many thematic maps are produced by processes that in part are unabashedly subjective and vague. The literature of the late twentieth century shows a steady transition from the study of scientific error and accuracy to the more general study of uncertainty and vagueness (Zhang and Goodchild 2002).

By 1900 the process of earth measurement had been developed into an advanced science. National mapping agencies were able to define accurate geodetic reference frames, or datums, based on careful measurement of the shape of the earth within their jurisdictions and to use them for the determination of position to accuracies on the order of one meter. Geodetic control networks were established and used as the basis for determining the positions of other features in a hierarchy of decreasing accuracy. With most of the land surface controlled by colonial powers, it was possible to believe that map accuracies would steadily improve through time as more resources were poured into the mapmaking process.

The U.S. National Map Accuracy Standards published in 1947 define the accuracy requirements of basic topographic mapping in that country. The standards specify: "For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. . . .Vertical accuracy, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval." Maps that meet the standards are required to note their compliance, but maps that fail to meet the standards "shall omit from their legends all mention of standard accuracy" (U.S. Bureau of the Budget 1947).

It is common in this context to distinguish between accuracy and precision. The precision of a measuring device, such as a compass, measures the variation in repeated measurements of the same property. But if the instrument is biased, these measurements will cluster around a mean that is different from the truth. By contrast, accuracy measures the difference between repeated measurements and the truth and incorporates therefore both precision and bias. Both terms are somewhat awkward, since what is actually measured in each case is the reverse: *im*precision and *in*accuracy.

Standards of positional accuracy invariably address absolute accuracy, or the deviation of individual points from their correct positions on the earth. Of more relevance in many applications, however, is relative accuracy, which refers to errors in the relative positions of points a short distance apart. For example, if a road were distorted by taking points 10 meters apart and distorting them in random directions by 10 meters, the result would be chaotic, cartographically unacceptable, and useless for many applications, and yet would meet the U.S. National Map Accuracy Standards for a map at a scale of 1:24,000, since none of the points will have been displaced by more than the specified limit of 1/50 inch. This issue was unimportant as long as maps were made by hand insofar as cartographers could smooth out such relative errors. It became much more important in the late twentieth-century era of automated geospatial data capture; geographer David M. Mark (1983) was able to show its critical relevance in the geomorphic analysis of maps.

This apparently straightforward perspective is nuanced in many ways. Because a flat paper map must distort the curved surface of the earth, it is impossible for any map to have a constant representative fraction, or ratio between distances on the paper map and distances on the earth. D. H. Maling (1988) discussed many of the issues associated with measuring from maps, and many of these issues have become much more prominent with the advent of the precise measuring and calculating tools known as geographic information systems (GIS) beginning in the mid-1960s. Indeed, the first project to identify itself as a GIS, the Canada Geographic Information System (Tomlinson 1998), was almost entirely concerned with obtaining accurate measurements of area from maps, a task that was notoriously tedious and inaccurate when performed by hand.

In the 1950s the problems of accurately targeting intercontinental ballistic missiles drove the need for a single universal geodetic model of the earth to replace the local models used by national mapping agencies. Although the new World Geodetic System 1984 (WGS84) provided a poorer approximation to the actual shape of the earth in most local areas, its universal nature allowed the maps produced by different countries to fit at their borders, avoiding many of the complications that had plagued international navigation. The 1980s saw the advent of the Global Positioning System, a military system whose full capabilities for accurate positioning were not made available to civilians until the end of the century. The satellite constellation known as Navstar GPS allowed millimeter-level determinations, sufficient to support survey-grade accuracies and to monitor tectonic movements on a continuous basis.

Despite national map accuracy standards and the testing programs used to assure adherence to them, the inherent inaccuracy of geospatial data was often surprising. Figure 5 shows two U.S. Geological Survey data sets, both subject to the U.S. National Map Accuracy Standards. The roads are from 1:24,000 mapping and meet the standard of fewer than 10 percent of points being mislocated by more than twelve meters. The underlying aerial photograph is part of the Digital Orthophoto Quarter Quadrangles program, with a one-meter spatial resolution and a published and assured positional accuracy of six meters. Although the evident positional differences are within those expected given the standards, the degree of misfit could be disconcerting, as when the data were displayed using the National Map Viewer.

While topographic mapping has long been subject to standards of accuracy, the same has not been true of many types of thematic maps. It has been difficult, for example, to define truth in the context of place-names insofar as a name applied by one community to a feature can be quite different from the name applied by another community or by an earlier community, and conflicts over naming have occasionally escalated to international incidents.

Substantial attention has been focused on one particular type of thematic map, variously known as the area-class map or categorical coverage. This type of map shows an area partitioned into irregular but homogeneous patches that possess some property. Maps of this nature, representing the spatial variation of such properties as soil type, vegetation class, land cover type, or surficial geology type, have been produced in vast numbers in support of land management programs. Unfortunately, it has proven enormously difficult to establish processes of accuracy assessment for such maps. At its

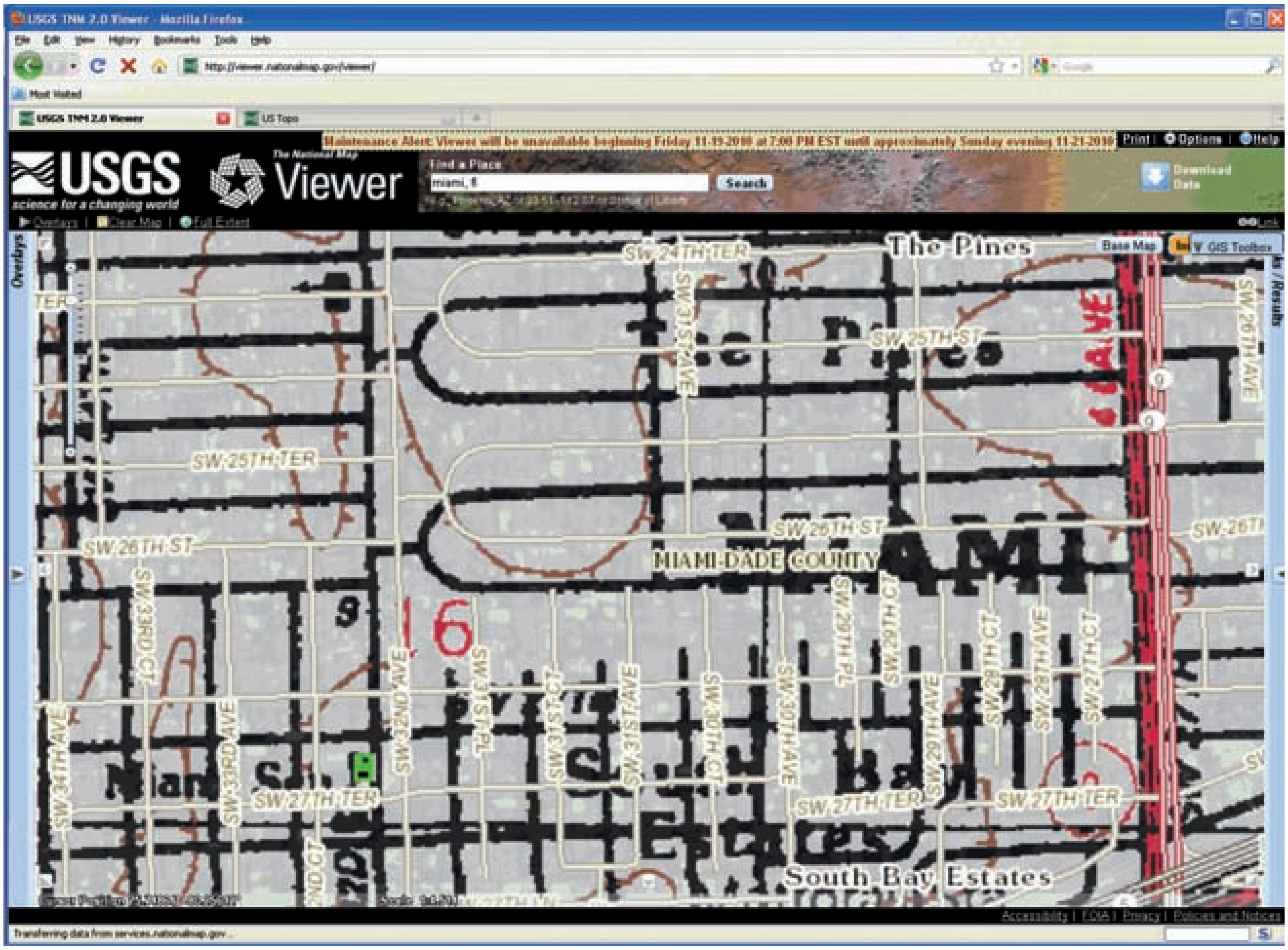

FIG. 5. SCREEN SHOT FROM THE NATIONAL MAP VIEWER. The map viewer is maintained by the U.S. Geological Survey. This detail of part of Miami, Florida, shows the mismatch between the roads (positional accuracy standard 12 m) and the underlying image (positional accuracy standard 6 m). Screen capture 16 November 2010.

heart, the problem revolves around the lack of rigor with which classes are defined and the consequent failure of two independent mapmakers to produce identical maps. A common approach has been to ask whether the class assigned to a given patch is correct based on a field check or a reference source of higher accuracy. The number of patches with correctly assigned classes could then be tabulated and summarized in one of a number of suitable statistics (Congalton and Green 2009). But since the definition of each class almost certainly allows for some degree of doubt, and since the patch is almost certainly not perfectly homogeneous, the question of whether patch classes are correct is fraught. After all, patch boundaries might not be in their correct locations, and both the number of patches and their boundaries might well vary when the same area is mapped by different and presumably expert mapmakers (Goodchild 2008).

Understandably, research attention was redirected to concepts and paradigms that move away from a strict perspective of scientific measurement. A-Xing Zhu (1997), for example, explored the use of fuzzy sets, arguing that if mapmakers are unable to define classes rigorously and to assign patches to them in a scientifically replicable way, they may at least be willing to assign degrees of membership in classes subjectively. In a similar vein, Peter F. Fisher and his colleagues compared fuzzy sets, rough sets, and other conceptual frameworks as a basis for modeling and understanding uncertainty (Fisher, Cheng, and Wood 2007).

By the turn of the century it was clear that both perspectives—the more rigid scientific view and this broader, more flexible approach—would be needed for a comprehensive approach to the uncertainty associated with maps. Capturing and representing the properties of the earth's surface was clearly not something analogous to measuring simple properties such as temperature. Instead, the infinite complexity of the earth's surface required a more open-minded approach that was able to accommodate the ambiguity that would inevitably be present in compressing real-world complexity into a simple representation.

That said, substantial problems remained in reconciling a broader approach with the strong belief in the scientific and evidence-based reasoning that underlies many concepts of government regulation and jurisprudence. Fairness dictates that land use regulations cannot be based on the subjective judgment of public officials, however well qualified, if they are to withstand a court challenge as arbitrary and capricious. The widespread adoption of computer-based GIS by agencies in support of their decision making has in part been driven by the need to document and to establish accountable procedures, despite the obvious uncertainties of the underlying data. The computers that came to dominate the world of geographic information production and use in the late twentieth century appeared to provide the kind of implicit authority and accountability that more traditional forms of mapping lacked.

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SEE ALSO: Analytical Cartography; Cartometry; Property Mapping Practices; Scale; Standards for Cartographic Information; Tissot's Indicatrix; Uncertainty and Reliability

BIBLIOGRAPHY:

Congalton, Russell G., and Kass Green. 2009. *Assessing the Accuracy of Remotely Sensed Data: Principles and Practices*. 2d ed. Boca Raton: CRC Press/Taylor & Francis.

Fisher, Peter F., Tao Cheng, and Jo Wood. 2007. "Higher Order Vagueness in Geographical Information: Empirical Geographical Population of Type *n* Fuzzy Sets." *GeoInformatica* 11:311–30.

Goodchild, Michael F. 2008. "Statistical Perspectives on Geographic Information Science." *Geographical Analysis* 40:310–25.

Maling, D. H. 1988. *Measurements from Maps: Principles and Methods of Cartometry*. Oxford: Pergamon Press.

Mark, David M. 1983. "Relations between Field-Surveyed Channel Networks and Map-Based Geomorphometric Measures, Inez, Kentucky." *Annals of the Association of American Geographers* 73:358–72.

Thompson, Morris M. 1979. *Maps for America: Cartographic Products of the U.S. Geological Survey and Others*. Reston: U.S. Department of the Interior, Geological Survey National Center.

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

U.S. Bureau of the Budget. 1947. *United States National Map Accuracy Standards*. Rev. Washington, D.C.: U.S. Bureau of the Budget.

Zhang, Jingxiong, and Michael F. Goodchild. 2002. *Uncertainty in Geographical Information*. New York: Taylor & Francis.

Zhu, A-Xing. 1997. "Measuring Uncertainty in Class Assignment for Natural Resource Maps under Fuzzy Logic." *Photogrammetric Engineering & Remote Sensing* 63:1195–1202.

Administrative Cartography. Administrative cartography, which encompasses the processing, production, and publication of maps, atlases, and map series for public service, is a key responsibility of administrative authorities, including the armed forces. Although this category excludes topographical mapping, a mode of mapping that emerged out of war and military cartography to support wayfinding, it does include thematic maps introduced centuries ago in response to economic development and scientific-technical advances as well as improved, more cost-effective production methods. Thematic cartography and its methods emerged toward the end of the eighteenth century and became broadly applied in the developed countries of Europe as well as in North America and Japan as new governmental organizations arose. In the twentieth century, administrative cartography benefited from technical progress, particularly in photogrammetry and remote sensing, and enhanced worldwide cartographic coverage promoted by international professional associations as well as the United Nations and other new supranational authorities that arose at least partly because of the trauma of the two world wars. Since approximately 1970, computer-assisted cartography and geographic information systems (GIS) have played an increased role in both administrative cartography and cartography in general, and numerous publications arose to document these developments. Indeed, the growing accumulation of richly informative administrative thematic maps led Australia to publish a yearly *Thematic Mapping Bulletin*, starting in 1970, and in 1983 the *Journal of Government Information* published a special issue on government mapping in the United States.

Among the earliest tasks in administrative cartography were cadastral surveys and large-scale cadastral maps, produced to promote the efficient collection of property taxes. The perfection of lithography in the nineteenth century fostered the reproduction of cadastral maps, which simultaneously served as large-scale topographic maps, as in the southern German states. When the income tax displaced the real-property tax as the principal source of revenue, basic proof of ownership became the main purpose of the cadastre. In many parts of the world settled by Europeans, land and cadastral surveys preceded the transfer of ownership to individuals, and land appraisals required detailed base maps. In the United States, maps of Indian lands delineated the boundaries of native reservations, and farm-size parcels defined efficiently by a survey grid promoted the settlement of vast tracts once held by indigenous peoples. In Europe, agricultural plot maps improved land redistribution and consolidation in traditional agricultural settlements by clarifying ownership and providing a basic description of natural resources and the rural environment. The Russian Revolution of 1917 led to the Osnovnoy zakon o sotsializatsii zemli, or the Basic Law on the Socialization of Land, in 1918, and after 1945 other Soviet-dominated and communist countries, such as China, implemented this system of communal ownership. When private ownership was reestablished after 1990, the cadastral map regained its importance as the framework of development, as it also had after 1945, when the colonies of the Third World gained independence.

In developed countries, because of postwar reconstruction, industrialization, population growth, and urbanization as well as the later consequences of pollution and deindustrialization, the large-scale cadastral map became even more important as a framework for planning and redevelopment. City survey offices were formed, and the cadastre began to serve more purposes. In some countries, the scale gap between cadastral and topographic maps was closed by intermediate-scale maps such as Germany's 1:5,000 base map. In metropolitan areas, neighboring towns collaborated on the production of larger maps, while in sparsely populated areas aerial photo maps provided a detailed description of surface features. Where topographic maps showed few, if any, terrain features, authorities that needed this level of detail began producing land use maps. In many countries in which large forested tracts were not private land, and thus not described by cadastral maps, administrative forestry maps emerged as an essential management tool.

A new and prolific branch of administrative cartography arose to support regional and urban planning at various levels. The rise of government-instigated planning in the twentieth century was a response to diverse historical events, most notably the two world wars as well as the desire to shape man and nature according to totalitarian or utopian ideologies such as Marxism, fascism, and national socialism. In particular, the peace treaties following World War I, which destroyed the multiethnic states of Austria-Hungary and the Ottoman Empire, required new political boundaries at multiple levels, for which Germany's recovery provides numerous examples. Not only was Germany forced to cede territory, but the removal of the remaining aristocratic rulers reduced the number of small German states. At the same time, mining, especially lignite mining, as well as industry began to dominate densely populated areas. When the Nazis seized power in the early 1930s, a centralized state under a charismatic and autocratic leader instituted rigorous planning practices, and the affected population had little recourse for appeal or protest. The Reichsstelle für Raumordnung was established in 1935, and at the Reichsamt für Landesaufnahme, the Abteilung für Landeskunde was introduced in 1940. In the course of rearmament, new arms factories and military training areas were planned and developed, and new mining and industrial zones were established to ensure the Reich's independence with regard to strategic goods. After the outbreak of World War II, regional planning was imposed on Nazi occupied territories, especially in East-Central Europe, where a racist settlement policy, the Generalplan Ost, was enforced.

Germany's defeat in 1945 left the country not only devastated but divided into four zones of occupation and forced to absorb displaced populations from the eastern provinces. Within the zones of occupation the German *Länder* (states) were formed, some based on the original Prussian subdivisions. In the Soviet-occupied zone, the states were quickly abolished again, and the whole area transformed into a socialist planned economy and unitary state, which was incorporated into the Soviet economic bloc, the Sovet ekonomicheskoy vzaimopomoshchi (the Council for Mutual Economic Assistance, known as COMECON). The West German states developed planning atlases, and the entire Federal Republic of Germany, established in 1949, was covered in the *Atlas zur Raumentwicklung*. The respected Bundesanstalt für Landeskunde und Raumordnung was formed by combining the Reichsstelle für Raumordnung and the Abteilung für Landeskunde of the Reichsamt für Landesaufnahme.

European unification efforts in the 1950s led to cross-border planning initiatives, such as the Swiss-French-German regional atlas covering northwestern Switzerland, the Black Forest region, and Alsace, and, eventually, to pan-European planning. A European conference of ministers responsible for regional planning and cartography met to discuss options, and in 1993 a European planning atlas project was begun. The Soviet Union, especially in the 1940s and early 1950s under I. V. Stalin, embodied a ruthless, totalitarian form of centralized state planning. In the United States the Tennessee Valley Authority demonstrated that humane large-scale planning efforts were possible in democracies under particular circumstances.

Statistical mapping also played a role in administrative cartography, particularly in the nineteenth and twentieth centuries. In all advanced countries statistical authorities established for economic development, legislative reapportionment, or other purposes published summary tabulations in cooperation with public health ministries, unemployment ministries, or other relevant authorities. These publications eventually included statistical maps, introduced timidly as a means of inquiry and then for analysis and decision making. In the twentieth century, both the methods and the number of statistical maps exploded—and eventually their distribution as well, through the Internet—as they were also produced by supranational agencies, such as the United Nations, the European Community, and the European Union.

The most important contribution of official statistics was the national census, which resulted in a wealth of statistical maps and atlases, sometimes leading to unintended politically explosive consequences, as demonstrated in the first half of the century by the ethnic, language, and race maps of parts of Europe. Other important administrative uses of statistical maps included the reconfiguration of voting districts and the presentation of election results. In the United States, which was a pioneer in the development of comprehensive statistical atlases, statistical maps focused on slavery attracted public interest before and during the Civil War (1861–65), and the statistical atlas based largely on the 1870 Census and published in 1874 provided a systematic, scientific overview that led to a flowering of the national atlas as a cartographic genre in the twentieth century.

National atlases were developed as multiyear projects, typically managed by the central government, the national academy, or a collaboration of scientific societies. In Finland, which was part of the Russian Empire from 1809 until the overthrow of the Russian monarchy in 1917, the Suomen maantieteellinen seura published the 1899 *Atlas de Finlande/Atlas öfver Finland*, as a response to Russia's attempts to justify its occupation. The atlas of Finland exemplified the role of the national atlas as an emblem of national identity or independence and provided a prototype for newer national atlases, which also promoted science and education or provided a tool for planning and decision making. The *Atlas of Canada*, published in 1906 by the Canadian government with all of these purposes in mind, was very much a product of administrative cartography. The regional atlas, covering part of a country or a large administrative unit, was a similarly intended variant of the national atlas.

Over the course of the twentieth century, administrative cartography, drawing largely on thematic cartography and cadastral mapping, became ubiquitous as governmental administration became larger and more complex at both local and national levels. This explosion also reflected technical and scientific advances, which eventually reached lesser-developed countries, as well as ideological ambitions. Late twentieth- and twenty-first-century challenges such as population growth, environmental pollution, the need for more effective disaster response, and the need to increase revenue to support a growing demand for government services also contributed to an expansion of administrative cartography.

This enlarged administrative cartography was quintessentially restrictive. As public administration assumed a broader role in managing infrastructure and mediating social and political relations, a pervasive prohibitive cartography arose to advertise and enforce government regulations, which had increased in both number and geographic detail throughout the twentieth century. In the United States, for instance, maps unheard of in 1900 were in wide use by century's end to protect buried infrastructure; support land use zoning, building codes, disaster mitigation efforts, flood insurance programs, and wildlife management (with constraints on hunting and fishing); regulate the use of airspace, waterways, and groundwater; limit exterior modifications of buildings in designated historic districts; and narrow the residential options of convicted sex offenders. In addition, overhead imaging and the Global Positioning System (GPS) had become powerful tools for surveillance and intervention, and satellite tracking systems that integrated GPS with wireless telephony helped parents track their children, fleet operators monitor their trucks and buses, and judicial authorities enforce court-ordered constraints on parolees and abusive spouses. No longer just a necessary adjunct of public management, administrative cartography had become a convenient means of micromanaging lives and property.

JOACHIM NEUMANN

SEE ALSO: Aeronautical Chart; Atlas: National Atlas; Cadastral Map; Census Mapping; Electoral Map; Environmental Protection; Hazards and Risk, Mapping of; Land Use Map; Planning, Urban and Regional; Tax Map; Urban Mapping

BIBLIOGRAPHY:

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

Kübler, Andreas. 2007. *Chronik Bau und Raum*: *Geschichte und Vorgeschichte des Bundesamtes für Bauwesen und Raumordnung*. Tübingen: Ernst Wasmuth Verlag.

Monmonier, Mark. 2010. *No Dig, No Fly, No Go: How Maps Restrict and Control*. Chicago: University of Chicago Press.

Obermeyer, Nancy J., and Jeffrey K. Pinto. 2008. *Managing Geographic Information Systems*. 2d ed. New York: Guilford Press.

Scott, James C. 1998. *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*. New Haven: Yale University Press.

United Nations. 1951; 1953; 1954; 1975. *World Cartography*. New York: United Nations, Department of Economic and Social Affairs.

Admiralty Hydrographic Office (U.K.). See Marine Charting: Great Britain

Advertising, Maps as. Advertisements are intended to attract attention, provide information, and persuade their audience to purchase, rent, use, or subscribe to something. During the twentieth century, advertisers employed visual images (text, pictures, and other graphic images, including maps) and sounds to reach more people through a growing variety of communications media. During the nineteenth century traditional painted shop signs had been augmented by more ephemeral notices and posters printed on paper for posting on buildings, billboards, and other surfaces. Such advertising carried over into the twentieth century, along with advertisements in periodicals, books, and brochures illustrated with photographs as well as other graphic images. Spoken advertising, already broadcast by radio, was combined with visual images when talking motion pictures were introduced during the 1920s. The development of television from the 1950s onward brought audiovisual commercials into the home. The invention of the Internet in 1990 soon led to online advertising and shopping by the growing numbers of computer owners, a technological trend continued into the twenty-first century by laptop computers, cell phones, and other portable electronic devices. The spread of advertising has had worldwide impact, especially in the Western world and among socioeconomic groups able to afford the new communications technology. The growth of commerce was obviously a major incentive for advertising products and services during the twentieth century. Government and nonprofit organizations also became advertisers, although in that sphere advertising and propaganda are often hard to distinguish.

Typically, the effectiveness of visual advertising is based upon attracting the reader's attention to its graphic features. While graphic images employed in twentieth-century advertising were predominantly pictorial, maps played a distinctive and significant role and were effective for several reasons. Maps in advertising frequently distort familiar geographic regions into unusual shapes, often in a humorous or entertaining way, to attract viewers. They can also be used to create the impression that the product is up-to-date by employing modern technology, for example a new projection (see fig. 8 below).

Location was a dominant cartographic message, but it was presented in different ways. Most maps in advertisements showed the reader where to find the goods or services being advertised. The destination could be a single location, such as the 1907 bird's-eye view sketch map of Death Valley, California, on which the publisher of the *Death Valley Chuck-Walla* magazine offered to print any advertiser's company name and location in red, either at postcard size or larger for folding and mailing. In contrast, a 1975 British advertisement included a map of multiple heritage sites that could be visited using tokens collected from Cadbury's Chocolate House Cakes. Railway maps, such as the Cotton Belt route of the St. Louis Southwestern Railway advertised in the *Dallas Morning News* in 1946, typically emphasized their own lines and stops, while minimizing or omitting those of competing lines. Folding road maps of states and regions, distributed free by oil companies from the 1920s through the 1970s, provided more general wayfinding information for motorists but always bore advertising and often highlighted gas stations selling the advertised brand. States, towns, and chambers of commerce typically advertised their locales by providing state road and city street maps for travelers and residents, although by the late 1990s such paper maps began to be replaced by web-accessible electronic maps accompanied by online advertising. Nevertheless, display racks in twenty-first-century visitor centers and hotel lobbies remained full of colorful tourist brochures printed on paper, each usually including a large-scale map locating the local museum, fun park, or other attraction being advertised.

Another way of incorporating location into advertising was by a cartographic image characterizing the nature or quality of the product or services being advertised. Most common was the inclusion of a world map to emphasize the global nature of the services offered, a device frequently used in air and sea transportation (fig. 6). The phrase "all over the map" appeared frequently in advertising during the early to mid-twentieth century and was sometimes portrayed in cartographic form, such as by Western Electric Company's 1946 advertisement showing its lines spreading across a map (e.g., in the *Saturday Evening Post*, 27 July 1946). On a similar theme, a 1991 Lexis-Nexis advertisement reinforced the statement that its Turbo software provided a road map to the world of information by an image of a computer disk covered with a road map centered on Dayton, Ohio, the company's headquarters (e.g., in *Database Searcher*, 1980s and 1990s).

Sometimes the map was merged with another image evoking some quality of the advertised goods or services, a type of visual metaphor harking back to the heraldic Leo Belgicus symbolizing the united Low Countries on Michael von Aitzing's map of 1583 and later versions. On a American railway map of 1896, the line extending from the Great Lakes to the West Coast also outlines the head, back, and tail of a hunting dog drawn in pointing stance above text reminding travelers to ask ticket agents of the Northern Pacific Railway Company for pointers about journeys westward (fig. 7). Another memorable advertising map showed how the British Army in South Africa in 1900 during the Anglo-Boer War had followed a route whose shape spelled the word Bovril, the brand of meat extract issued in rations for the troops (Hindley and Hindley 1972, fig. 3.9). Later in the century a map advertisement for Wendy's restaurants showed Italy fashioned from a variety of luncheon meats, while a 1960s Swissair advertisement promoting European travel depicted the map of Europe as a dragon, its gaping mouth formed by Spain and its feet by Italy (McDermott 1969, 153–54, fig. 5).

A number of factors contributed to the increased use of maps in advertisements during the twentieth century. In America motorists became accustomed to using free road maps when planning cross-country journeys along as yet poorly marked local roads. Only after midcentury did the establishment of the national system of numbered highways and the construction of interstate highways designed for fast, convenient, long-distance travel diminish the need for oil company road maps, which had disappeared before the advent of electronic in-car navigation systems at the end of the century.

Military conflicts during the twentieth century also boosted map use. In 1900 *The Century Dictionary and Cyclopedia* advertised the maps in its accompanying atlas for following the war in South Africa and the Philippines (*New York Times*, 6 January 1900, 5). During both world wars training in map use and interpretation

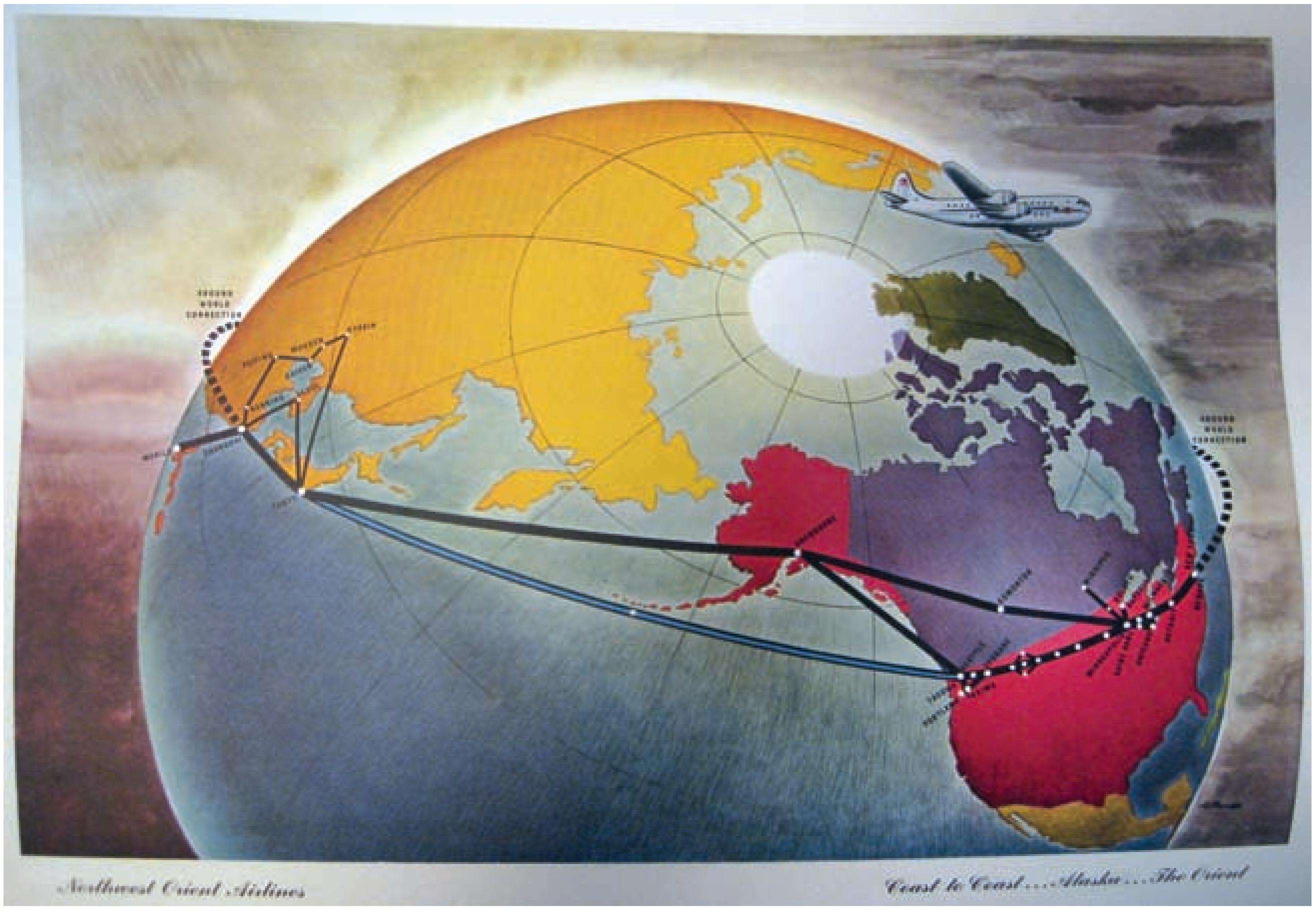

FIG. 6. NORTHWEST ORIENT AIRLINES MAP ADVERTISEMENT, LATE 1940s. The unusual point of view in this advertisement emphasizes that the airline circles the globe, and the image is reminiscent of map illustrations created by Richard Edes Harrison for *Fortune* magazine earlier in the 1940s.
Map from the collection of John Taylor, Madison. Permission courtesy of Delta Air Lines, Atlanta.

of aerial photographs received during military service meant that discharged servicemen returned to civilian life more familiar with maps.

From the 1930s journalistic cartography was on the rise. Increasingly maps in news and feature articles in newspapers and magazines introduced the public to geographic areas and locations around the world. In the early 1940s cartographer Richard Edes Harrison created maps for *Fortune* magazine showing the world from unaccustomed perspectives (Schulten 1998). They were followed in 1946 by R. Buckminster Fuller's Dymaxion globe on a projection unfolding to show the continents on a string of triangular facets. A Honeywell Corporation advertisement used Fuller's projection to advertise the message that it could provide automation systems throughout the world (McDermott 1969, 150–51) (fig. 8). During the 1960s astronauts first stepped onto the moon and looked back at the earth from space. That view of the earth as a blue marble, at once humbling and inspiring, became an iconic representation of the planet.

The advent of interactive websites for generating maps on demand, such as MapQuest and Lycos Maps, changed the late twentieth-century map user from a passive map viewer into a participant in the mapmaking process. For example, an Internet search for seafood restaurants in a city would bring up a selection whose map locations could be compared to find the nearest one. At the same time, GIS software enabled advertisers to be more proactive in seeking out customers. A 2005 MapInfo advertisement recommended its TargetPro software for profiling, analysing and understanding customers and markets in order to predict buying behavior (Odih 2007, 178–79). The TargetPro advertisement superimposed a bull's-eye target pattern upon a collage of maps to emphasize its message graphically.

Commercial artists, rather than professional cartographers, were typically employed to create map advertisements. Inadequate knowledge of geography and cartography sometimes led to errors. In the late 1960s an international airline contracted for an advertisement

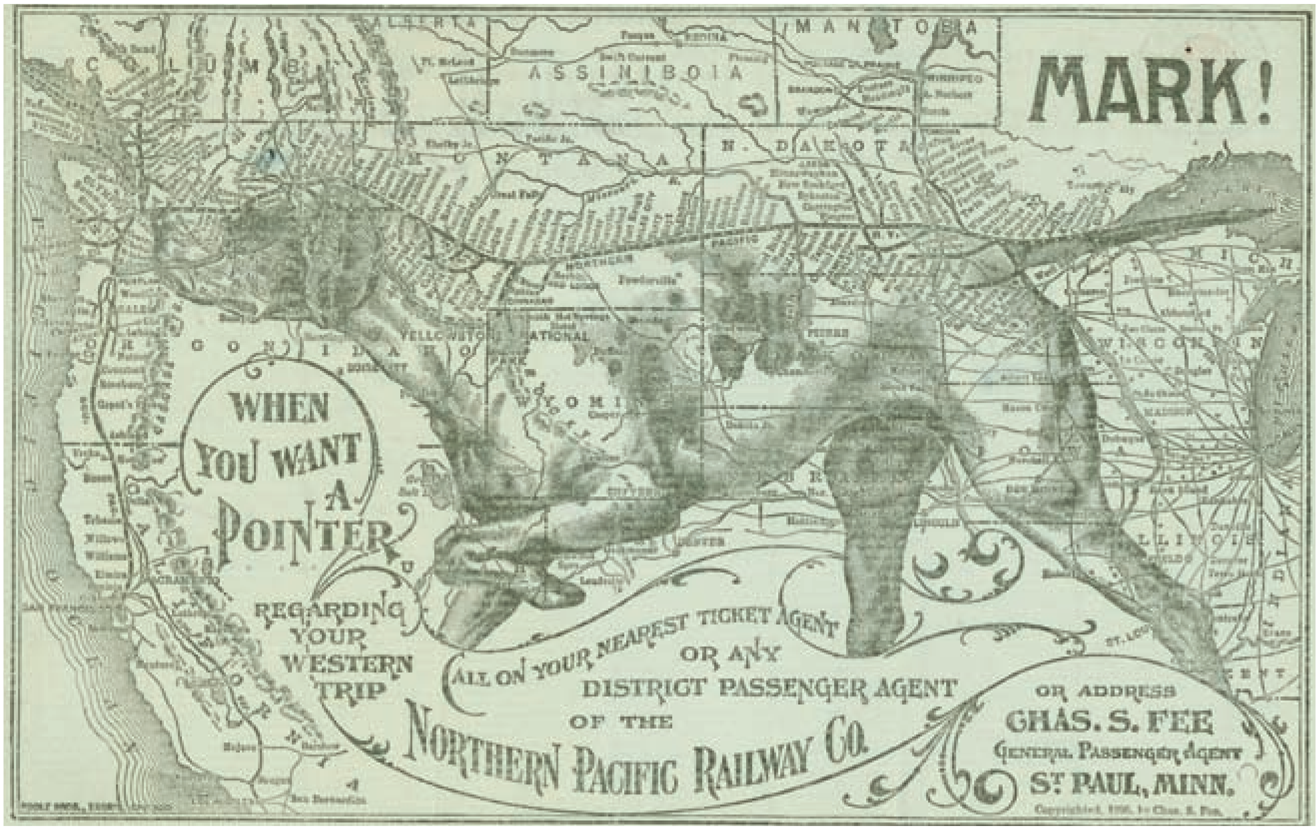

FIG. 7. NORTHERN PACIFIC RAILWAY MAP ADVERTISEMENT, 1896. "Mark! When You Want a Pointer Regarding Your Western Trip." This typical railway map showing lines and stations is combined with the graphic image of a hunting dog in pointing stance looking westward, thus creating a visual metaphor for the text of the advertisement.
Size of the original: 13.8 × 21.4 cm. Image courtesy of the Washington State Historical Society, Tacoma.

designed to show connectivity between an airport on the outskirts of New York City and a major airport in Europe. The artist employed a unique projection and global perspective, but the route was plotted incorrectly—connecting the Outer Banks of North Carolina with the destination in Europe. The ad was published in the *New York Times Magazine*, and when the mistake was noted in a letter to the airline by Paul D. McDermott, the airline's comical response was that the artist was trying to avoid traffic congestion in the New York area. The airline also refused permission to use the advertisement in a cartographic publication because it felt

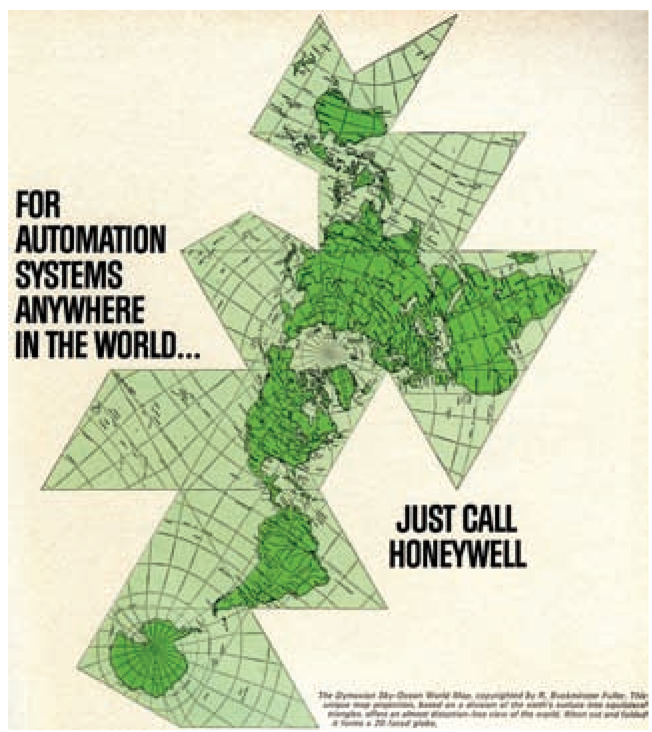

FIG. 8. HONEYWELL CORPORATION ADVERTISEMENT USING DYMAXION PROJECTION, 1968. This advertisement for the Honeywell Corporation presents the world map in the form of R. Buckminster Fuller's Dymaxion Globe, one of the most innovative and influential map projections of the twentieth century.
Size of the original: 19.5 × 15.7 cm. From *Scientific American* 219 (September 1968):169. The Fuller Projection Map design is a trademark of the Buckminster Fuller Institute. © 1938, 1967, 1992. All rights reserved.

it would reflect poorly on its navigational capabilities. Although the ad was withdrawn, it mysteriously reappeared several months later.

Like earlier railway maps, twentieth-century airline maps showed connectivity among the airports they served but not necessarily the shortest routes. Information about map scale, projection, and graticule was often omitted. Those deficiencies were usually outweighed by the graphic artist's skillful use of color and other variables to produce creative and appealing designs. The twenty-first-century cartographer seeking ways to improve the communicative power of maps could well draw inspiration from the design of twentieth-century advertising maps. In addition to evolving design styles, a chronological sequence of advertising maps, such as those displayed at the Swissair website (under marketing and advertisements), offers the viewer an historical overview of the century's changing lifestyles and popular tastes.

PAUL D. MCDERMOTT

SEE ALSO: Airline Map; Marketing of Maps, Mass; Persuasive Cartography; Railroad Map; Travel, Tourism, and Place Marketing

BIBLIOGRAPHY:

Akerman, James R., ed. 2006. *Cartographies of Travel and Navigation*. Chicago: University of Chicago Press.

Harris, Nathaniel. 2002. *Mapping the World: Maps and Their History*. San Diego: Thunder Bay Press.

Hindley, Diana, and Geoffrey Hindley. 1972. *Advertising in Victorian England, 1837–1901*. London: Wayland.

McDermott, Paul D. 1969. "Cartography in Advertising." *Canadian Cartographer* 6:149–55.

Nicholson, T. R. 2008. "Road Maps and Advertising in Britain, 1860–1940." *Cartographic Journal* 45:43–61.

Odih, Pamela. 2007. *Advertising in Modern and Postmodern Times*. Los Angeles: Sage Publications.

Robinson, Arthur H. 1952. *The Look of Maps: An Examination of Cartographic Design*. Madison: University of Wisconsin Press.

Schulten, Susan. 1998. "Richard Edes Harrison and the Challenge to American Cartography." *Imago Mundi* 50:174–88.

Wells, William, Sandra E. Moriarty, and John Burnett. 2006. *Advertising: Principles & Practice*. 7th ed. Upper Saddle River: Pearson Prentice Hall.

Yorke, Douglas A., and John Margolies. 1996. *Hitting the Road: The Art of the American Road Map*. San Francisco: Chronicle Books.

Aeronautical Chart. Aeronautical charts are special-purpose maps designed for guiding pilots and navigators from one place to another and for monitoring their positions along the way. These charts were originally known by a variety of names, but the term aeronautical chart became established during World War II with the worldwide distribution of the U.S. Army Air Force's standard 1:1,000,000 World Aeronautical Chart (WAC) series (Harvatt 1969, 193). While the term was originally limited to charts with scales ranging from 1:250,000 to 1:1,000,000, it came to embrace all aviation charts during midcentury.

The earliest aeronautical charts were generally in the form of standard topographic maps overprinted or highlighted with information such as rivers, lakes, railroads, prominent buildings, landing fields, and high-tension electric cables, essential to pilots flying at low speeds and low altitudes for short periods in fine weather. These early charts were associated with aero clubs that sprung up throughout Europe between 1909 and 1914, inspired by the work of Prussian balloonist Hermann W. L. Moedebeck, who established the first International Commission on Aeronautical Maps in 1911.

Among the early aero club leaders were Moedebeck, credited with the first practical aeronautical chart, the *Cöln* sheet (1909) of a planned 1:300,000 scale multisheet chart of Central Europe sponsored by the Deutscher Luftschiffer-Verband; Austrian Karl Peucker, an early advocate of depicting relief by color gradients (fig. 9); and Charles Lallemand, president of the Association française pour l'avancement des sciences, who promoted the Aéro-Club de France's 1:200,000 chart, the first national aeronautical chart, which was based partly on resolutions adopted in 1911 by the International Commission on Aeronautical Maps (Ristow 1960, 6–10; Ehrenberg 2006, 214).

World War I spurred advancements in many areas of flight as the airplane came to play a major role in the war effort; these innovations included maps for planning long-distance flights and bombing raids. The Aéro-Club de France and the Service géographique de l'armée expanded production of their 1:200,000 aeronautical charts of France, separate series begun in 1911. The Prussian General Staff introduced a 1:300,000 aviation map of northwestern Europe. The Hydrographic Department of the British Admiralty issued 1:253,440 Air Packet Flying Maps for the Royal Navy Air Service based on Ordnance Survey maps, which covered coastal areas of Great Britain (1915–18). These were issued in twelve-inch sections for use in the small open cockpits of that era (Nicholson 1988, 6).

The strip chart was another innovation. A variant form of the visual chart, it traced a strip of land along a given route. These were normally mounted on rollers that were scrolled forward during the flight (fig. 10). The British Royal Navy, the Italian Aeronautica Militare, and the U.S. Army Air Services contributed to this effort. Scale varied, but generally ranged from 1:250,000 to 1:500,000. Both British and Italian cartographers depicted views of monuments and buildings that served as checkpoints. Courses, airports, and airfields were marked and colored, frequently in red (Woodhouse 1917, 332–33). In the United States, strip maps were used primarily for pilot training. A number were revised and updated using aerial photography.

The strip-chart format was a major legacy of the war, particularly for regions outside Europe where compre-

FIG. 9. DETAIL FROM *BIELEFELD*, 1912, BY KARL PEUCKER. Published in Vienna, photolithography by the K. u. K. Militärgeographisches Institut, 1:200,000. This detail is from one of several experimental visual air maps prepared by Peucker for the Deutscher Luftschiffer-Verband to test various methods of portraying terrain and noted landmarks.
Size of the entire original: ca. 65 × 44.4 cm; size of detail: ca. 11 × 26.5 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C.

hensive medium-scale topographic map coverage was limited. Official air navigation strip map production dominated production in Argentina, Australia, Brazil, Peru, and North America during the early interwar years. Pan American–Grace Airways, the dominant international carrier in South America, also produced strip maps for its pilots and navigators (1938). These maps were similar in scale (1:500,000), content, and purpose. Most were designed with the assistance of pilots and flight-tested for accuracy. They ranged in size from 20 to 28 centimeters in width and up to 152 centimeters in length, covering an area about 130 by 350 kilometers. Many included insets of airport diagrams (Ehrenberg 2006; Sebert 1986, 89–91).

In Europe, the areal (nonstrip) format continued to prevail during this period with the French 1:200,000 and German 1:300,000 visual chart series, and later in the 1930s with 1:500,000 visual charts (fig. 11). In 1921 Great Britain's Geographical Section, General Staff (GSGS) of the British Directorate of Military Survey (DMS) issued a provisional 1:253,440 aeronautical chart of the British Isles, adapted from the Ordnance Survey's (OS) quarter-inch map. Separate Royal Air Force and Civil Air editions followed (Nicholson 1988, 7–9).

The earliest aeronautical chart series that can be considered a navigational instrument in the modern sense was the first generation of U.S. Coast and Geodetic Sur-

FIG. 10. UNTITLED AIR NAVIGATION STRIP MAP OF THE KAISER WILHELM CANAL (KIEL CANAL), ROYAL NAVY AIR DEPARTMENT, 1 JUNE 1915. Published in London by the Hydrographic Department of the Admiralty, 1:506,880. Mounted on British War Department aviator roller chart holder with compass (London: Houghton-Butcher, 1915). One of the first strip maps designed specifically for air navigation, with compass rose.
Size of the entire original: 14 × 142 cm. Image courtesy of the Ralph E. Ehrenberg Collection.

FIG. 11. DETAIL FROM *CARTE DE FRANCE ET DES PAYS LIMITROPHES AU 500,000e (COUPURE SPÉCIALE), TOURISME AÉRIEN FEUILLE NO.* 2, JULY 1936. Published in Paris by the Service géographique de l'armée, 1:500,000, heliograver. Standard French army topographic map overprinted with air routes provided by the Service de la Circulation Aérienne du Touring-Club de France, including lighted airways linking major cities such as Nancy and Strasbourg symbolized by a series of spiked circles representing lighted beacons.
Size of the entire original: ca. 98.5 × 71.3 cm; size of detail: ca. 10.6 × 32.4 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C. Permission courtesy of the Cartothèque, Institut géographique national.

vey (USC&GS) 1:500,000 sectional charts (1930–37), which provided the pilot with both visual and radio navigation information necessary for safe flight under adverse conditions on and off established airways. Charles A. Lindbergh's epic flight from New York to Paris in 1927 inspired this series, and his subsequent tours of the United States, the Caribbean, and Europe popularized general aviation and generated more flying off established airways than on them. The introduction of all-metal monoplanes with retractable landing gears and supercharged engines increased the range and speed of passenger aircraft and hastened the emergence of a national airways infrastructure and air traffic control centers in the United States, as well as the development of low- to medium-range radio range navigation, which made all-weather instrument flying possible. This series provided coverage of the continental United States in eighty-seven sheets, each of which was thoroughly flight checked before publication. The Lambert conformal conic projection was used since radio signals, which follow great circles, could be laid down as straight lines. A new point symbol in the form of four radiating bands of color represented the radio range stations (fig. 12). Relief was depicted by a combination of spot heights and contours, which provided the United States with its first topographic map of the country on a relatively large scale (Ross 1932). This series was the workhorse of visual charts in the United States, remaining in print until the end of the century, although it was reduced to thirty-seven sheets printed back to back in the late 1960s as an economizing measure.

With the spread of general aviation, a number of commercial map publishers entered the field offering new and better products beginning in 1928. In Great Britain, Allweather Motor Maps Ltd. (later Raynoil Maps Ltd.), the Aviation Department of the Automobile Association, and Edward Stanford Ltd. introduced several techniques later adopted by government and military publishers. These included the "Michelin fold," a method for converting large areal maps into accordion-fold strip maps, and various processes for waterproofing maps to protect them from rain and oil and provide erasable writing surfaces for notations (Nicholson 1988, 10–11).

In the United States, the Rand McNally and Jeppesen Airway Manual companies introduced new map forms. Rand McNally's *Standard Indexed Map Series with Air Trails* (1928–36) provided a series of state maps that popularized the areal map and the Lambert conical projection. Rand McNally also issued a primer on the elements of air navigation by Thoburn C. Lyon (Bay 1955), which was later expanded and published by the USC&GS as *Practical Air Navigation and the Use of the Aeronautical Charts of the U.S. Coast and Geodetic Survey* (1935–72). Lyon's book introduced more than a million pilots to aeronautical charts.

Unable to compete with government and military resources, these firms soon abandoned the aviation market, with the exception of Jeppesen (after 1970, Jeppesen Sanderson Inc.). Jeppesen thrived because it pioneered two entirely new charts: an instrument enroute chart that improved point-to-point navigation, and an instrument approach chart that provided navigation into airports even during inclement weather. Designed specifically for radio navigation, these charts displayed only radio stations, radio frequencies, and airway directions and distances (fig. 13). Additionally, two-sided instrument

FIG. 12. DETAIL FROM *YELLOWSTONE PARK (W-3)*, DECEMBER 1940. Published in Washington, D.C. by the USC&GS, 1:500,000. The first modern aeronautical chart series combined visual and radio navigation with the introduction of the Civil Aeronautics Authority's innovative radio range stations that transmitted in Morse code the letters *A* (• —) and *N* (— •) along four courses, highlighted in pink tint, that guided pilots to their destination by means of an aural radio compass that served as a homing device.
Size of the entire original ca. 58.7 × 102.9 cm; size of the detail: ca. 16.2 × 33.5 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C.

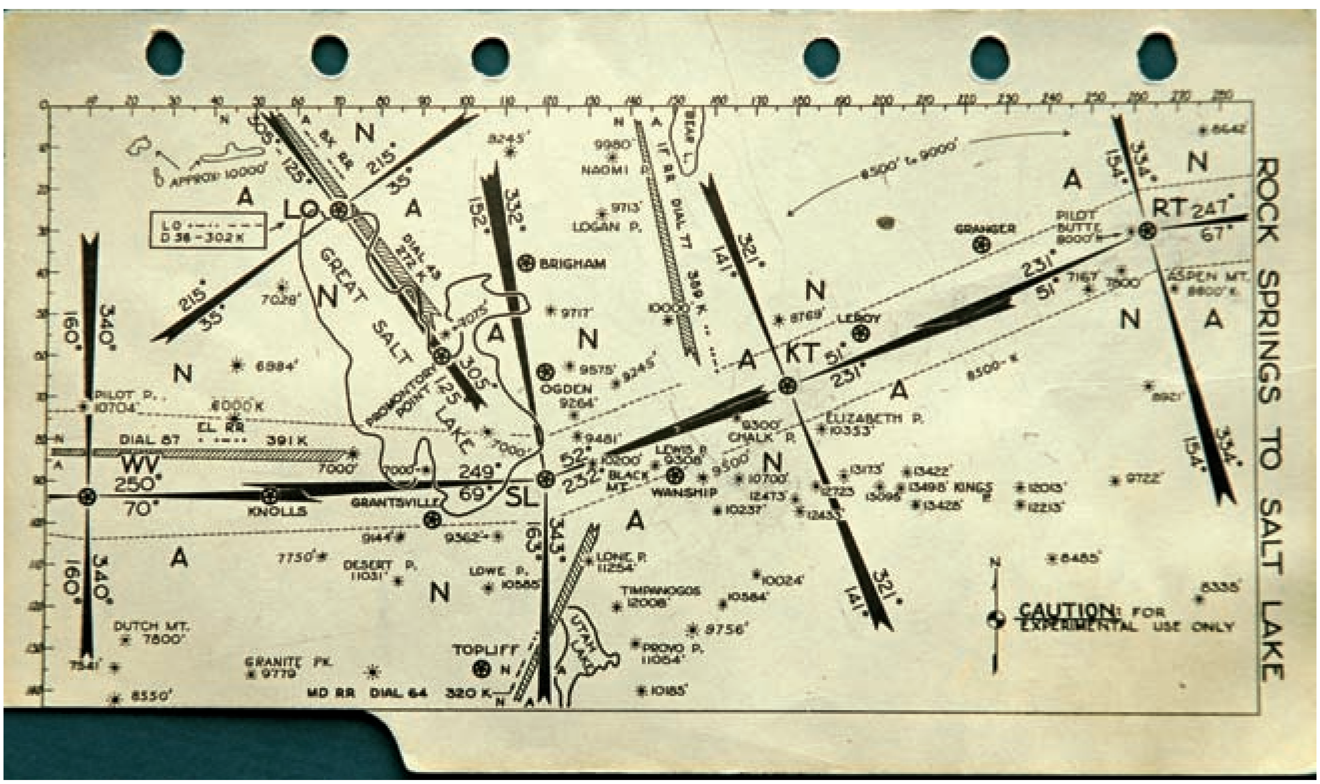

FIG. 13. *ROCK SPRINGS TO SALT LAKE*, BY ELREY B. JEPPESEN, CA. 1936. Published in Cheyenne, Wyoming, from Jeppesen Airway Manual, 1:2,500,000. Jeppesen, a United Airlines pilot, created the first instrument enroute charts, which revolutionized the way pilots navigated by replacing visual landmarks with radio signals that required flying by ear rather than eye.
Size of the original: 13 × 21 cm. Image courtesy of Ralph E. Ehrenberg. Permission courtesy of the Elrey B. Jeppesen Collection, Museum Archives, The Museum of Flight, Seattle.

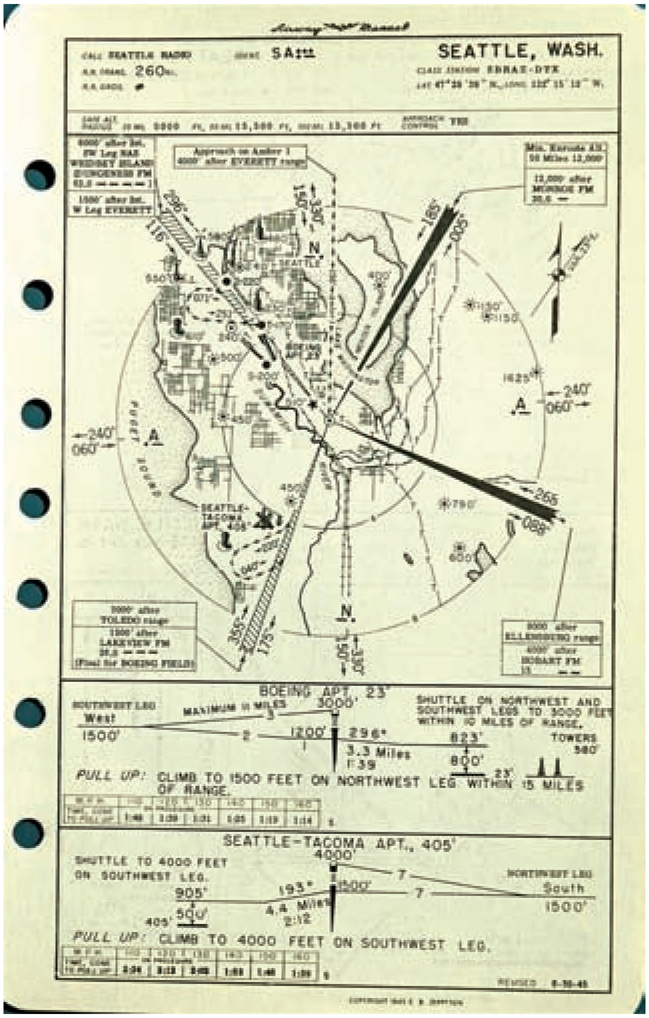

FIG. 14. *SEATTLE, WASH*[INGTON. APPROACH CHART] (PLAN VIEW), BY ELREY B. JEPPESEN, REVISED 30 AUGUST 1945. Published in Denver by Jeppesen and Company, 1:364,587. Representative of the approach charts, introduced by Jeppesen in about 1939, with a plan view of the navigation area in the vicinity of the airport centered on a radio range station and two schematic profile views that portray altitudes and magnetic courses to be flown during final let down.
Size of the original: 21 × 13 cm. Image courtesy of Ralph E. Ehrenberg. Permission courtesy of the Elrey B. Jeppesen Collection, Museum Archives, The Museum of Flight, Seattle.

approach charts (also called approach plates) included a vicinity map, an airport diagram, and a narrative step-by-step descent procedure. By 1939 the narrative was replaced by a schematic profile view of the descent symbolized by a heavy, solid black line that represented the flight track to be flown along with required altitudes and magnetic courses (fig. 14).

Jeppesen's instrument enroute charts (1934–) and approach charts (1936–) were eventually made available to pilots on a twenty-eight-day cycle. Sold on a subscription basis, they were designed for a loose-leaf handbook, titled *Airways Manual*, which encouraged easy updating. Terminal area charts were added after World War II (Rosenkrans 1978). By the end of the century, Jeppesen Sanderson, Inc., dominated the instrument chart industry with an 80 percent market share. More than 300,000 pilots and 400 commercial airlines were guided by "Jepps" (Katok, Tarantino, and Tiedeman 2001, 7).

World War II contributed significantly to the development of the aeronautical chart. GSGS and the newly established U.S. Army Map-Chart Division (later Aeronautical Chart and Information Center, or ACIC) developed a family of related aeronautical charts to meet the requirements of new aircraft that ranged from fast tactical fighters to long-range aircraft. While only a single chart was required for all phases of flight operations during the first decades of flying when planes took off, cruised, and landed at about the same relatively slow speed, five basic charts were developed for pilots and navigators during the war for flight planning, cruising, descent, approach, and landing and taxiing. Each category had a distinctive scale: planning/plotting (1:2,000,000–1:5,000,000), long-range enroute (1:3,000,000), visual enroute (1:500,000–1:1,000,000), local area (1:100,000–1:250,000), and terminal (vicinity, airport diagrams, and approach plates) (Burton 1953, 40–46; Harvatt 1969, 191–93).

Special new radio navigation charts of the hyperbolic type (Consol, Decca, Gee, and Loran) were developed to assist heavy bomber and transport navigators plot long-distance nonstop precision flights. They were overprinted on Mercator charts with curving blue, green, purple, and red lattice lines representing transmission stations. Consol and Loran plotting charts continued to guide transoceanic and desert flights until the 1970s, when navigators were replaced by computers (Steele 1998, 210–11; Kok 2005, 90).

International standards for aeronautical charts, an effort begun by Moedebeck and continued by the Paris-based International Commission on Air Navigation (ICAN, founded 1919), was put on firm footing during the war with the Convention on International Civil Aviation, established in 1944. Three years later the International Civil Aviation Organization (ICAO) was founded. As a United Nations agency established to foster international air transport and improve air navigation, the ICAO's major objectives included the standardization of scales, symbols, and formats for aeronautical charts. The first ICAO specification related to the basic set of visual charts introduced during the war, which were designed to allow easy transfer from one phase of flight to another. By 1995, ICAO specifications covered fifteen types of charts (Park 1956, 27–28; Steele 1998, 213) (fig. 15).

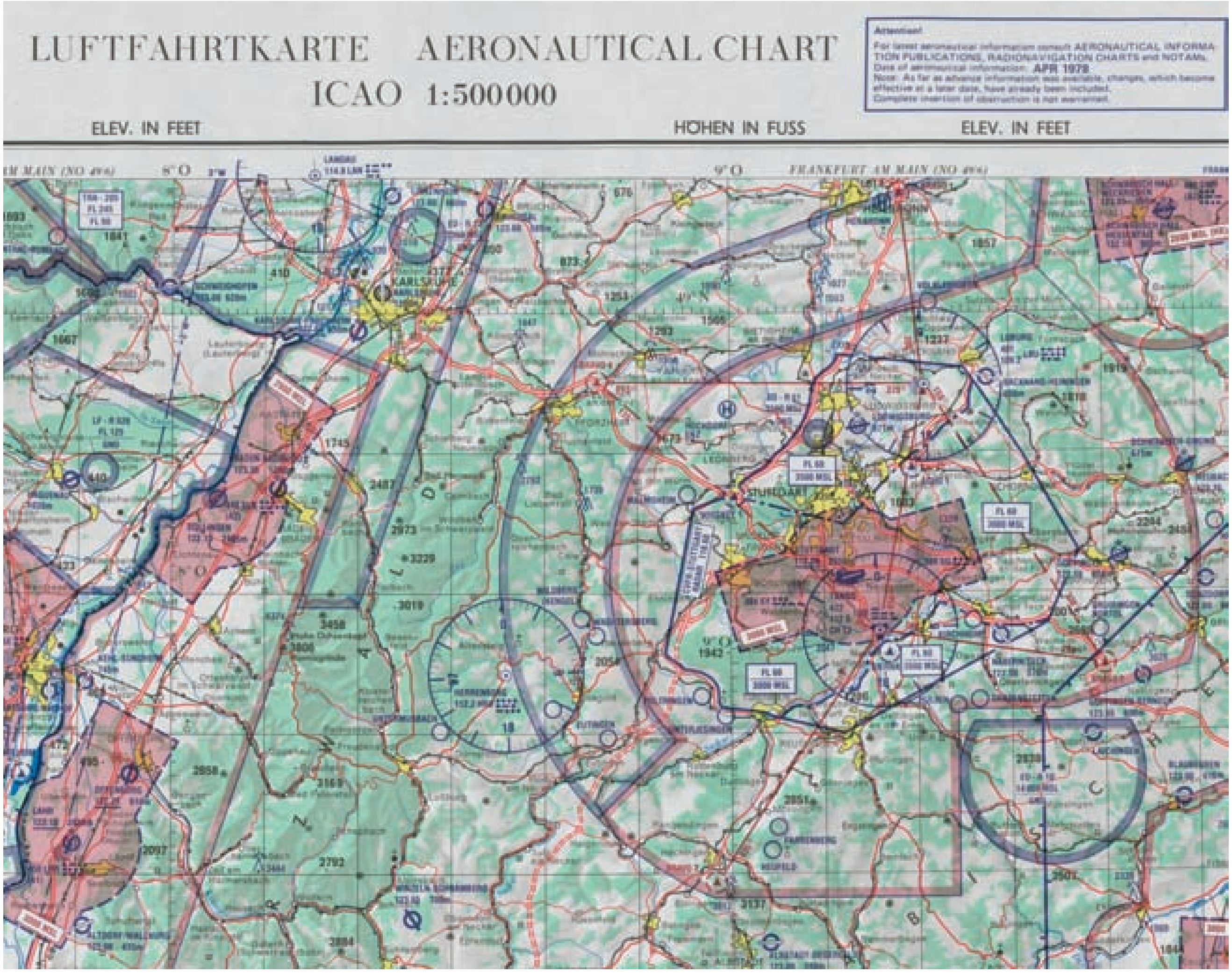

FIG. 15. DETAIL FROM THE INSTITUT FÜR ANGEWANDTE GEODÄSIE, *LUFTFAHRTKARTE AERONAUTICAL CHART ICAO 1:500,000, STUTTGART (NO 47/6)*, 15TH ED., MARCH 1978. Published in Frankfurt am Main by the Bundesanstalt für Flugsicherung. Title and detail of Germany's standard visual navigation chart with radio navigation facilities, air traffic controls (tinted blue and red), and airspace restrictions; produced according to standards issued by the International Civil Aviation Organization (ICAO). Size of the entire original: 60.4 × 86.5 cm; size of detail: ca. 25.4 × 32.2 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C. Permission courtesy of the DFS Deutsche Flugsicherung GmbH. In a standard disclaimer they advise that "it is prohibited to use the ICAO chart depicted in this book for flight guidance purposes. It is not suitable for navigating flights."

The United States was the only major country to emerge from the war with its commercial and military aviation industries stronger than when it began. Europe and Canada had suspended all nonmilitary flying, and most of Europe's and Asia's aircraft industries were destroyed. America's aeronautical chart producers were also strengthened. ACIC printed and distributed about 200 million aeronautical charts during the war, including 51 chart series and 7,500 different charts. Jeppesen benefited as well, compiling charts on contract for ACIC and the U.S. Hydrographic Office.

The development of new radio navigation aids and jet-powered aircraft in the 1950s once again altered the form and format of aeronautical charts. As very-high-frequency omnidirectional radio range stations (VOR), its military equivalent, tactical air navigation (VORTAC), and VOR airways (designated Victor airways) superseded the low-to-medium frequency radio range stations and airways, the traditional symbols associated with the latter were replaced with a complex system of compass roses and lines representing the new VOR stations and Victor airways. These airways, designated by the letter V, included information relating to minimum and maximum enroute altitudes, terrain clearances, mileage between facilities, and VOR radial and route bearings.

In response to high-performance jet aircraft, the U.S. Air Force (USAF) and U.S. Office of Naval Research carried out a series of analytical studies and pilot evaluations that led to the introduction of new charts such as the 1:1,000,000 Operational Navigation Chart (1958–) and the 1:2,000,000 Jet Navigation Chart (1953–). They used shaded relief, improved typefaces, and minimal details to provide quicker interpretation at faster speeds and higher altitudes and were printed in larger formats to reduce the number of sheets required for the greater flying distances (Ristow 1960, 41–43).

Aeronautical enroute charts were divided into low- and high-altitude enroute charts following the Federal Aviation Administration (FAA) decision in 1964 to control airspace by dividing air traffic into two categories in an effort to reduce costly flight delays and aircraft collisions. Flights below 18,000 feet mean sea level were thereafter controlled by visual flight rules (VFR), flights above by instrument flight rules (IFR). Subsequently, visual and instrument charts were referred to by these abbreviations. While VFR charts remained basically unchanged, the new IFR charts in the United States were now issued as low-altitude enroute charts and high-altitude enroute charts, with the latter limited to jet airways (fig. 16). Similar charts by military chartmakers and European commercial publishers followed. By the end of the century, most scheduled flights were made with IFR charts along routes controlled by radio and electronic navigation systems, which had made visual navigation unnecessary.

Changes also were made with terminal and approach charts following World War II. Working with the Civil Aeronautics Authority (later FAA), Jeppesen introduced standard instrument approach procedures (1947) and instrument landing system approach charts (1948), the first of a number of different types that appeared as new radio navigation facilities were developed.

Approach charts generally also served as departure procedure charts, but with the emergence of busy, complex airport hubs in the early 1970s, pilots and air controllers demanded that the FAA furnish written procedures for entering and leaving airways. In response to user comments, Jeppesen converted these narratives to graphic form with standard instrument departure charts (SIDs) and standard terminal arrival routes (STARs) (Terpstra 1975).

The jet age also induced cartographers to devise two types of cockpit moving-map displays. One was in the form of paper or translucent strip maps mounted on electrically driven rollers with a moving pointer that tracked the aircraft's ground position. It was used for navigating helicopters and jet airliners flying routes of a repetitive nature (figs. 17 and 18). The other display consisted of microfilm strip maps (35, 70, and 105 mm wide) sequentially driven by computers and optically projected on a display mounted on the instrument panel. It was used primarily for navigating fast, low-flying combat planes with advanced sensors and weapons systems (Guttmann 1965–66; Stringer 1984).

The foundation for a paperless cockpit was advanced with the development of digital technology, flightworthy cathode ray tube color displays, and liquid crystal displays that contributed to new electronic computation, storage, and display systems. Computer-generated moving map displays were introduced on the Boeing 767 and Airbus A 310 (1982–83), following pioneering work in France and the United States on ground simulators and demonstration flights in National Aeronautics and Space Administration's Boeing 737 flying laboratory. These displays depicted track and heading with respect to any selected route along with weather conditions for all phases of flight, from take-off to landing (Bernard 1983). Raster digital aeronautical charts were introduced in the mid-1980s, but their inferior quality

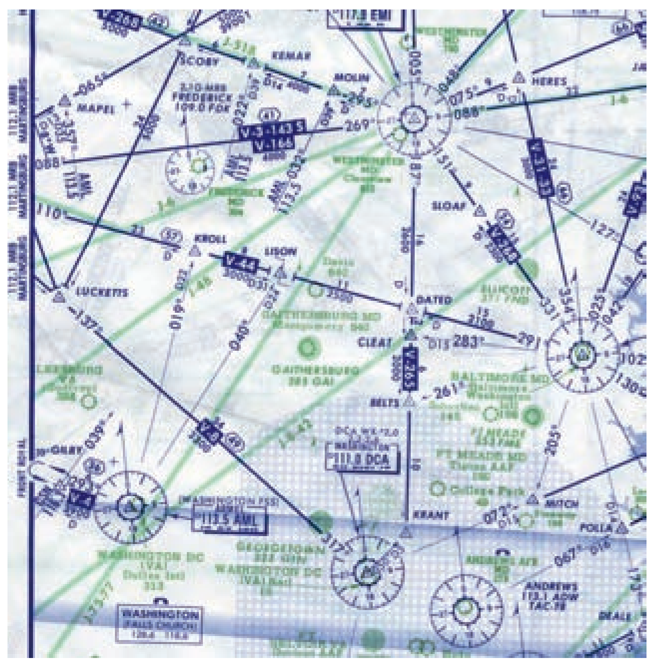

FIG. 16. DETAIL FROM *JEPCO AVIGATION UNITED STATES LOW ALTITUDE ENROUTE CHART U.S. (LO) 25*. Published in Denver by Jeppesen Sanderson, 1:729,134. Three-dimensional controlled airspace is portrayed on Jeppesen low altitude enroute charts, which display both blue-colored Victor airways (V), with distances and altitudes, and green-tinted high-altitude Jet airways (J), each linked by VORs symbolized by compass roses.
Size of the entire original: 42 × 81 cm; size of detail: ca. 9.9 × 9.8 cm. Image courtesy of Ralph E. Ehrenberg. Permission courtesy of the Elrey B. Jeppesen Collection, Museum Archives, The Museum of Flight, Seattle.

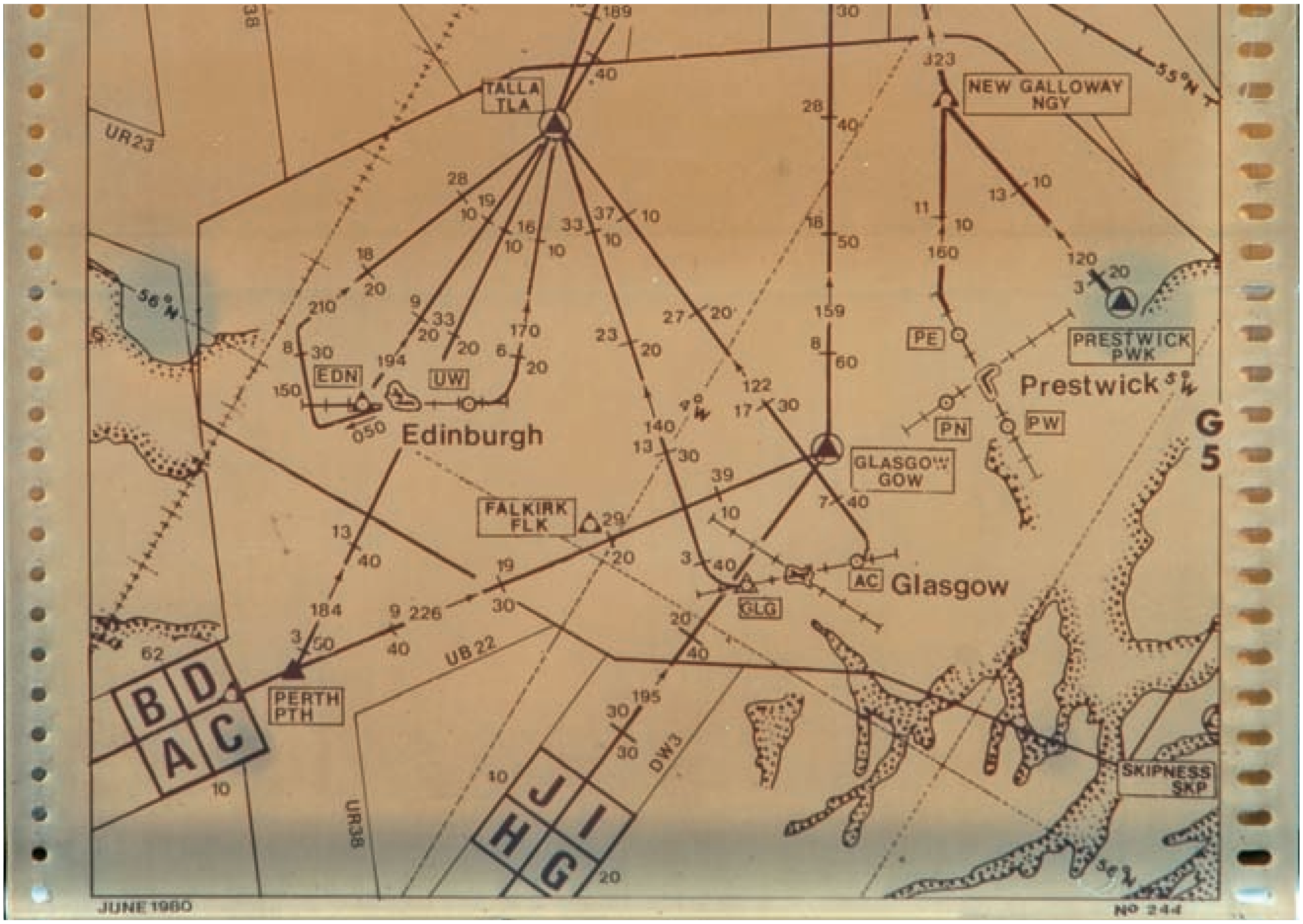

FIG. 17. DETAIL OF PICTORIAL DISPLAY CHART, DOPPLER/ROUTE LONDON-ABERDEEN-INVERNESS, ISSUE NO. 4, JUNE 1980, 1:546,855. Translucent spooled film base. Published in Chessington, Surrey, England by Racal-Decca Navigator Ltd., July 1980–April 1981.
Size of the entire original: 227 × 20 cm. Image courtesy of the Ralph E. Ehrenberg Collection.

continued to limit their in-flight usefulness through the end of the century (Ayliffe 1996). Following the military's release of its Global Positioning System (GPS) for civilian use and testing in 1993, handheld and panel-mounted moving map displays began to appear in aircraft cockpits during the latter half of the 1990s linking GPS position, velocity, and time with standard air navigation data (Clarke 1998, 142–44).

RALPH E. EHRENBERG

SEE ALSO: Airline Map; International Civil Aviation Organization; International Map of the World; Projections: Projections Used for Aeronautical Charts; Shelton, Hal; World Aeronautical Chart

BIBLIOGRAPHY:

Ayliffe, Alec. 1996. "Raster Digitized Mapping for the Royal Air Force." *Journal of Navigation* 49:143–53.

Bay, Helmuth. 1955. "Air Trails Maps: A Chapter in the Early History of Aeronautical Charts." *Surveying and Mapping* 15:322–24.

Bernard, Maurice. 1983. "New Display Systems for the Next Generation of Civil Aircraft." *Journal of Navigation* 36:379–87.

Burton, Alfred H. 1953. *Conquerors of the Airways: A Brief History of the USAF-ACIC and Aeronautical Charts*. St. Louis: United States Air Force, Aeronautical Chart and Information Center.

Clarke, Bill. 1998. *Aviator's Guide to GPS*. 3d ed. New York: McGraw-Hill.

Ehrenberg, Ralph E. 2006. "'Up in the Air in More Ways Than One': The Emergence of Aeronautical Charts in the United States." In *Cartographies of Travel and Navigation*, ed. James R. Akerman, 207–59. Chicago: University of Chicago Press.

Guttmann, Eric S. 1965–66. "Chart Logistics for Advanced System Requirements." *Navigation* 12:339–47.

Harvatt, B. E. 1969. "Aeronautical Charting in the United Kingdom—Past and Present." *Allgemeine Vermessungs-Nachrichten* 76, no. 5:187–97.

Katok, Elena, William Tarantino, and Ralph Tiedeman. 2001. "Improving Performance and Flexibility at Jeppesen: The World's Leading Aviation-Information Company." *Interfaces* 31, no. 1:7–29.

Kok, Hans. 2005. "Luchtvaartkaarten voor 'long-range navigation' in de periode 1940–1970." *Caert-Thresoor* 24, no. 3:84–92.

Nicholson, T. R. 1988. "An Introduction to the Ordnance Survey Aviation Maps of Britain, 1925–39." *Sheetlines* 23:5–18.

Park, James R. 1956. "Aeronautical Charts: The Role of the International Civil Aviation Organization in Cartography." *Canadian Surveyor* 13:27–35.

Ristow, Walter W. 1960. *Aviation Cartography: A Historico-bibliographic Study of Aeronautical Charts*. 2d ed., rev. and enl. Washington, D.C.: Map Division, Reference Department, Library of Congress.

FIG. 18. PICTORIAL DISPLAY CHART MOUNTED ON INSTRUMENT PANEL OF A RESTORED HAWKER SIDDELEY HS-121 TRIDENT 3B AIRCRAFT, MANCHESTER AIRPORT. An example of an interchangeable spool loaded moving map operating in conjunction with Decca Navigator, a hyperbolic radio navigation system of ground transmitting chains, by a pioneer of pictorial presentation of navigation data. Image courtesy of Neil Lomax.

Rosenkrans, W. A. 1978. "Aeronautical Chart Servicing." *Journal of Navigation* 31:39–51.

Ross, Raymond L. 1932. "The United States Sectional Airway Maps." *Military Engineer* 24:273–76.

Sebert, L. M. 1986. "Canada's First Aeronautical Charts and the Eight-Mile Map Series." *Cartographica* 23, no. 4:79–119.

Steele, Philip. 1998. "History of Air Maps and Charts." *Journal of Navigation* 51:203–15.

Stringer, F. S. 1984. "The Development of Flight Deck Displays." *Journal of Navigation* 37:217–31.

Terpstra, James E. 1975. "SIDS, STARS and Common Departures." *Flight Operations* 64, no. 9:40–44.

Woodhouse, Henry. 1917. "Aëronautical Maps and Aërial Transportation." *Geographical Review* 4:329–50.

Agricultural Adjustment Administration (U.S.). Established in 1933 as a New Deal effort to shore up farm income, the Agricultural Adjustment Administration (AAA) played an important role in the development of aerial photography in the United States. Eager for an efficient way to measure cropland area, the AAA hired out-of-work civil engineers in 1933 to compare photogrammetric and ground survey approaches. Satisfied with the results, it launched a systematic aerial survey project in 1937 (fig. 19), and secured photographic coverage of 90 percent of the nation's farmland by late 1941. Though intended for surveillance rather than mapping, the imagery became a valuable database for soil mapping, conservation, and land planning. In addition, the AAA trained numerous local officials in the proper use of air photos and demonstrated the value of aerial photography for public administration. The photogrammetric expertise and film-processing infrastructure developed within the AAA's parent agency, the U.S. Department of Agriculture (USDA), became a priceless resource for military planners during World War II.

Cropland area was a key element of national farm policy when the Franklin D. Roosevelt administration, which came to power in March 1933, sought to reverse the drastic decline in prices paid to farmers by reducing production. The initial strategy used a tax on processors of agricultural products to compensate growers who agreed to plant fewer acres. After the Supreme Court declared the tax unconstitutional in January 1936, the production-control program became a conservation program, with grants for improving tillage to reduce erosion and idling farmland to retain or restore soil productivity. Troubled by the devastating drought of 1936, Congress accepted soil conservation as a justifiable public expenditure. The Agricultural Adjustment Act of 1938, which authorized a price-support program with voluntary acreage allotments for corn, cotton, rice, tobacco, and wheat, required the USDA to estimate the likely size of the year's harvest at the local level and to apportion national quotas back to states, counties, and individual farms.

Whatever the source of funds, program goals and public confidence required a systematic effort to monitor compliance. To promote participation and ensure performance, the AAA adopted a hierarchical strategy that included five regional divisions for oversight and technical support, statewide agricultural committees with advisory and supervisory roles, county committees for confirming performance and authorizing payment to individual farmers, and township committees to help farmers fill out forms and help the county committee verify claims. Field inspectors visited individual farms with photos in hand and marked field boundaries and the type of crop planted. Officials in the county or state office then used planimeters to estimate field size and tabulated acreage by crop type for each farm.

Although aerial measurement was less expensive than ground-traverse surveys, AAA photogrammetrists were wary of inaccuracies resulting from tilt and relief. Regions developed their own guidelines, described in manuals outlining procedures for calculating correction factors from corresponding lengths measured on the ground and photo, and dividing each photo into zones requiring a common correction factor. To further improve accuracy, planimeter operators used prints enlarged from the negatives' nominal scale of 1:20,000 to approximately 1:7,920 (one inch representing 1/8 mile). Although error

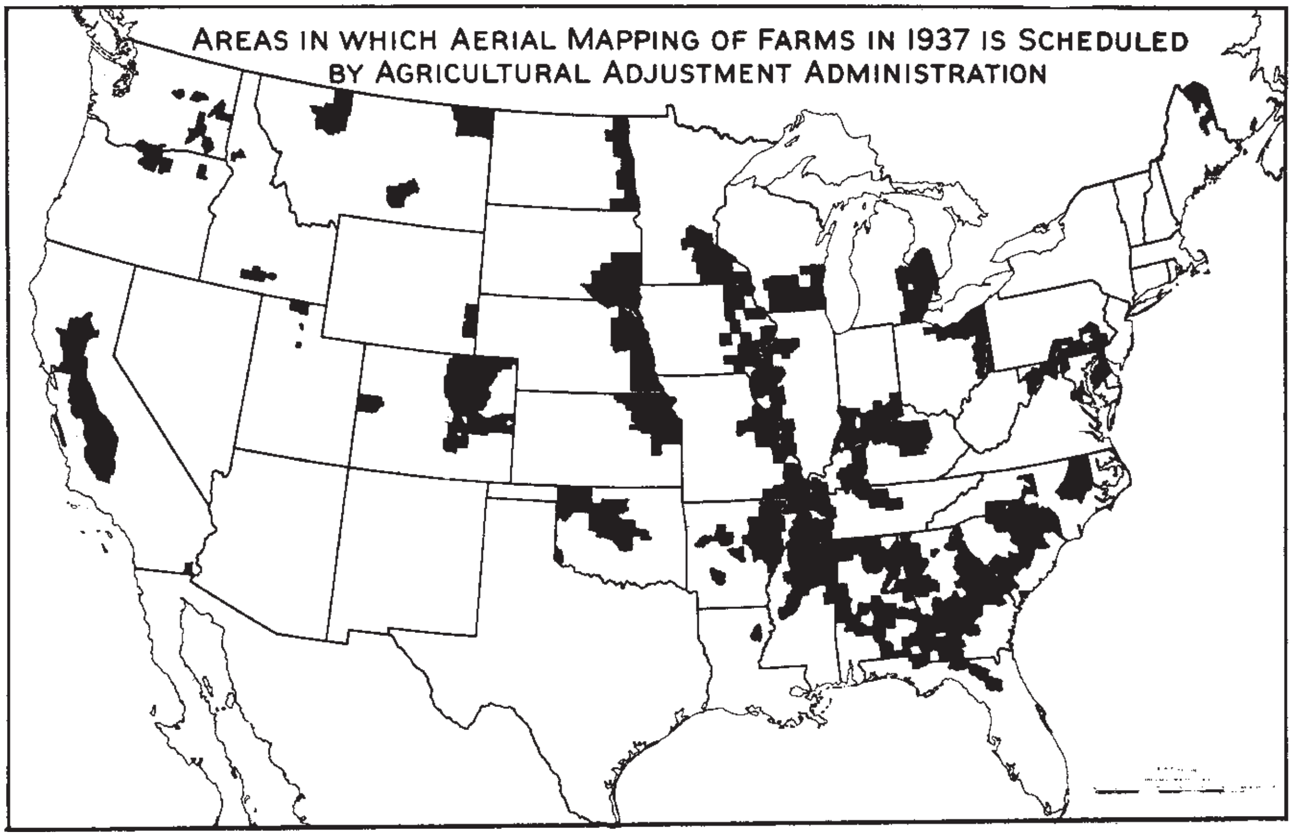

FIG. 19. *AREAS IN WHICH AERIAL MAPPING OF FARMS IN 1937 IS SCHEDULED BY AGRICULTURAL ADJUSTMENT ADMINISTRATION.* In its initial year the AAA's aerial compliance mapping project focused on some of the nation's most productive farmland.

Size of the original: 10.4 × 16.2 cm. From Tubis 1937, 22. Copyright by the American Society for Photogrammetry and Remote Sensing.

was unavoidable, zoned correction factors were believed to provide estimates accurate to within 1 or 2 percent of the true acreage.

MARK MONMONIER

SEE ALSO: Administrative Cartography; Biogeography and Cartography; Cartometry; Photogrammetric Mapping: Air Photos and Geographic Analysis; Soils Map

BIBLIOGRAPHY:

Blaisdell, Donald C. 1940. *Government and Agriculture: The Growth of Federal Farm Aid*. New York: Farrar and Rinehart.

Coblentz, C. S. 1939. "Restitution of Aerial Enlargements for Area Determination." *Photogrammetric Engineering* 5:138–46.

Monmonier, Mark. 2002. "Aerial Photography at the Agricultural Adjustment Administration: Acreage Controls, Conservation Benefits, and Overhead Surveillance in the 1930s." *Photogrammetric Engineering & Remote Sensing* 68:1257–61.

Tubis, Harry. 1937. "Aerial Photography Maps Our Farmlands: The Program of the Agricultural Adjustment Administration." *Photogrammetric Engineering* 3, no. 2:21–23.

Air-Age Globalism. The 1940s witnessed a revolution in the way the world was visually imagined and graphically represented. World War II, unlike its predecessor, was conducted in what U.S. President Franklin D. Roosevelt described as "a world-wide arena, an arena that may become so narrowed that only the Americas will retain the ancient faiths" (quoted in Henrikson 2008, 35). The battlefield of World War II had a new aerial dimension, and the airplane gave American ideas transcendence, both physical and metaphysical. Air-age globalism thus had ideological content as well as geographical bearing. The primal event was the 7 December 1941 Japanese attack on Pearl Harbor, a disorienting shock that permitted the formation of a wholly new geographical and also political outlook.

A key factor in this revolution was the development of a new cartography to complement, and to clarify, the "new geography" that came into fashion during the war years (Henrikson 1975, esp. 22–23; Schulten 2001, 204–38). To create a restructured worldview was not the conscious purpose of most World War II cartographers, who sought only to produce maps that were more accurate, comprehensive, and useful. There was

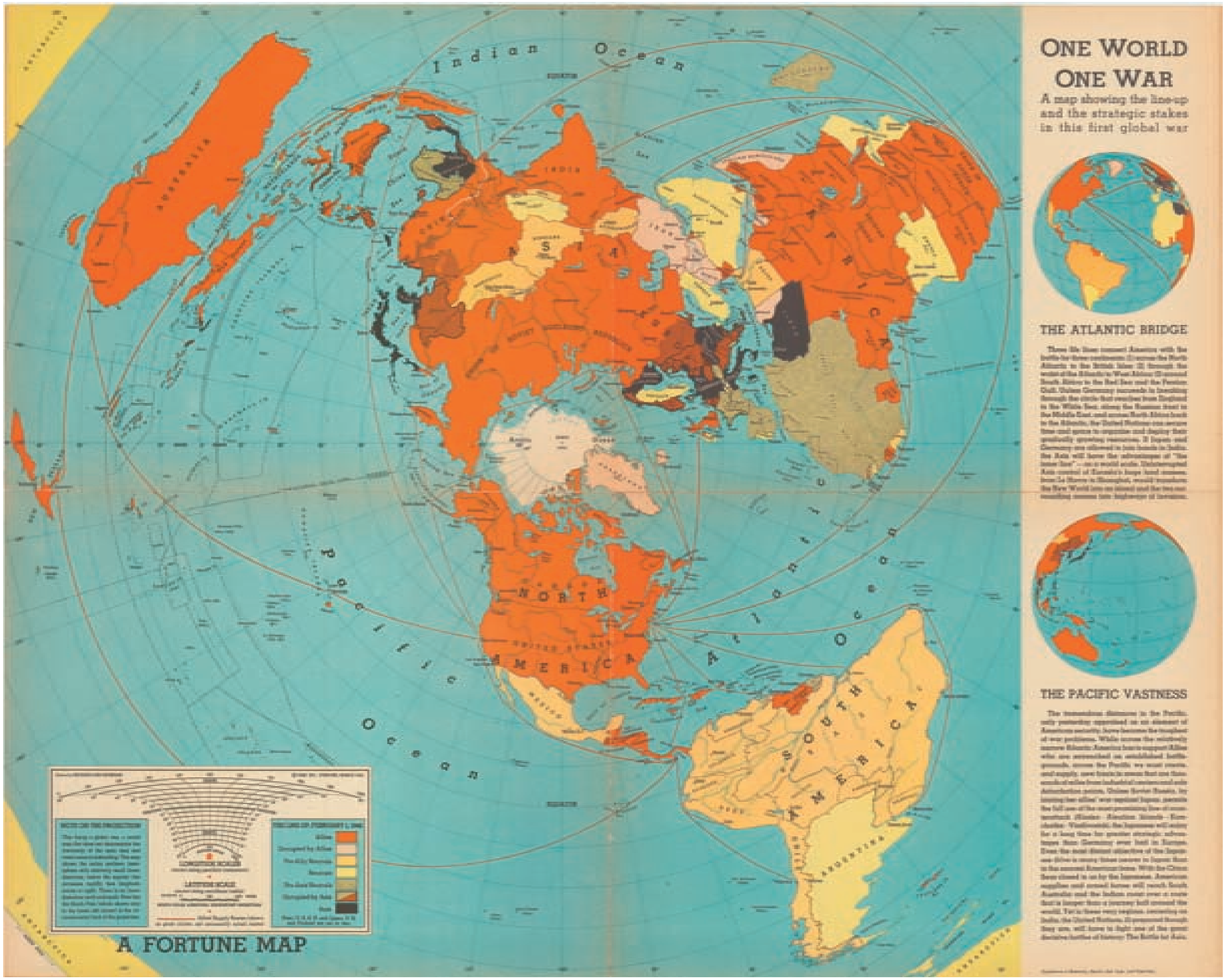

FIG. 20. *ONE WORLD, ONE WAR*, POLAR AZIMUTHAL EQUIDISTANT PROJECTION. Size of the original: 54 × 67.8 cm. From *Fortune* 25 (March 1942), map insert.

for some, however, a more general goal. Erwin Raisz, lecturer in cartography at Harvard University, sought to show what was on the "geographic landscape" (Raisz 1944, 8). In a similar vein, the aim of the scientific illustrator–turned–professional cartographer Richard Edes Harrison was to impart "the geographical sense," or a more "flexible" awareness of global relationships, by presenting the earth on a variety of map grids and from many different angles and elevations (Harrison 1944, 10–12) (fig. 20).

Despite their emphasis on the agility of the visual imagination and the need for a multi-map perspective that avoided a fixed outlook, Harrison and the other new geographers and cartographers of World War II shared a definite substantive conception of the world. They were in fact, if not admittedly, holders of a special vision, a view of the earth and its surrounding space that may conveniently be called air-age globalism.

First and foremost, the earth was recognized as round. *Recognized* is used here deliberately because air-age globalists sometimes implied that they were simply acknowledging the full implications of a truth that had once been known, but had been effectively forgotten. "If you look through a good collection of old maps," wrote the explorer Vilhjalmur Stefansson, "you learn it is only during the last hundred years, approximately since 1850, that Europeans, and their intellectual cousins the Americans, have been thinking of the earth as if it were flat, from which have come such strange ideas as that the nearest way to China from the United States is west, that it is logical to fly the Pacific on your way to China, and that places like the Hawaiian Islands lie on a nearly direct road between the two countries" (Stefansson 1944, 229).

The source of these misapprehensions, it was commonly asserted, was the Mercator projection—a cylindrical projection with its line of tangency conventionally at the equator. Mercator's was the world of sea power—that of Admiral A. T. Mahan. In order to avoid the strategic fallacies of the flat-earth "Mercator mind," Americans sometimes were advised during the war to give up looking at flat maps altogether and instead to contemplate their household globes, using pieces of string rather than rulers for measuring distance and finding direction. Among the few wartime planners with access to a globe large enough actually to plot strategy and to prescribe boundaries was President Roosevelt. As commander-in-chief of the U.S. armed forces, he was given as a Christmas present in 1942 a huge fifty-inch globe, the largest detailed military globe ever made (fig. 21).

FIG. 21. FRANKLIN D. ROOSEVELT AND THE PRESIDENT'S GLOBE. Manufactured by the Weber Costello Company under the supervision of the Map Division of the Office of Strategic Services and the War Department, and presented by General George C. Marshall in 1942.
Permission courtesy of the Franklin D. Roosevelt Presidential Library and Museum, Hyde Park, New York.

As people extended their ken around the spherical earth, they gradually came to a new awareness of the world's continuity and unity—a second characteristic of air-age globalism. There were preexisting intellectual foundations for this quasi-visual conception: the older liberal doctrine of economic interdependence and the newer political notion of the indivisibility of peace. "When I say that peace must be planned on a world basis," explained Wendell L. Willkie in *One World*, his widely read report on a 1942 round-the-world trip, "I mean quite literally that it must embrace the earth. Continents and oceans are plainly only parts of a whole, seen, as I have seen them, from the air" (Willkie 1943, 203).

Willkie's world image was actually a transitional one, halfway between the older land-sea dualism and a newer air monism, which was a third feature of air-age globalism. The idea of earth as surrounded by a navigable ocean of air was startlingly illustrated by "air maps" on which all topographical features and political boundaries were left out, leaving only points representing major cities with airports with present and future route-lines drawn between them (Raisz 1944, 22–23). Even an "air globe" appeared. From the design of an air map used by American Airlines in its newspaper advertisements, Rand McNally created a twelve-inch globe, entirely featureless except for landing spots. More realistic were quasi-photographic perspective maps, in which a finite extraterrestrial point of view was taken. Richard Edes Harrison superbly prepared a dramatic set of perspective maps, with distinctive curved-horizon edges and bright naturalistic colors, which were collected in *Look at the World*, a cartographic landmark (Harrison 1944). The U.S. military used Harrison's maps in training pilots and helping others to visualize parts of the world they had never seen and otherwise could only imagine. *A War Atlas for Americans*, prepared by the Office of War Information, included vivid, topographically highlighted perspective maps executed by a team of cartographers (Council on Books in Wartime 1944).

A fourth, closely related characteristic of air-age globalism was the "shrinkage" of the earth owing to increasingly rapid air transport and travel. Thinking in ordinary mileage terms was "all right in a two-dimensional world of length and breadth," allowed N. L. Engelhardt, a geographer at Columbia University's Teachers College, "but in a Global World that has shrunk so much under the impact of the Air Age, we must think in terms of the third dimension of height and the fourth dimension of time" (Engelhardt 1943, 128). Because less time was required to traverse the earth, air-age logic ran, the world itself was smaller. One of Engelhardt's illustrations, a typical if extreme case of time-factor compression, was a drawing showing the earth resting in the palm of a hand (25).

A fifth and perhaps the most distinctive feature of air-age globalism was polar centrism. The Northern Hemisphere, the convex arena in which most of the globe-sweeping spectacle of World War II's battles took place, could best be viewed from the vantage of the Arctic. Thus it became increasingly fashionable in the years after Pearl Harbor to center world maps at the North Pole. The type of map changed as well as its focus. To air-age globalists the most generally satisfactory map was the azimuthal equidistant projection, not only because it could display the whole world continuously but also because from the center (the North Pole) it alone shows both true direction and accurate (as well as shortest) distance. A defect is that its scaling system enlarges the periphery and makes the central portion—the Arctic zone—appear smaller than it actually is, thus always favoring northerly routes.

As an emblem of the air age, the North Pole–centered world map was a powerful symbol. The new United Nations organization used a Harrison polar map on an azimuthal equidistant projection as the base-pattern for its flag, on which no political boundaries are shown (fig. 22). Some economically oriented strategists thought that the circumpolar military air routes of wartime could become transpolar commercial routes in peacetime, envisioning the Arctic area as a new "World Mediterranean." Others, such as the Russian-born U.S. aircraft designer Alexander P. De Seversky, saw mostly danger coming from the North. Between the expanding spheres of U.S. and Soviet air dominance, there was a vast area of overlap, an "aerial no-man's land" of strategy indeterminacy (De Seversky 1950, 108–11 [see fig. 331]). In truth, as these very different visions indicate, the ideology of air-age globalism never completely coalesced.

FIG. 22. OFFICIAL FLAG OF THE UNITED NATIONS. Adopted by resolution of the UN General Assembly on 20 October 1947.
Image courtesy of the Cartographic Section, Dag Hammarskjöld Library, United Nations, New York.

The role of cartography in anticipating and framing the issues of a more globalized human future, however, was a historic achievement.

ALAN K. HENRIKSON

SEE ALSO: Geopolitics and Cartography; Harrison, Richard Edes; Journalistic Cartography

BIBLIOGRAPHY:
Council on Books in Wartime. 1944. *A War Atlas for Americans*. Foreword by Elmer Davis. New York: Simon and Schuster.
De Seversky, Alexander P. 1950. *Air Power: Key to Survival*. New York: Simon and Schuster.
Engelhardt, N. L. 1943. *Toward New Frontiers of Our Global World*. New York: Noble and Noble.
Harrison, Richard Edes. 1944. *Look at the World: The Fortune Atlas for World Strategy*. New York: Alfred A. Knopf.
Henrikson, Alan K. 1975. "The Map as an 'Idea': The Role of Cartographic Imagery during the Second World War." *American Cartographer* 2:19–53.
———. 2008. "FDR and the 'World-Wide Arena.'" In *FDR's World: War, Peace, and Legacies*, ed. David B. Woolner, Warren F. Kimball, and David Reynolds, 35–61. New York: Palgrave Macmillan.
Raisz, Erwin. 1944. *Atlas of Global Geography*. New York: Global Press.
Robinson, Arthur H. 1997. "The President's Globe." *Imago Mundi* 49:143–52.
Schulten, Susan. 2001. *The Geographical Imagination in America, 1880–1950*. Chicago: University of Chicago Press.
Stefansson, Vilhjalmur. 1944. "The North American Arctic." In *Compass of the World: A Symposium on Political Geography*, ed. Hans W. Weigert and Vilhjalmur Stefansson, maps by Richard Edes Harrison, 215–65. New York: Macmillan.
Willkie, Wendell L. 1943. *One World*. New York: Simon and Schuster.

Airbrush. Invented in 1879, the airbrush is a handheld spray gun about the size of a thick pen used to spray atomized liquid pigments smoothly and with high precision. Its popularity peaked during the mid to late twentieth century, before the advent of the digital era. Common uses of the airbrush were to retouch photographs, create glossy commercial art, and, to a lesser extent, to draw shaded relief and other continuous tone map art. Few cartographers use airbrushes today.

An airbrush works by passing a stream of compressed air through an elongated barrel where it mixes with pigments, typically held in a small, cuplike reservoir. In better models a dual-action trigger on top of the barrel, operated by the index finger, controls the mixture of air and pigment. Air enters through the underside of the barrel via a thin rubber hose connected to either an electric air compressor or a can of compressed air. Pushing the trigger down releases a stream of air; pulling it slowly back retracts a needle with a fine point from the nozzle of the barrel, increasing the amount of ink entering the air stream. Depending on the model, airbrushes can deliver a swath of pigment ranging in width from a hairline to several inches. To reduce the likelihood of clogging, pigments of choice are watery ink and paint (Price 2001).

At the end of the twentieth century the dozen remaining manufacturers of airbrushes included Paasche, Iwata, and Badger; the Paasche AB was the model favored by top shaded relief artists a generation earlier. Learning how to use an airbrush takes much time and practice. It is a temperamental instrument prone to clogging and splattering without warning, and it requires constant cleaning.

During the twentieth century shaded relief created by airbrushing was usually monochromatic and had a soft, generalized appearance (Imhof 1982, 198–99) (fig. 23). To maintain tight registration between the relief art and other map elements such as drainage, cartographers would airbrush on drafting film and other stable-base media. Using a contour map lightly printed on the media surface as a guide, the shaded relief was drawn by applying light transparent tones with multiple strokes of the airbrush. Eventually the shaded relief increased in density and took final form. Finally, to remove the underlying contours, the cartographer would use mild bleach that did not harm the relief art, or, in later reproduction steps, photographic filtering. In addition to shaded relief, other map elements made with airbrush included coastal vignettes, flow arrows, lowland tones, and landcover colors. During the 1950s and 1960s, U.S. cartographer Hal Shelton used an airbrush in splatter mode to speckle his maps with green ink to simulate forest textures (Patterson and Kelso 2004).

The airbrushing technique lives on in digital form. Raster graphical software, such as Adobe Photoshop and Corel Painter, and drawing tablets, like those made by Wacom, permit cartographers to enhance digital shaded relief by hand and add artistic flourishes to maps. The process and results are remarkably similar to traditional airbrushing—without the cleanup.

TOM PATTERSON

SEE ALSO: Drafting of Maps: Drawing Instruments; Imhof, Eduard; Relief Depiction; Shelton, Hal; Tanaka, Kitirō; Terrain Analysis and Cartography; Topographic Map

BIBLIOGRAPHY:

Imhof, Eduard. 1982. *Cartographic Relief Presentation*. Ed. Henry J. Steward. Berlin: Walter de Gruyter.

Patterson, Tom, and Nathaniel Vaughn Kelso. 2004. "Hal Shelton Revisited: Designing and Producing Natural-Color Maps with Satellite Land Cover Data." *Cartographic Perspectives* 47:28–55.

Price, Wendy. 2001. "Relief Presentation: Manual Airbrushing Combined with Computer Technology." *Cartographic Journal* 38:107–12.

FIG. 23. AIRBRUSHED SHADED RELIEF CENTERED ON YOSEMITE VALLEY, CALIFORNIA. By Bill Vonallmen, U.S. National Park Service.
Image courtesy of Tom Patterson.

Airline Map. An airline map is a medium- to small-scale geographical map that depicts airline routes, route networks, or airport destinations (Gartner and Popp 1995). Five major types of airline maps evolved during the course of the twentieth century to promote airlines and commercial aviation, aid in flight planning and scheduling, and provide in-flight entertainment. These types have straightforward descriptive names: timetable maps, souvenir maps, in-flight magazine maps, in-flight tracking charts, and dynamic electronic maps.

Timetable and souvenir maps generally formed part of the complimentary flight packets that major airlines distributed to passengers from the beginning of air travel in Europe following World War I until the 1970s (Gardner 1927). Timetable maps are small-scale route network maps that depict all routes and airport destinations comprising an airline's route system. Initially patterned after maritime and railroad timetables, they ranged from simple outline maps printed on timetable covers—a common practice among start-up airlines—

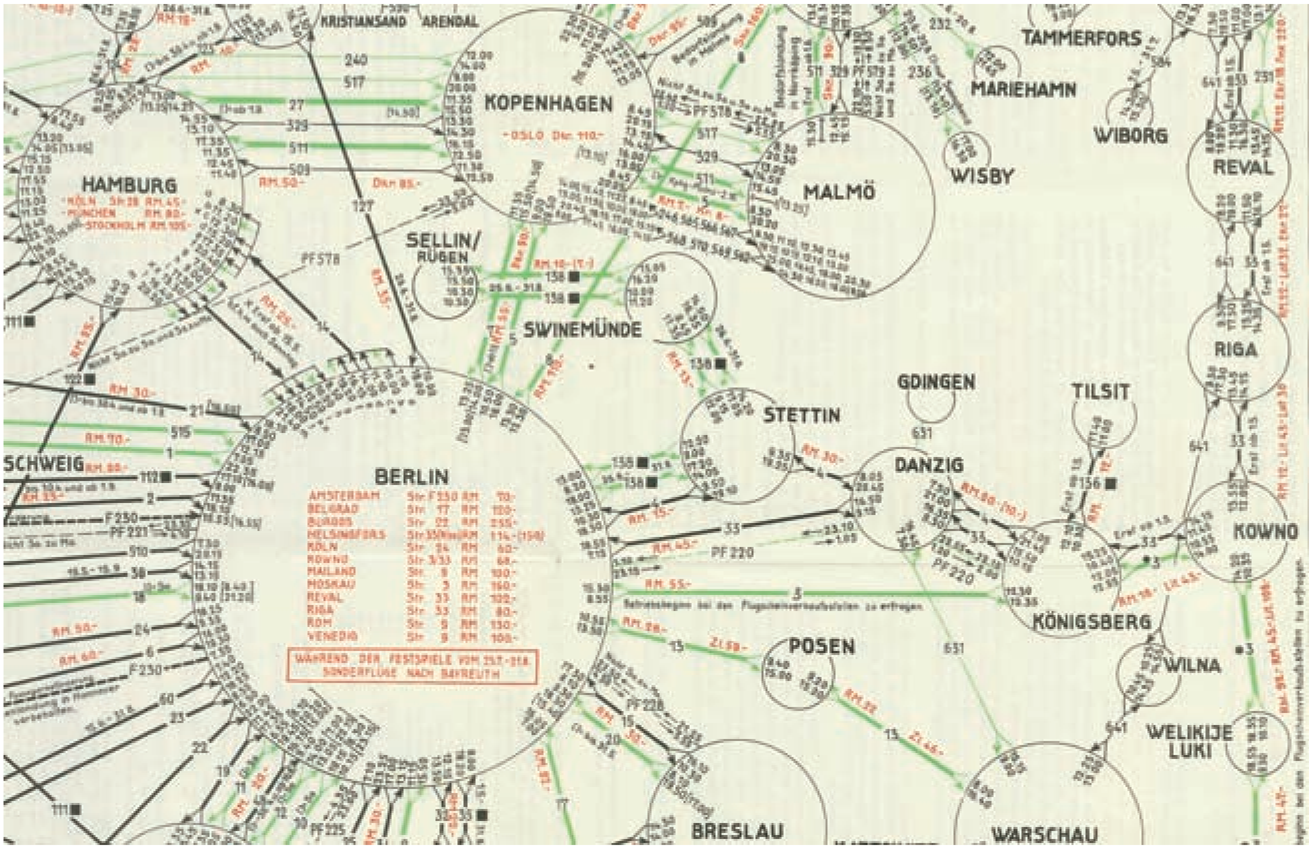

FIG. 24. DETAIL FROM THE *DEUTSCHE LUFTHANSA A.G. SOMMERFLUGPLAN*, FROM 4 APRIL TO 2 OCTOBER 1937. Berlin, 1937. During the first half of the twentieth century, diagrammatic timetable maps, such as this one of Europe and North Africa, were used to provide detailed airline arrival and departure information in graphic form.
Size of the entire original: 59 × 84 cm; size of detail: 22 × 34.2 cm. Image courtesy of the Ralph E. Ehrenberg Collection.

to complex double-page world maps keyed to locator maps. Variants of this genre included schematic maps with flight routes depicted as straight or curved lines without geographical boundaries and detailed diagrammatic maps that displayed departure and arrival times between airports in graphic form, the latter issued primarily by Central European, South African, and Chinese airlines through the 1950s (fig. 24).

The earliest souvenir maps were generally formatted as linear strips in the tradition of historic strip format travel maps or contemporary World War I air navigation strip charts, with the flight route depicted by a bold line within a narrow band of geographical and aeronautical information (fig. 25). These strip maps were issued as foldout pocket maps that ranged up to three meters in length, as page-size maps in booklets, and as insets on large-format route network maps. Pocket strip maps were universally popular in North America until the early 1930s and in Europe until the 1950s. Map booklets and large-format maps, similar in design and layout to American oil-company road maps, were favored by American carriers and their map publishers between 1933 and 1947, notably General Drafting, H. M. Gousha, and Rand McNally, following the establishment of a national transcontinental route system too extensive for coverage by individual strip maps.

Strip maps issued during this period generally displayed sufficient cultural and topographic information for passengers to locate their position during flight, since they were designed initially for the relatively slow-flying, low-altitude aircraft of the interwar years, when air travel was still a novelty and identifying points of interest on the ground was one of its great pleasures (Anonymous 1930). The inclusion of narrative itineraries and insets of aerial photographs and sketches of landmarks aided this process. Additional information relating to flight procedures, aircraft reliability, and navigation aids was typically included with booklets and network maps to promote safety and a sense of competence as well as reassure passengers timid about flying.

In the two decades following World War II the look of souvenir and timetable maps changed, as major airlines extended their routes worldwide, and the combination of long-haul aircraft, pressurized passenger cabins, radar, and the jet engine dramatically reduced barriers of time and distance (Bilstein 1995). The strip map was replaced by network maps based on air-age map projections popularized during the war. In the immediate postwar years, airlines and their map publishers used oval and orthographic world network maps to convey the impression of aviation's global reach. Richard Edes Harrison, for example, chose an oval projection to display Pan American World Airways' extensive route structure on a timetable map in use from 1947 through 1950. Northwest Orient Airlines pioneered great circle flight routes linking major European, North American, and East Asian cities in 1947, and the maps that followed introduced a generation of airline passengers to gnomonic, Lambert conformal conic, and polar azimuthal projections (fig. 26).

Map content became more generalized as aircraft speeds and flight ceilings progressively increased, carrying air travelers at velocities and altitudes that impeded the identification of particular landmarks. Cartographic artists Vahe Kirishjian (American Airlines, ca. 1952–56), F. H. Reitz (British Overseas Airways Corporation, ca. 1954–69), and Hal Shelton were at the forefront of developing more realistic images of the earth's surface for this new air age. Shelton set the standard in 1949 with a United Airlines network map that he developed in booklet form for the Jeppesen company (fig. 27). The world's leading producer of instrument flight charts, Jeppesen entered the airline souvenir map market with this publication. Shelton's unique "natural color" system blended colors and physiographic features to portray the dominant types of vegetation as they appear from space (Patterson and Kelso 2004). Shelton and Jeppesen dominated the American airline map market for nearly three decades with about twenty airlines under contract. Many competing airline map publishers also adopted Shelton's style of relief shading.

The most productive period of souvenir map output coincided with the first jet age (1958–70), a period of rising personal wealth, extended leisure time, and unprecedented increases in air passenger volume. Nearly one hundred national, regional, and international air-

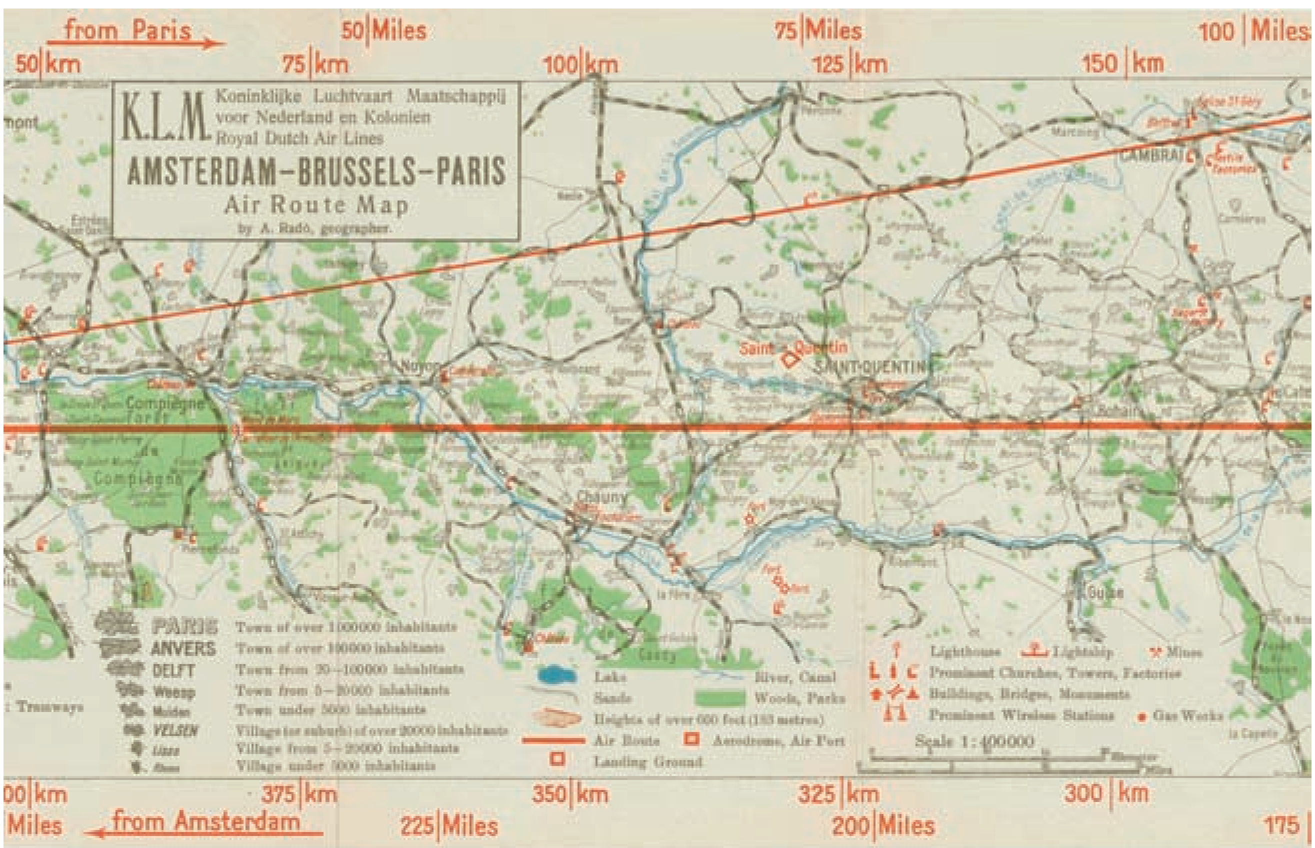

FIG. 25. DETAIL FROM *K.L.M. AMSTERDAM-BRUSSELS-PARIS AIR ROUTE MAP*, 1:400,000, BY SÁNDOR (ALEXANDER) RADÓ, CA. 1928. Glogau: Geograph. Institut Carl Flemming & C. T. Wiskott AG. Radó formatted this early souvenir route map in the style of contemporary air navigation strip charts and highlighted prominent landmarks in red to inform and entertain air travelers.
Size of the entire original: 18 × 119 cm; size of detail: 18 × 28.2 cm. Image courtesy of the Ralph E. Ehrenberg Collection.

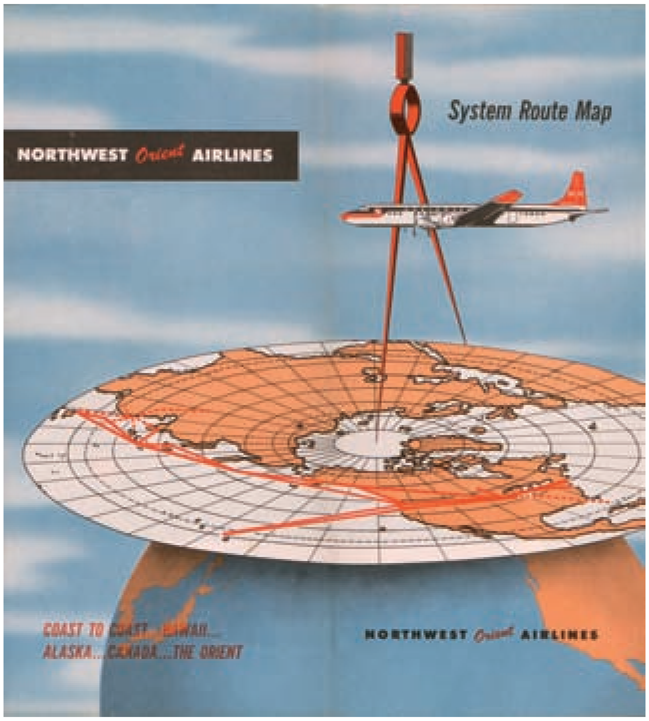

FIG. 26. DECORATIVE COVER FROM NORTHWEST ORIENT AIRLINES SOUVENIR BOOKLET, *SYSTEM ROUTE MAP*, 1956. Chicago: Rand McNally. Following the introduction of new long-haul aircraft after World War II like the Boeing 377 Stratocruiser that shattered age-old barriers of time and distance, cartographers adopted air-age map projections such as the polar azimuthal to display the great circle routes. Size of the original: 22.8 × 20.6 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C. Map © Rand McNally; R.L. 11-S-001.

lines issued maps during this period, often with frequent revisions. For example, Scandinavian Airlines issued a regional series of network route maps for five years, starting in 1960 (fig. 28), and the bilingual booklet, *Air France: Itinéraires long-courriers = Long-Distance Flights*, with as many as seventeen double-page regional route maps, was in print for nine years (1969–77). Print runs of 500,000 were not uncommon. Shelton's popular United Airlines map series averaged 1.3 million maps issued yearly from 1959 to 1970, with a high of 2.5 million maps distributed in 1967.

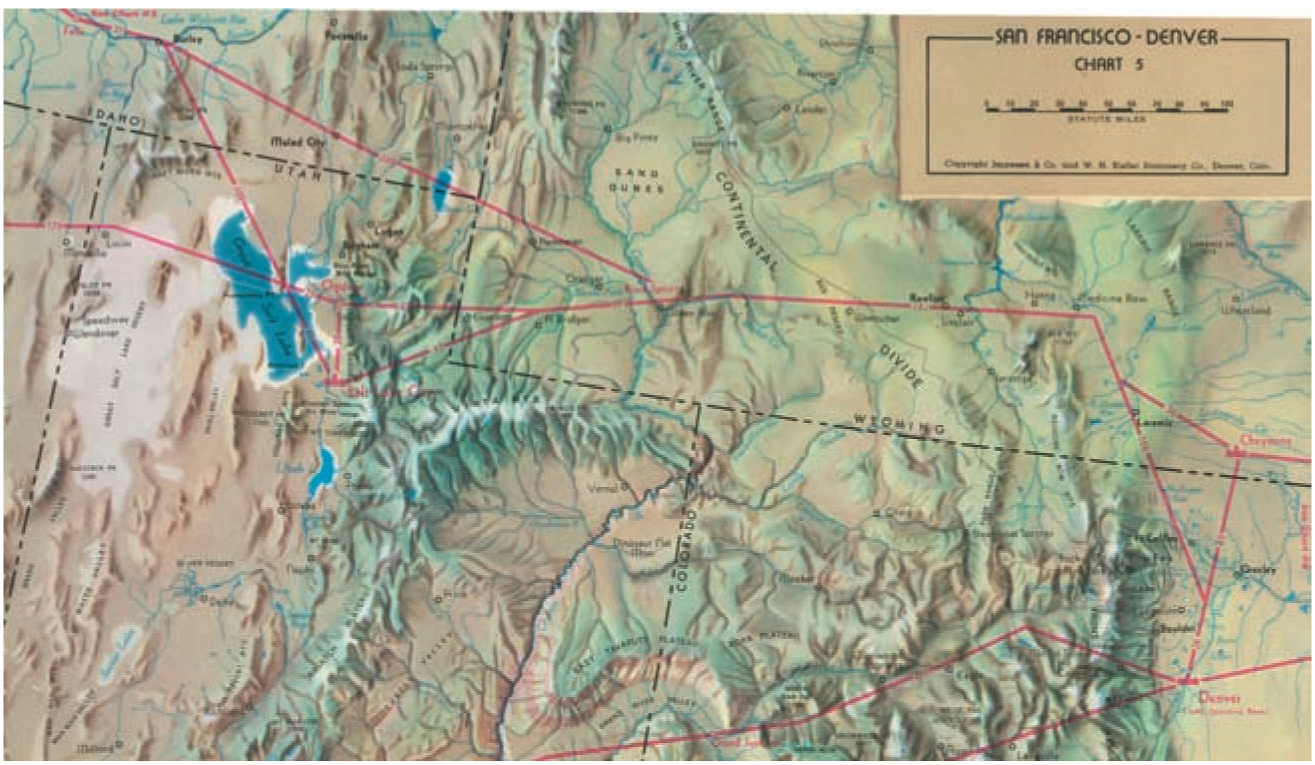

FIG. 27. HAL SHELTON, *SAN FRANCISCO–DENVER CHART 5*, 1:2,500,000. Denver: Jeppesen & Company, 1949. Detail of one of seven sectional network maps in booklet format, *Air Maps of United Air Lines*, by cartographic artist Shelton, who developed a unique style of relief shading that set the standard for airline souvenir maps. Size of the original: 21 × 29 cm; size of detail: 16.1 × 27.9 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C. Permission courtesy of Jeppesen, Englewood.

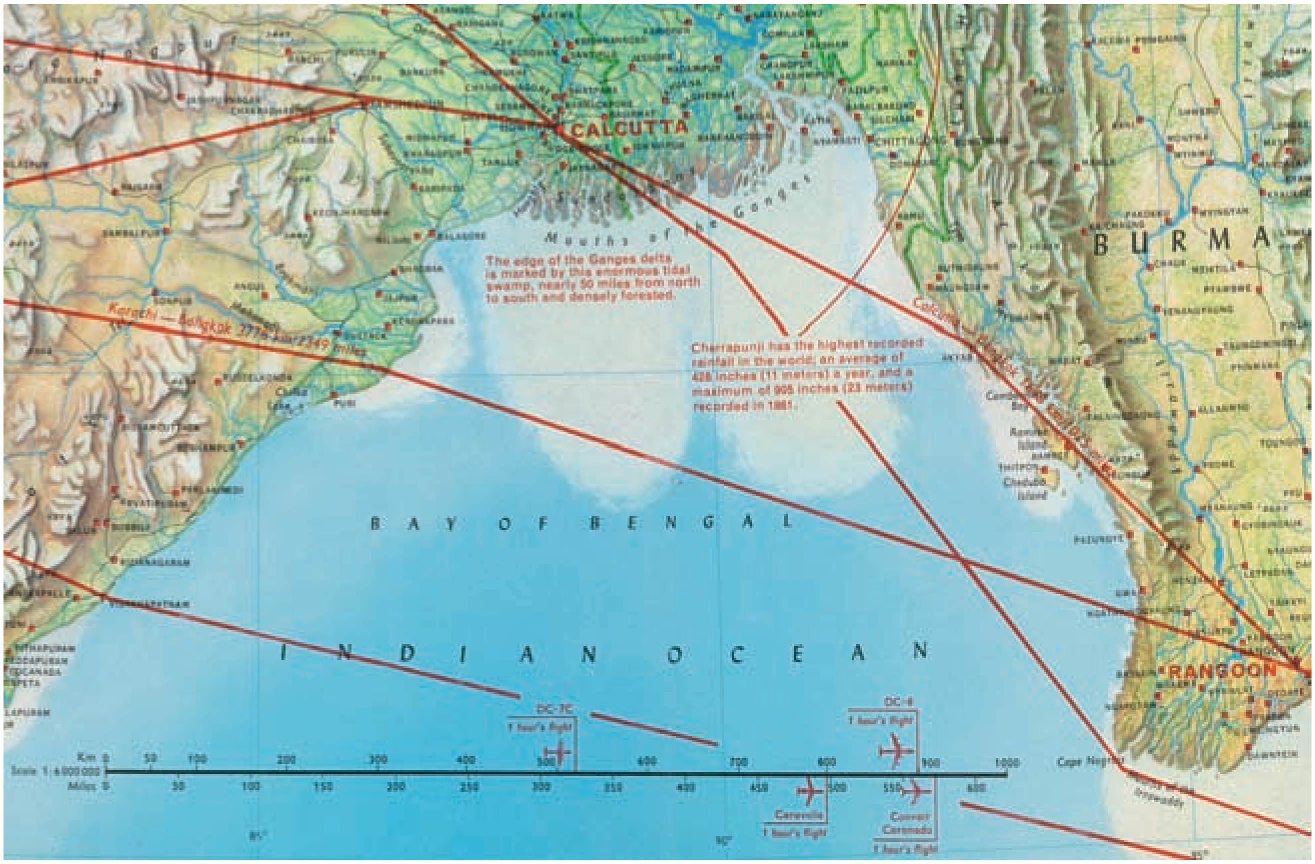

FIG. 28. DETAIL FROM THE *SAS FAR EAST ROUTE MAP*, 1:6,000,000, 1963. Stockholm: Esselte Map Service. In this typical route network map from the first jet age era, the cartographer embellished the bar scale to subtly promote Scandinavian Airlines new jet fleet by contrasting the time advantages of jet airliners (Caravelle, DC-8, and Convair Coronado) with conventional airliners (DC-7C).
Size of the entire original: 46 × 78 cm; size of detail: 15.9 × 24.3 cm. Image courtesy of the Ralph E. Ehrenberg Collection.

Souvenir map production decreased dramatically in the 1970s as the air travel experience was altered by the introduction of wide-bodied jumbo jets and the rising popularity of in-flight movies. By the end of the decade, most airlines had replaced complimentary flight packets and souvenir maps with in-flight magazines. Another product of the jet age, the in-flight magazine, generally featured a network map, often formatted as a multipage foldout (Thurlow and Jaworski 2003).

New airline maps appeared in timetables and in-flight magazines in the 1980s in response to the continued growth of air traffic and the widespread development of a hub-and-spoke system of connecting flights triggered by the Airline Deregulation Act of 1978 in the United States. These included simplified "destination maps" that used point symbols and city names to describe the places served but omitted line symbols showing the routes; "hub-and-spoke maps," on which inset maps of individual hub city networks and their commuter routes complemented a standard network map; and diagrammatic "terminal maps" designed to help passengers making flight connections find their departure gate. American Airlines was one of the first to feature destination maps, while Eastern and Delta were early proponents of hub-and-spoke maps (fig. 29).

In-flight tracking charts date from the establishment of the North Atlantic route between Europe and North America following World War II. Beginning in 1947, charts on the Lambert conformal conic and gnomonic projections were briefly issued to passengers by American Overseas Airlines and Trans-Canada Airlines with instructions for plotting an aircraft's position along its route with the aid of the pilot's flight reports. This practice was reintroduced by a number of international carriers in the early 1970s with Captain's Briefing Maps, and remained popular until superseded by dynamic electronic maps. Asinc Airshow, a California firm, installed the first moving maps in 1984 in Swissair and Scandinavian Airlines passenger cabins. Airshow was a realtime map display synchronized with a plane's flight-deck electronics. Viewed on video screens attached to seatbacks or bulkheads, Airshow depicted the flight route,

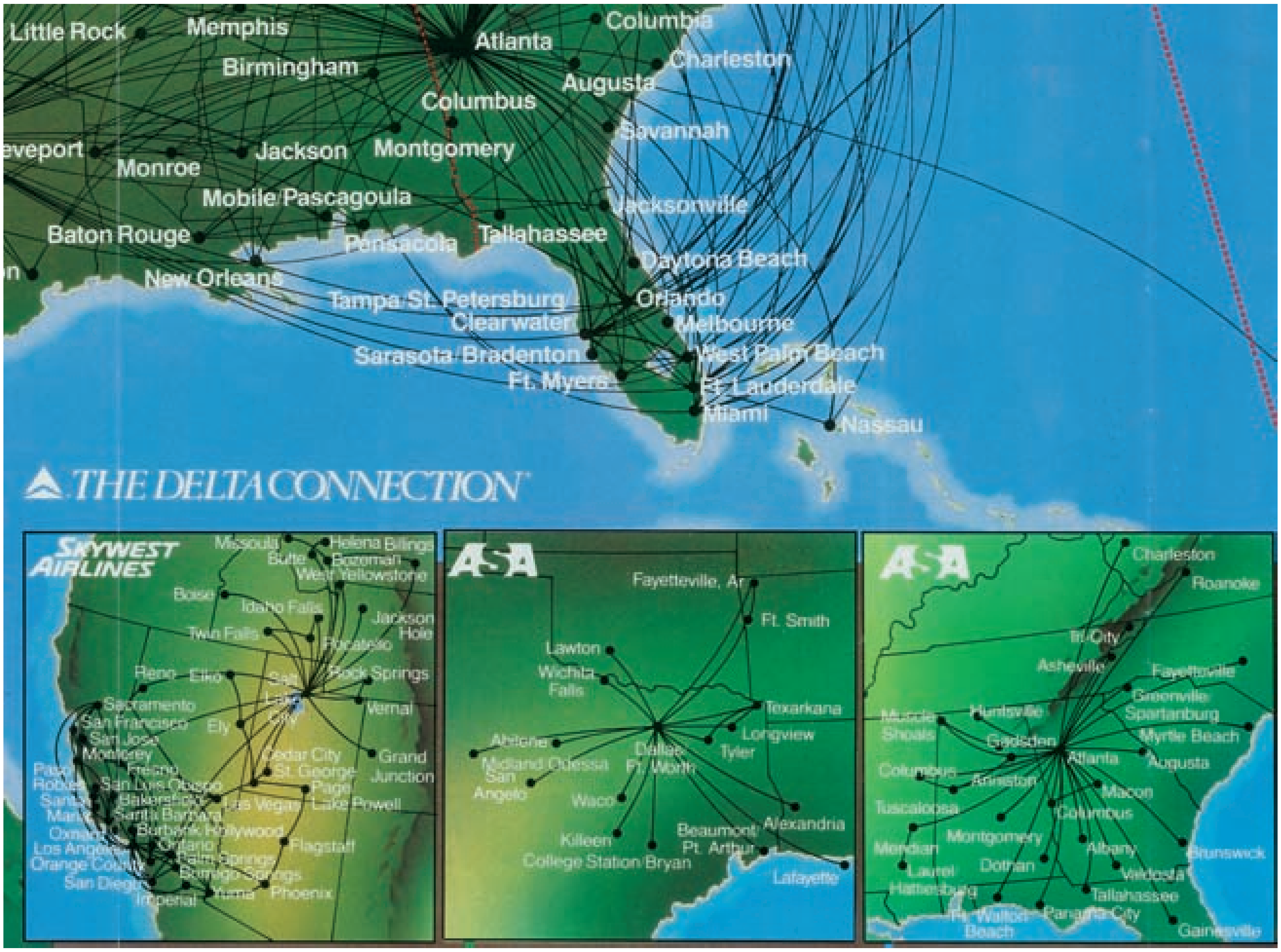

FIG. 29. DETAIL FROM THE *DELTA SYSTEM ROUTE MAP*, SCALE VARIES. Publisher not given. Effective April 1988. This map displays Delta's hub-and-spoke air traffic system of interconnecting flights, which replaced the point-to-point nonstop flight system for most airlines following deregulation by combining a network map of the entire route system with inset maps of hub city networks of commuter routes. Size of the entire original: 47 × 66 cm; size of detail: 15.2 × 20.5 cm. Image courtesy of the Ralph E. Ehrenberg Collection. Permission courtesy of Delta Air Lines, Atlanta.

groundspeed, and altitude along with the distance and time to destination (Govil 2004, 245–49).

RALPH E. EHRENBERG

SEE ALSO: Advertising, Maps as; Aeronautical Chart; Shelton, Hal; Travel, Tourism, and Place Marketing

BIBLIOGRAPHY:

Anonymous. 1930. "On Your Left, Ladies and Gentlemen—." *Aero Digest* 16 (June):96.

Bilstein, Roger E. 1995. "Air Travel and the Traveling Public: The American Experience, 1920–1970." In *From Airships to Airbus: The History of Civil and Commercial Aviation*, vol. 2, *Pioneers and Operations*, ed. William F. Trimble, 91–111. Washington, D.C.: Smithsonian Institution Press.

Gardner, Lester D. 1927. "German Air Transport." *Aviation* 23: 253–60.

Gartner, Georg F., and Andreas Popp. 1995. "Kartographische Produkte für Flugpassagiere." *Kartographische Nachrichten* 45:96–107.

Govil, Nitin. 2004. "Something Spatial in the Air: In-Flight Entertainment and the Topographies of Modern Air Travel." In *MediaSpace: Place, Scale and Culture in a Media Age*, ed. Nick Couldry and Anna McCarthy, 233–52. London: Routledge.

Patterson, Tom, and Nathaniel Vaughn Kelso. 2004. "Hal Shelton Revisited: Designing and Producing Natural-Color Maps with Satellite Land Cover Data." *Cartographic Perspectives* 47:28–55.

Thurlow, Crispin, and Adam Jaworski. 2003. "Communicating a Global Reach: Inflight Magazines as a Globalizing Genre in Tourism." *Journal of Sociolinguistics* 7:579–606.

Akademie für Raumforschung und Landesplanung (Academy for Spatial Research and Planning; Germany). The Akademie für Raumforschung und Landesplanung (ARL) was founded in 1946 as an independent, extramural, self-governing public organization. Its roles have included research (predominantly applied, but also theoretical) and consulting in support of government policy, public administration, and economic planning on every type of spatial issue at all levels: federal, provincial, regional, and neighborhood. In this capacity the ARL strongly influenced German cartography during the latter half of the twentieth century.

The organization's reach has been broad. As a member of Germany's Leibniz-Gemeinschaft of scientific institutions, it has contributed to numerous domestic and international projects. And together with the Bundesamt für Bauwesen und Raumordnung (BBR), the Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) in Bonn, and the Leibniz-Institut für Länderkunde in Leipzig, the ARL is the most significant German institution in the field of spatial analysis and planning. Typically the *Bundesländer* (federal states) have provided 70 percent of its funding and the central government the remaining 30 percent. The ARL is located in Hanover, the capital of Lower Saxony, the federal state that supervises its activities.

Focusing on promoting scientific research on spatial phenomena and facilitating knowledge transfer for regional development, the ARL has presented its findings to scholars, politicians, government officials, and the public through conferences and lectures as well as extensive publications, including maps, atlases, and monographs on cartographic principles and practice.

The ARL is the lineal descendant of the Reichsarbeitsgemeinschaft für Raumforschung (RAGfR), established in Berlin in 1935 as an interdisciplinary scientific institution and active until 1940. The mission of the RAGfR was to coordinate spatial research within the various scientific disciplines and provide scientific support for regional policy initiatives. Like its institutional successor, the RAGfR was organized around interdisciplinary teams and working groups with members from various university departments. Directed by Konrad Meyer, a professor of agricultural science and a high-ranking SS (Schutzstaffel) officer, the RAGfR played a leading role in developing planning strategies for territories in Eastern Europe conquered or coveted by Nazi Germany. The relevance of the RAGfR to cartography reflects its own cartographic activities, most notably, its *Thüringen-Atlas* (1942), and more generally its contributions to spatial and regional planning.

A further element of continuity linking the RAGfR of Nazi Germany to the ARL of the young Federal Republic of Germany (FRG) was Meyer, who was commissioned in 1970 to write on the history of the RAGfR for the ARL's encyclopedia of spatial research. An active member of the ARL, Meyer argued that because denazification had been successful, the organization's origins were not problematic. In 2008, at a conference in Leipzig, the ARL examined the Nazi roots in its early history (Mäding and Strubelt 2009). A review of articles published between 1936 and 1953 in *Raumforschung und Raumordnung* revealed unfortunate research continuities between the two institutions. Furthermore, Heinrich Hunke, a planner and economist who served as the ARL's first general secretary from 1949 to 1954, was a high-ranking official during the Nazi era, and the geographer Kurt Brüning, the ARL's first president, had previously worked for the RAGfR.

The ARL inherited from the RAGfR an organizational structure that includes a board of trustees, a steering committee, a scientific board, and a meeting of members. Research is conducted by permanent or ad hoc interdisciplinary committees (sections with associated working groups or regional networks). At the heart of ARL is a comparatively small management office with full-time staff. The secretary general directs this office and represents the ARL in joint international endeavors, and senior academics manage each of the five specific scientific sections: demography, social structure, and settlement structure; economics, infrastructure, and technology; natural resources, environment, and ecology; spatial planning and spatial policy; and legal foundations of spatial development. One additional expert directs ARL publications.

The ARL's research is disseminated through its own publications, notably *Raumforschung und Raumordnung*, the leading journal for planning issues in Germany, which is published six times a year in collaboration with the BBR. Papers and periodicals include the prestigious *Forschungs- und Sitzungsberichte der ARL* and *Abhandlungen* as well as a less formal series *Arbeitsmaterial der ARL*.

In the years following World War II, the ARL made a sizeable contribution to spatial planning in West Germany's federal states (*Länder*), which had been given the lead role in spatial planning in the new federal republic. In this context, it issued the ten volumes of the *Deutscher Planungsatlas* between 1960 and 1989 in collaboration with the respective planning authorities of the federal states. The *Planungsatlas* is structured by federal states, with Lower Saxony and Bremen treated in one volume. (A supplemental summary volume of the atlas for the Federal Republic of Germany as a whole was originally envisioned, but never realized.) The atlas was intended to provide thematic maps as background information for regional development planning. Most of the atlases for the individual federal states contain base maps for spatial planning rather than planning maps per se. Because of the long time required to develop some of the regional volumes, individual maps with comprehensive accompanying texts were published instead of self-contained volumes for some of the *Länder* (e.g., forty-nine sheets for North Rhine-Westphalia), and updated maps were published to supplement some of the older volumes. Since completing the atlas, the ARL has not committed itself to a cartography project of similar magnitude, and cartography at the ARL declined in importance.

In the field of thematic cartography the ARL carried out pioneering work of theoretical and practical importance. Nearly as significant as the *Planungsatlas* was *Thematische Kartographie* by Werner Witt, which the ARL published in 1967 (2d ed. 1970) in its scientific papers series. Between 1967 and 1971 Witt, and later Erik Arnberger, directed an active research group on thematic cartography and data processing, which laid the foundations for cartographic automation in German-speaking countries.

In the early twenty-first century, the ARL's activities became increasingly international, spurred by the need for European cooperation in planning matters and a growing use of English on the Continent. In addition to its English-language series "Studies in Spatial Planning," introduced in 2002, the ARL inaugurated a series of "Position Papers," also in English, intended for an audience of European planners. With the ARL's support, Germany has been a leader in spatial planning in the European Union. The ARL has also actively fostered young academics working in spatial research by organizing youth forum conferences and workshops, awarding scholarships to young European planning professionals, and staging a prize competition (the Werner-Ernst-Preis) for the best contribution by a junior researcher.

HARTMUT ASCHE AND CHRISTOF ELLGER

SEE ALSO: Bundesamt für Kartographie und Geodäsie (Federal Office for Cartography and Geodesy; Germany); Military Mapping by Major Powers: Germany

BIBLIOGRAPHY:

Akademie für Raumforschung und Landesplanung, ed. 1960–89. *Deutscher Planungsatlas*. 10 vols. Hanover: Gebrüder Jänecke; Bremen: Walter Dorn.

Leendertz, Ariane. 2008. *Ordnung schaffen: Deutsche Raumplanung im 20. Jahrhundert*. Göttingen: Wallstein Verlag.

Mäding, Heinrich, and Wendelin Strubelt, eds. 2009. *Vom Dritten Reich zur Bundesrepublik: Beiträge einer Tagung zur Geschichte von Raumforschung und Raumplanung*. Hanover: Akademie für Raumforschung und Landesplanung.

Meyer, Konrad. 1970. "Reichsarbeitsgemeinschaft für Raumforschung." In *Handwörterbuch der Raumforschung und Raumordnung*, ed. Akademie für Raumforschung und Landesplanung, 2d ed., 3:2719–20. Hanover: Gebrüder Jänecke.

Witt, Werner. 1970. *Thematische Kartographie: Methoden und Probleme, Tendenzen und Aufgaben*. 2d ed. Hanover: Gebrüder Jänecke.

Allegorical Map. See Literature and Cartography

Almagià, Roberto. Roberto Almagià was the most authoritative Italian historian of cartography during the first half of twentieth century. He was born in Florence on 17 June 1884, to wealthy Jewish parents, and attended the University of Rome, where he was a student of Giuseppe Dalla Vedova, one of the founders of modern Italian scientific geography. He inherited Dalla Vedova's chair in 1915 and remained there until his retirement in 1958.

Almagià's interests in the history of cartography developed during his first teaching appointment at the University of Padua (1911–14), after he had already published essays of general geography. In his first works, as in his book about the theories of tides in classical antiquity (*La Dottrina della marea nell'antichità classica e nel medio evo*, 1905), Almagià showed a deep respect for history and an inclination to consider dynamic and relational factors even in physical geography. William Morris Davis's morphological theories in geography and Benedetto Croce's idealistic historicism, then very influential in Italian culture, penetrated Almagià's thinking.

Almagià's studies in the history of cartography (about one third of his scholarly production) are characterized by vast erudition and effort in reconstructing the available information about influential mapmakers (most of them active in the sixteenth and seventeenth centuries) and the impact of their maps, as exemplified in 1922 in the preface to his book about Giovanni Antonio Magini's atlas (*Italia*) of 1620. His scholarship on the history of cartography during the European Renaissance reflected prevailing interests in the biography of mapmakers, cartobibliography, and the publication of facsimile editions. Almagià contributed to each of these activities, and wrote monographs on Magini, Cristoforo Sorte, Benedetto Bordone, Pirro Ligorio, Giacomo Gastaldi, Lucas Holstenius, and many other sixteenth- and seventeenth-century authors.

In addition to these works, Almagià was also the first Italian scholar to follow A. E. Nordenskiöld's example in promoting the publication of far-reaching collections of maps, from his *L'"Italia" di Giovanni Antonio Magini e la cartografia dell'Italia nei secoli XVI e XVII* (1922) to *Monumenta Italiae cartographica* (1929) and the four folio volumes of *Monumenta cartographica Vaticana* (1944–55). These publications greatly influenced the development of Italian studies in this subject and familiarized foreign scholars with these rare cartographic documents. In writing some of these annotated books, Almagià was also able to find important unknown documents, such as Magini's great map of Italy of 1608.

In 1944–45 fascist racial laws compelled Almagià to abandon teaching at the University of Rome and take refuge in the Vatican, where he dedicated himself to editing the *Monumenta cartographica Vaticana*, his most recognized work. He was president of the Società Geografica Italiana, 1944–45, and president of the Geographical Committee of the Accademia dei Lincei from 1949. International recognition of his accomplishments include the Cullum Medal awarded by the American

Geographical Society in 1952 and the Victoria Medal awarded by the Royal Geographical Society in 1959. Roberto Almagià died in Rome on 13 May 1962.

GIORGIO MANGANI

SEE ALSO: Histories of Cartography

BIBLIOGRAPHY:

Almagià, Roberto. 1961. *Scritti geografici (1905–1957)*. Rome: Edizioni Cremonese.

Codazzi, Angela. 1964. "The Contribution of Roberto Almagià to the History of Cartography." *Imago Mundi* 18:78–80.

Corna Pellegrini, Giacomo, ed. 1988. *Roberto Almagià e la geografia italiana nella prima metà del secolo: Una rassegna scientifica e una antologia degli scritti*, esp. 419–30 (Almagià bibliography). Milan: Edizioni Unicopli.

Crone, G. R. 1962. "Professor Roberto Almagià." *Geographical Journal* 128:367–68.

Migliorini, Elio. 1963. "Roberto Almagià (1884–1962)." *Rivista Geografica Italiana* 70:2–25.

Alpine Cartography. High-quality alpine cartography aims to achieve a balance between a quite abstract geometrical and a satisfactory pictorial representation of the earth's mountainous surface. In school maps (both wall maps and smaller handheld maps), the pleasing pictorial representation will predominate, whereas well-trained alpine tourists and other users accustomed to abstraction will select maps with a more accurate geometrical representation. In any case, the central problem of alpine cartography is the adequate representation of barren land, glaciers, and especially the rocky areas of geologically young folded mountains (such as the European Alps or Rocky Mountains) because of their abrupt changes in slope and areas of very steep to vertical terrain. Hence, as those regions contain the most striking examples of complicated surface shapes, they can serve as models for topo-cartographic representation. Of course nonalpine high mountain terrain should be treated in the same careful manner (and represented with corresponding quality) as the spectacular alpine barren land, where exact surface data (photogrammetric contour lines or digital raster models) can be obtained without the disturbing influence of covering vegetation.

In the mid-nineteenth century, the first steps toward alpine cartography were taken in Switzerland (Cavelti Hammer, Feldmann, and Oehrli 1997), where alpine terrain occupies almost two-thirds of the territory. The pioneers, General Guillaume-Henri Dufour and Hermann Siegfried, created official maps of the entire Swiss Confederation using a type of representation called shadow hatchures. Their famous cartographic method and its derivatives greatly influenced the alpine cartography of all European countries with such terrain (Austria, France, Germany, Italy, and Switzerland) throughout the twentieth century.

Aside from official maps published by the central authorities of surveying and mapping, a number of factors led the alpine clubs of those countries to undertake important cartographic investigations. One was that the optimal scale of tourist maps is 1:25,000 (or sometimes larger), while official maps in general are smaller in scale. In addition, an official map series covering an entire country is usually divided into uniform sheets, which may sometimes cut a coherent alpine region into two or four parts. In such assembly-line cartography, the representation of alpine terrain has to obey general rules, and the details of morphological particulars cannot be taken into consideration. Last but not least, if extent and scale allow, map users expect the representation of a coherent region on a single map sheet.

The alpine clubs had their own cartographic sections and designed regional tourist maps, developing distinctive styles of mapping that varied with the individual cartographer. Such maps indeed represented an alpine region in a homogeneous way, but the sheets of different alpine regions often displayed very individual styles of color, rock representation, and treatment of relief.

The manner of representation also depended to a high degree on the availability of detailed information about the terrain, and hence on the technical feasibility of surveying. During the twentieth century, surveying and calculating technology progressed rapidly, resulting in a change in representational style. At the beginning of the twentieth century, terrain still was recorded by surveyors using surveyor's table (plane table) tacheometry. Using that instrumentation, it was impossible to map rock walls and very steep terrain directly and with sufficient accuracy. Therefore, cartographers had to use their artistic skill to give the impression of rocky regions.

Sebastian Finsterwalder, mathematician at the Technische Hochschule München, took the first step toward better recording methods by applying so-called plane table photogrammetry to reconstruct the position of single terrain points from photographic stereo pairs. Finsterwalder used the method for mapping glaciers in the Austrian Alps, but it was soon employed for general terrain mapping. The first topographical survey of the Ortler Range by the Austrian Militärgeographisches Institut in 1908 plotted the highest peak of the former Austrian monarchy (now in South Tirol, Italy) and gave its elevation as 3,899 meters, thus indicating that position and height of single inaccessible features were available and making possible more natural cartographic drawings.

The period of single-point reconstruction by plane table photogrammetry and interpolated contour lines lasted only until 1912, when it was replaced by direct evaluation of exact contour lines plotted with high geometric and morphological accuracy using stereoplotters (terrestrial photogrammetry). However, terrestrial photogrammetric recording of mountainous regions depends very much on the terrain itself, that is, on the possibility of installing suitable base lines and covering the entire area being mapped by useable stereo pairs. With the exact contour lines came a new problem—using them for the representation of steep rocky terrain created black spots, areas of very close or merging lines precluding additional topo-cartographic visualization enhancement.

Just before World War II, airborne photogrammetry provided the ideal universal method for complete data capture in alpine terrain. The first to test its application in 1929 for map compilation was Otto von Gruber, photogrammetrist at the Technische Hochschule Stuttgart. He selected a challenging mountain area, the Wilder Kaiser near Kitzbühel in the Tirol, a well-known climbing district with vertical and overhanging limestone walls, rock towers, and weathered karst plateaus. The resulting research map showed that contour lines could be employed in the representation of very complicated rocky areas by applying the following solution for the problem of the black spots.

As initially indicated, the main problem of mountain cartography is how to produce a representation of the relief that is both geometrically correct and visually satisfactory. In general, geometrical contour lines alone do not evoke a satisfactory spatial picture, and they need to be enhanced by additional graphical elements in order to achieve the desired relief effect. Two different approaches emerged.

One approach (A) involved making the impression of plasticity more prominent by relief shading illuminated from a constant direction (from the northwest) and by artistic rock representation without close attention to the exact contour lines. The other approach (B) emphasized the geometrical content of photogrammetric plotting and strengthened it by means of graphic elements (edge lines, hatchings, morphological shading) in order to achieve adequate representation of rock forms. Black spots were replaced by vertical hatching and edge lines following the structure of the rocks given by the contour lines.

Of course, both kinds of representation used identical basic data: exact photogrammetric contour lines. Under certain circumstances, such lines can increase the impression of relief by means of the so-called group effect, which occurs when a group of sufficiently dense equidistant neighboring lines on the map are similar in direction and curvature. The density of the lines depends on their constant vertical interval, which can be optimized for efficient visual representation using a mathematical model developed in the 1950s by Leonhard Brandstätter. His approach partitions the map into three elevation zones: a relatively flat or horizontal area with less than two contour lines per centimeter, a steep region where the distance between the lines is so small that visual separation becomes impossible (black spots), and an intermediate zone wherein his formula guarantees the best possible impression of relief (Brandstätter 1983, 82–84; Brandstätter 2007).

The different approaches to rock representation mentioned above caused two different lines of development of map design. Approach A, relief cartography involving artistic representation of rock areas without or with only minimal contour lines, was taken by Fridolin Becker, professor at the Eidgenössische Technische Hochschule (ETH) in Zurich; by the topographers and cartographers such as Leo Aegerter of the Österreichische Alpenverein (ÖAV); by Hans Rohn of the map publisher Freytag & Berndt, in Vienna; and by Eduard Imhof, a

FIG. 30. DETAIL FROM THE *LANDESKARTE DER SCHWEIZ 1:25000*, *FINSTERAARHORN*, 1974. Published by the Eidgenössische Landestopographie, Wabern-Bern (sheet no. 1249), this detail of an official Swiss map includes the Jungfraujoch, a well-known peak in the Bernese Alps of Switzerland, and illustrates the artistic emphasis on rock drawing while minimizing contour lines.
Size of the original: 53.8 × 73.7 cm; size of detail: 12.7 × 8.4 cm. © swisstopo. Reproduced by permission of swisstopo (BA13119).

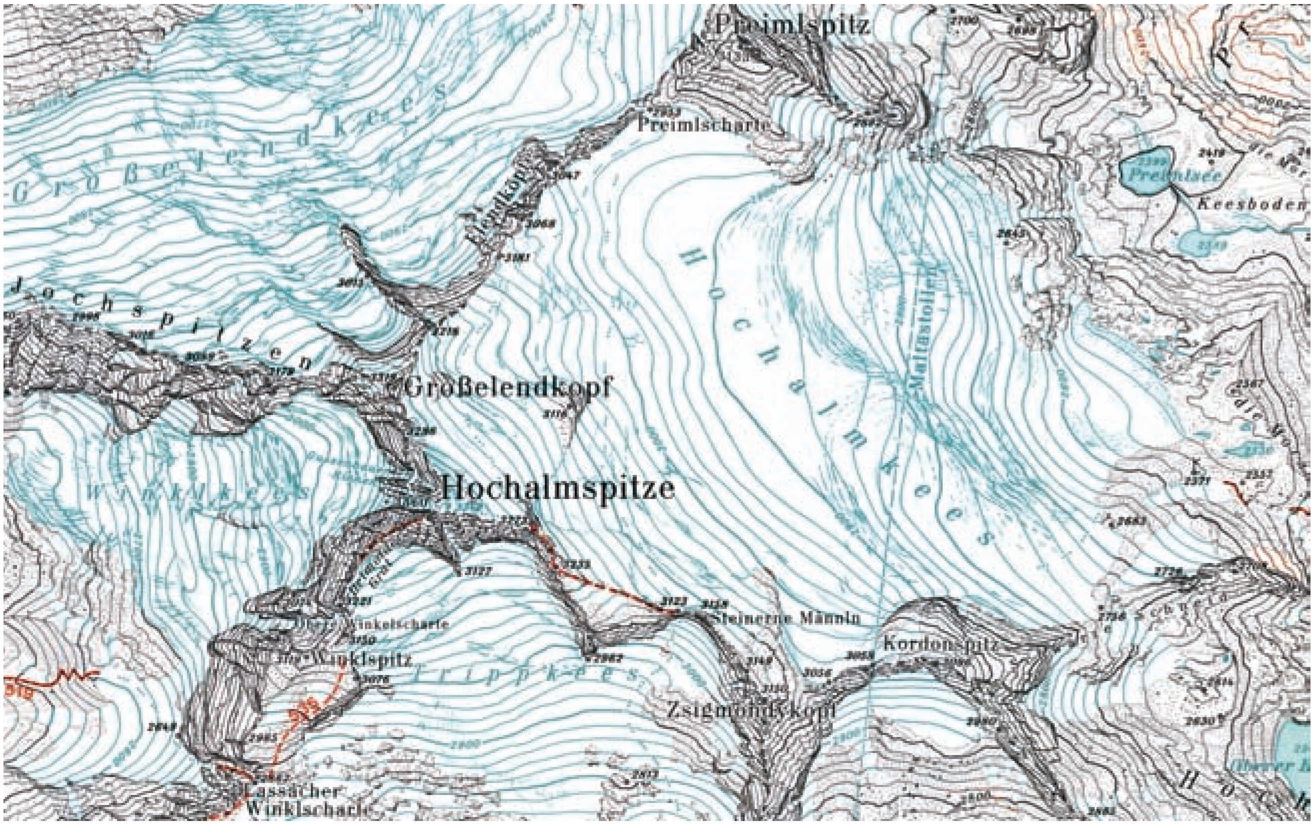

FIG. 31. DETAIL FROM *ALPENVEREINSKARTE*, NO. 44, *HOCHALMSPITZE-ANKOGEL*, 1:25,000, 1979, by Leonhard Brandstätter. Published by the Deutsche Alpenverein, Munich, and the Österreichische Alpenverein, Innsbruck, this section of the Eastern Alps of Austria includes the high peak, the Hochalmspitze, and is an example of Brandstätter's geometric-morphological method.
Size of the original: 77 × 102.6 cm; size of detail: 10.8 × 17.3 cm. Permission courtesy of the Österreichische Alpenverein, Innsbruck.

professor at the ETH. Imhof's theoretical studies (1965) and his extensive work as a practitioner of cartography left a lasting imprint on the Swiss school of cartography (fig. 30).

In contrast, approach B depended exclusively on the availability of exact contour lines. Therefore, it lacked the rich artistic tradition. Its beginnings date back to work done by Richard Finsterwalder, like his father Sebastian a professor at the Technische Hochschule München, and von Gruber during the 1920s. Finsterwalder prepared a scientific map of a limestone massif in Austria combining results of terrestrial photogrammetry with rock drawing (published in 1922). The first official map using geometrical principles (*Karte des Glärnisch-Gebietes*, 1:25,000) was designed by Walter Blumer, a Swiss freelance surveyor, in 1937. Fritz Ebster and Erwin Schneider, topographers and cartographers of the ÖAV, worked in almost the same way. Together, they designed several sheets of the Eastern Alps from the 1930s to the 1960s, sheets that combined contour lines from terrestrial photogrammetry and rock drawing by hatching and shading (Arnberger 1970). Finally Leonhard Brandstätter, an Austrian freelance cartographer, perfected the geometric-morphological method and published the detailed theory of the method (Brandstätter 1983). He also published some scientific map sheets and had the opportunity to design some maps for the Deutsche Alpenverein (DAV) and ÖAV (fig. 31). His method, the strict representation of black spots by hatching (structured by edge lines and morphological shading), gained acceptance as the most suitable way to represent complicated surface shapes by exact contour lines and as few additional elements of drawing as possible.

During the twentieth century, alpine cartography progressed from being very artificial and more or less arbitrary (due to a lack of information) to a very precise geometric process representing the most complex parts of the earth's surface. Hence, as geometry can be derived arithmetically from good (i.e., dense) digital terrain models, in the future alpine cartography will be performed by means of suitable graphic computer systems and plotters. However, terrain representation of high quality will not be possible without human interaction and therefore will continue to require appropriately educated experts.

GERHARD BRANDSTÄTTER AND ROBERT KOSTKA

SEE ALSO: Himalaya, Cartography of the; Physiographic Diagram; Relief Depiction

BIBLIOGRAPHY:

Arnberger, Erik. 1970. *Die Kartographie im Alpenverein*. Munich: Deutscher Alpenverein; Innsbruck: Österreichischer Alpenverein.

Brandstätter, Gerhard. 2007. "About Life and Work of a Patriarch of Austrian Alpine Cartography." *Grazer Schriften der Geographie und Raumforschung* 43:159–66.

Brandstätter, Leonhard. 1983. *Gebirgskartographie: Der topographisch-kartographische Weg zur geometrisch integrierten Gebirgsformendarstellug, erläutert an alpinen Beispielen*. Vienna: Franz Deuticke.

Cavelti Hammer, Madlena, Hans-Uli Feldmann, and Markus Oehrli, eds. 1997. *Farbe, Licht und Schatten: Die Entwicklung der Reliefkartographie seit 1660*. Murten: Cartographica Helvetica.

Imhof, Eduard. 1965. *Kartographische Geländedarstellung*. Berlin: Walter de Gruyter.

American Automobile Association (AAA). Promotional cartography dominated travel mapping in twentieth-century North America, where automobile interests were highly active in map distribution. Among the most prolific distributors of road maps was the American Automobile Association (AAA). Formed in 1902 to "secur[e] rational legislation . . . to protect the interests of owners and users of all forms of self-propelled pleasure vehicles [and to] promote and encourage . . . the construction and maintenance of good roads" (quoted in Flink 1970, 158), the AAA quickly became a leading political and legal advocate for motorists as well as automobile and highway interests (Flink 1970, 156–63). From the organization's earliest days, the map was an important advocacy tool.

The association's cartographic efforts from its founding until about 1914 reflected the difficulties early automobilists faced in traveling outside of their immediate surroundings, particularly the inadequacy of route marking. Most of these early publications were associated in some way with the surveying and marking of automobile routes, often in the person of the most famous "pathfinder" of the day, A. L. Westgard, a New York–based surveyor and compiler of county and state atlases. The 1905 *Atlas of the State of New Jersey* mentions what was likely the first AAA map publication, an eighteen-section map covering the northeastern United States published for the association by Westgard's Survey Map Company (Survey Map Company 1905, inside front cover). Unacknowledged by historians, this map was the likely source for map sets printed on cards (11.5 × 5 inches) in 1905–6 for the AAA by the Survey Map Company (fig. 32). These sets of map cards were usually assembled in state or regional folders, and each

FIG. 32. MAP ON CARD SHOWING EASTERN NEW JERSEY NEAR NEWARK.
Size of the original: ca. 29.5 × 13.9 cm. From *Official Maps and Routes of the American Automobile Association Sections 19 and 20 . . . Covering New Jersey* (New York: Survey Map Company, 1906). Image courtesy of Jeffrey D. Dunn.

folder came with itineraries of major routes as well as instructions explaining how purchasers could select and arrange the supplied maps and itineraries to construct a customized route guide for their trip. This flexible format set a pattern for customizable AAA map products that persisted into the following century (Jeff Dunn, personal communication, 2008; New York Public Library, Map Division 1971, 1:278; Otness 1975; Tom Rice, personal communication, 2008). Westgard appears again as the mapmaker for the 1906 edition of the *Automobile Blue Book*, the first of this popular compilation of itineraries (begun in 1901) to bear "the exclusive official endorsement" of the AAA (Automobile Blue Book 1906). When the AAA established its own cartographic office in 1911, among the first of its publications was a set of maps describing the route from New York to Jacksonville blazed by Westgard and followed by the 1911 Glidden Tour, an annual event the AAA sponsored from 1905 to 1913 to demonstrate the durability and practicality of long-distance automobile travel. Another 1911 publication charted the "Trail to Sunset" from Chicago to Los Angeles, one of several transcontinental routes logged by Westgard on well-publicized trips he made on behalf of the association from 1910 to 1913 (New York Public Library, Map Division 1971, 1:279; Anonymous 1913; Westgard 1920).

After the cartographic office moved with the AAA's national headquarters to Washington, D.C., in 1914, it completed a regular national series of state and regional highway maps, which remained the backbone of AAA cartography into the twenty-first century. Many local clubs affiliated with the AAA also published their own maps targeted at their members but made available nationwide through the national organization. Some of these were prepared by local clubs' own cartographic operations, notably by western clubs such as the Automobile Club of Southern California (ACSC). The ACSC was active in promoting and marking early motor routes in the Southwestern United States and offered AAA members unusually elegant and precise strip maps describing these routes, which often followed dubious road beds through sparsely populated and difficult mountain and desert terrain (fig. 33). Other local clubs contracted with commercial publishers such as H. M. Gousha Company, which published a map of metropolitan Chicago for the Chicago Motor Club from 1931 until the 1980s.

As roads and route marking steadily improved in the 1920s, the AAA touring bureau expanded its operations to meet more comprehensively the needs of the growing legions of automobile tourists. The association published its first guides to hotels and motorcamps in 1917 and 1920, respectively, and in 1926 it terminated

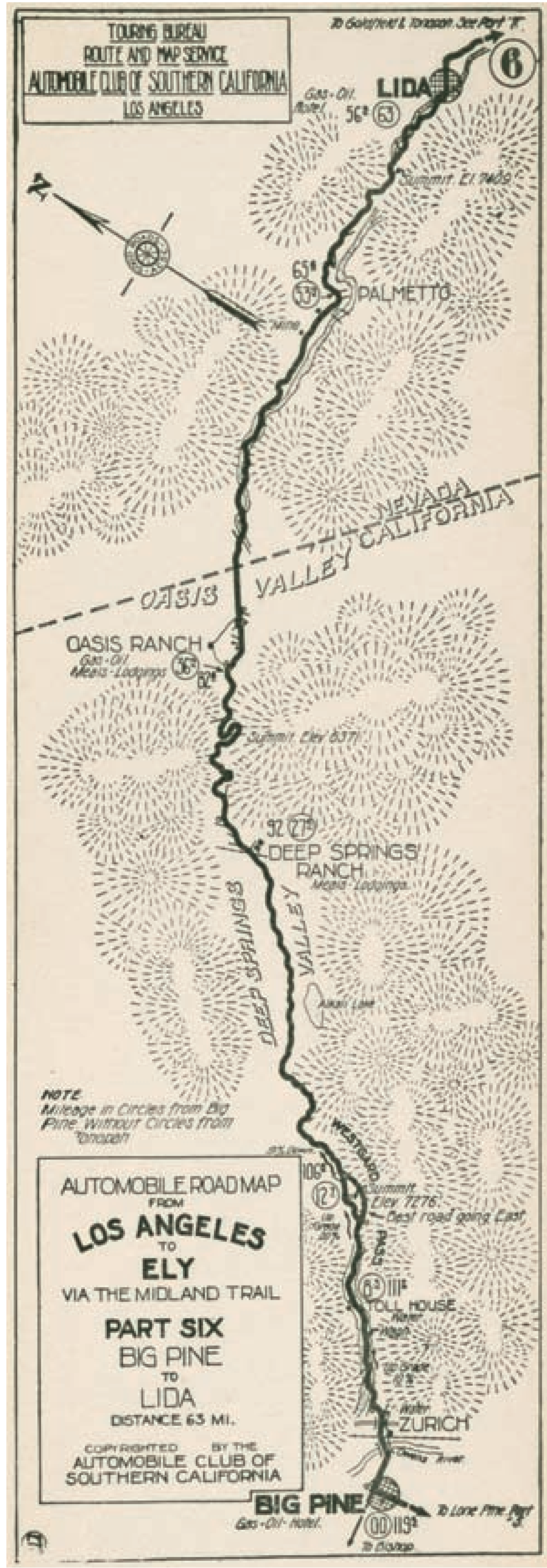

FIG. 33. *AUTOMOBILE ROAD MAP FROM LOS ANGELES TO ELY VIA THE MIDLAND TRAIL, PART SIX, BIG PINE TO LIDA*. Los Angeles: Automobile Club of Southern California, ca. 1925.
Size of the original: 26.5 × 9.5 cm. Image courtesy of the Newberry Library, Chicago.

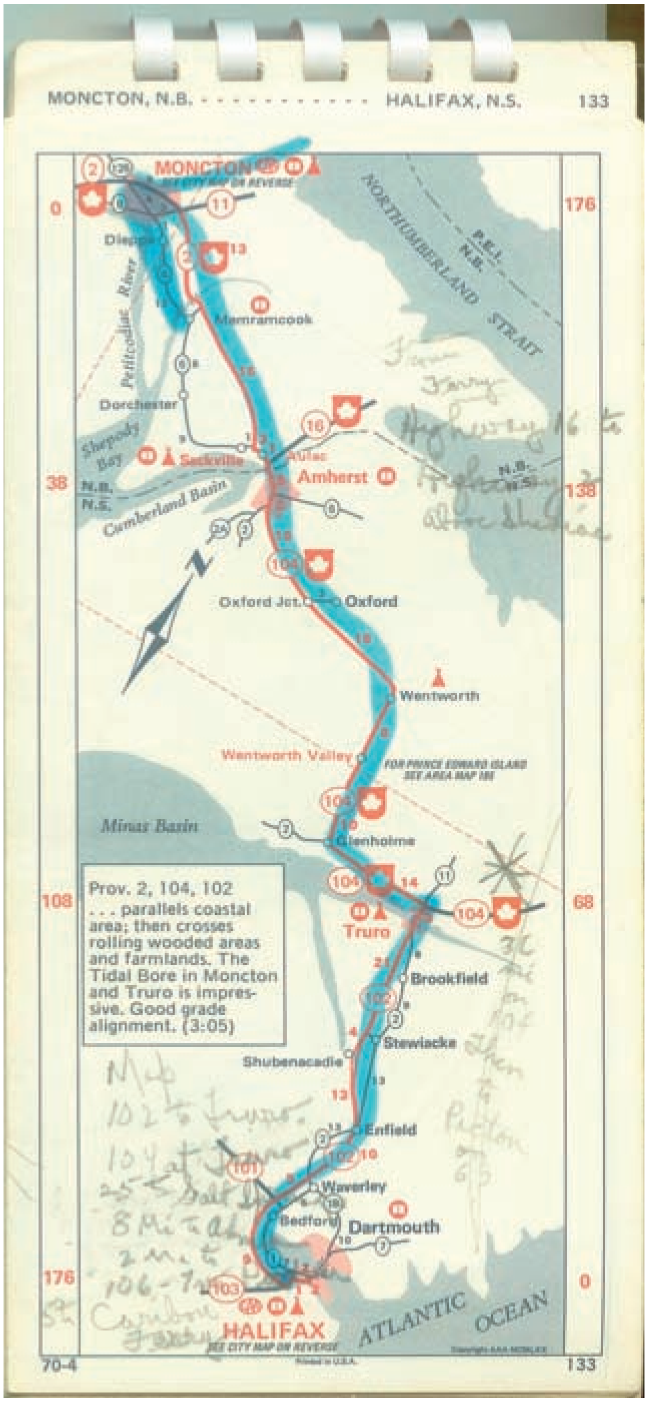

FIG. 34. SHEET FROM AAA TRIPTIK WITH HAND-DRAWN ROUTING. Route is shown from Halifax, Nova Scotia, to Moncton, New Brunswick, with additional annotations by the consumer. [Washington]: American Automobile Association, 1970.
Size of the original: ca. 23 × 10.9 cm. Image courtesy of James R. Akerman. Permission courtesy of the American Automobile Association.

its endorsement of the *Automobile Blue Books* while launching its own series of regional guidebooks. Early editions combined strip maps, regional maps, and itineraries with descriptive lists of points of interest, lodgings, restaurants, and other roadside services. The AAA's endorsement of lodgings and restaurants, based on annual inspections, was eagerly sought and advertised by roadside businesses. The system of endorsement, in turn, reinforced the authority of the AAA and its tourbooks and maps (Akerman 2002, 186–87). Membership grew rapidly from around 1940, when it passed one million, to the late 1970s, when it reached twenty million. AAA members consumed some 180 million maps in 1974 (Otness 1975, 8).

The publication of route cards and strip maps continued into the 1950s, although these were largely supplanted by custom portfolios of strip maps called TripTiks, introduced in 1937. TripTiks consist of multiple strip maps showing route segments of major highways and routings through urban areas, selected from preprinted stock and arranged according to an itinerary specified by a client. Packaging and hand-drawn routing information (fig. 34) underscored their personalized character, and indeed their value to many consumers as personalized souvenirs of automobile trips may have exceeded their navigational utility (Akerman 2000, 32–35). As such, they were an ideal way for the AAA to promote motoring and automobile journeys as significant lifetime experiences.

The AAA's flagship state and regional maps were bland compared to the complimentary road maps issued by oil companies. Yet, through their association with the leading national motor club, they became the official maps of the American roadscape. Moreover, their value to members was buttressed by free and flattering personalized maps and detailed tourbooks. Through these maps the AAA both stimulated and drew energy from the prevailing ethos of twentieth-century North American car culture, which promoted personal mobility and conspicuous consumption.

JAMES R. AKERMAN

SEE ALSO: Road Mapping: Canada and the United States; Route Map; Travel Tourism and Place Marketing; Wayfinding and Travel Maps: Road Atlas

BIBLIOGRAPHY:

Akerman, James R. 2000. "Private Journeys on Public Maps: A Look at Inscribed Road Maps." *Cartographic Perspectives* 35:27–47.

———. 2002. "American Promotional Road Mapping in the Twentieth Century." *Cartography and Geographic Information Science* 29:175–91.

American Automobile Association. 1911. *Strip Maps of the "Dixie Trail" North and South Automobile Route . . . Route of the 1911 "Glidden" Tour*. New York: American Automobile Association.

Anonymous. 1913. "To Map Two Trails across Continent." *New York Times*, 4 May.

Automobile Blue Book. 1906. *The Automobile Official 1906 Blue Book*. New York: Class Journal Company.

Flink, James J. 1970. *America Adopts the Automobile, 1895–1910*. Cambridge, Mass.: MIT Press.
New York Public Library, Map Division. 1971. *Dictionary Catalog of the Map Division*. 10 vols. Boston: G. K. Hall.
Otness, Harold M. 1975. "The Maps of the American Automobile Association." *Western Association of Map Libraries Information Bulletin* 6, no. 3:7–15.
Survey Map Company. 1905. *Atlas of the State of New Jersey*. New York: Survey Map.
Westgard, A. L. 1920. *Tales of a Pathfinder*. New York: A. L. Westgard. Reprinted Whitefish, Mont.: Kessinger, 2007.

American Cartographer, The. *The American Cartographer* was the first scholarly journal published in the United States devoted specifically to cartography. The American Congress on Surveying and Mapping (ACSM) began publishing it in 1974, following the inauguration of numerous other cartographic journals, notably *Kartographische Nachrichten* (Germany, 1951), *Cartography* (Australia, 1954), *Bulletin du Comité français de cartographie* (France, 1958), the *Cartographic Journal* (Britain, 1964), the *Cartographer* (Canada, 1964), and *Polski Przegląd Kartograficzny* (Poland, 1969). Initially published semiannually, it became a quarterly in 1986. Its title was changed to *Cartography and Geographic Information Systems* in 1990 and to *Cartography and Geographic Information Science* in 1999. The first change reflected the overwhelming developments in geographic information systems, while the second recognized the scholarly importance of the science (scholarship) behind the systems (technology). This later change also provided closer parity between the two components in the title and reflected the blurring of boundaries between cartography and other components within the broader arena of geographic information. Both title changes reflected actual publication content and were followed by increased emphasis on geographic information systems and science.

From its inception the journal was "Devoted to the Advancement of Cartography in All Its Aspects," a phrase that persisted on the masthead through the changes in title and into the next century. Most importantly, the statement reflects openness to a wide variety of content. The range of content was similar to that of its closest relatives, the Canadian and British journals, but early issues of the American journal contained more empirical user studies and later more geographical information systems and science content. Historical and philosophical studies and institutional reporting were more characteristic of the other journals.

The North American Cartographic Information Society, headquartered in the United States, initiated a related journal, *Cartographic Perspectives*, in 1989. It addressed themes similar to those in other cartographic journals, but its articles tended to be shorter and written for a broader readership. It was also more responsive to technological changes such as animation and the philosophical development of critical cartography.

The origins of *The American Cartographer* were deeply rooted in the post–World War II changes taking place in the discipline, especially in academic cartography. It came into being primarily because of the efforts of its first editor, Arthur H. Robinson, who had wide support within the Cartography Division of ACSM (a division that would become the American Cartographic Association and later the Cartography and Geographic Information Society). With the support of Edwin W. Miller, a member of the Land Surveys Division of ACSM who chaired the ACSM Publication Committee, the new journal gained approval of both the Publications Committee and the ACSM Board of Directors. The Cartography Division and its successors oversaw de facto the publication from the beginning, but it was not until after the turn of the century (2004) that the Cartography and Geographic Information Society incorporated independently and became the official publisher.

JUDY M. OLSON

SEE ALSO: Journals, Cartographic; Robinson, Arthur H(oward); Societies, Cartographic: Canada and the United States

BIBLIOGRAPHY:

Gilmartin, Patricia P. 1992. "Twenty-Five Years of Cartographic Research: A Content Analysis." *Cartography and Geographic Information Systems* 19:37–47.
Goodchild, Michael F. 1992. "Geographical Information Science." *International Journal of Geographical Information Systems* 6:31–45.
Wolter, John A. 1975. "The Emerging Discipline of Cartography." PhD diss., University of Minnesota.

American Geographical Society. On a stormy night in the autumn of 1851, a coterie of geographical enthusiasts gathered under the roof of John Disturnell's Geographical and Statistical Library, a shop on lower Broadway in Manhattan, conveniently near the city's travel agencies. There were thirty-one gentlemen in all that night, from many walks of life—teachers, tycoons, diplomats, publishers, a cleric—determined to establish a society for gathering and distributing geographical and statistical knowledge. Accordingly, they named their brainchild the American Geographical and Statistical Society, which took its place alongside similar institutions in France, Prussia, Britain, Mexico, Brazil, and Russia.

The cartographic emphasis of the Society during the first half century of its existence was on the collection of a significant map library. It eventually housed thousands upon thousands of sheets and atlases, many rare or unique. As for its own cartographic creations, the Society's works were illustrative compilations to accompany articles in its *Bulletin*. George Schroeter drew the Society's first homegrown maps. His *Paraguay*—theretofore a country tightly closed to the outer world, like Siam and Japan—appeared in the *Journal* of 1859. It is a handsome piece of mapmaking, with fine linework and delicate color tinting. (Color, please note, in 1859, in a scholarly periodical.) But until 1913 there would be only two staff cartographers at the Society: Schroeter and, later, Frederick Leuthner, both German in nationality and style. Shortly thereafter, Isaiah Bowman arrived and mapmaking at the Society dramatically accelerated.

By 1915, when Bowman became the director, the Society had a new home (its sixth, which opened its doors in 1911) in the free classical style at the corner of 156th Street and Broadway, with a library of 47,000 books, 36,000 maps, and floors made of glass to give the stacks an airy feel. It was the perfect setting for Bowman to pursue his vision of scholarly geographical research, with a particular emphasis in publishing. "The Society," he wrote, "changed from an amateur institution directed by the fancies of some and the judgments of others to one in which policy was formulated by scholars and approved by the Council" (Wrigley 1951, 17).

In 1916, when the *Bulletin* of the Society was transformed into the *Geographical Review* and the *Review* began to publish original areal research, the cartographic work took on a new cast and importance. More was demanded of the maps, an artful intuition to depict complex generalizations and combinations of more and less homogenous areas: climatic types, for instance, or earthquake zones, regional drainage, legal systems, vegetation, industry, and land use. Two draftsmen were at work full time; William A. Briesemeister was hired as a cartographer and continued to work at the Society for over fifty years.

The rise of human geography, with its infinite subjective units, required great cartographic sensitivity and judgment to render palpable such mental maps as, for instance, regions of local color. "Local color is an evasive quality, revealing itself in different hues to different seekers. It exists, none the less, and the geographer should be among the last to disdain its existence. A colorless regional monography falls short of the geographical truth" (Anonymous 1924, 659).

The Paris Peace Conference that closed World War I, and the Inquiry that preceded it to gather and prepare data for use at the conference, required just this sensitivity and judgment, plus a wealth of geographical information that could be found nowhere but at the Society. Thus the headquarters of the Inquiry were set up at the Society's building behind locked doors. To augment the Society's collection, a prodigious amount of data was assembled, enough to fill the three army trucks that shuttled it to the ship headed for the conference. Included were more than three dozen newly minted large-scale base maps covering principal problem areas that were prepared and later published by the Society.

Bowman proved a force at the conference, an ideal venue for his organizational skills, where he was involved in negotiations including a "treaty between the Free City of Danzig and Poland, the plebiscite in Teschen, Bulgarian counterproposals for peace terms, and the 'never-ending' Adriatic problem" (Wrigley 1951, 23). Meanwhile, a long-standing boundary dispute between Guatemala and Honduras had come to a head, and the Society was asked to suggest a form of settlement. Bowman arranged for an economic survey to be carried out in 1919. The ensuing map was adopted in the final settlement of the quarrel, which took fourteen years to conclude.

This was so much stage setting for the Society's greatest contribution to mapmaking: the *Map of Hispanic America, Scale 1:1,000,000* (1922–45), commonly known as the Millionth Map. Albrecht Penck had formally aired the notion of creating a standardized international millionth map at the International Geographical Congress in Berne in 1891. Quibbles over a generally acceptable scheme had stalled the project for decades, but by 1920 the time was right for Bowman, because of his interest in the area, to propose that the Society tackle the Hispanic portion, from the Mexican–United States border to Cape Horn, including the West Indies.

It was a fantastic undertaking: 107 sheets (4° latitude by 6° longitude) would be needed to cover the 8,000,000 square miles; three chiefs of the Society's Hispanic-American Division (first Alan G. Ogilvie, then Raye R. Platt, finally Charles B. Hitchcock) would come and go; dozens of compilers and draftsmen were employed; twenty-five years and a half-million dollars were consumed (much of it from the pockets of Society councilors Archer M. Huntington and James B. Ford).

The maps are commanding for their beauty and clarity. They express topography by contour lines and twenty gorgeous gradings of hypsometric tints; political boundaries (including the various meanderings of disputed lines) are delineated; cities and towns ranked; roads, railroads, pack trails, lighthouses, telegraph and wireless stations, mines, marshes, landing fields, and anchorages located; perennial and intermittent streams differentiated (and their limits of navigation, down to canoes, marked); and the surveyed and the conjectural distinguished (fig. 35). The lettering, over 200,000 names, was done by hand. The mind boggles.

Each sheet started as a blank piece of paper. Compilers searched for and plotted every possible original survey, from highest quality to lowest. Then reliable supplementary material was used. Recourse to previously compiled maps came last—as well as ingenuity and critical acumen of the highest order—to fill the blanks. One original survey was conducted by the Society, to the headwaters of the Amazon. "No survey of this area had ever been made, and it seemed regrettable that on a map

FIG. 35. DETAIL FROM THE *IQUIQUE* SHEET OF THE *MAP OF HISPANIC AMERICA, SCALE 1:1,000,000*, 1927. Size of the entire original: 64 × 69 cm; size of the detail: ca. 10.6 × 17.5 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries. Permission courtesy of the American Geographical Society, New York.

of Hispanic America of the scale and character of the Society's map the principal source of the world's greatest river should be only conjecturally indicated" ([Wright?] 1946, 15). Help came from private businesses and individuals undertaking surveys to clarify a few knotty problems. Some of the Andean sheets incorporated over 250 surveys and field sketches; an average sheet required nineteen man-months of work to compile. Each sheet was to have an accompanying handbook, but only one made it into print (Ogilvie 1922).

O. M. Miller was also working at the Society during this time, having arrived in 1922 to run the School of Surveying. The school attracted a number of explorers, such as Sir George Hubert Wilkins, and with their contributions, the Society compiled and published several pioneering maps of the polar regions, including the *Map of the Antarctic* (1:4,000,000, four sheets, 1928–29), the *Physical Map of the Arctic* (1:20,000,000, 1930), and a *Bathymetric Map of the Antarctic* (1:20,000,000, 1930).

Miller developed the first plotter for the use of oblique aerial photographs in making small-scale maps and together with Briesemeister devised a bipolar conic conformal projection for the Americas. The projection's unique scale-preservation properties has made it the best and most widely used cartographic representation of the Western Hemisphere to date (Pinther 2001–2, 22, no.1:8). Miller's oblique stereoscopic projection is used on a number of the Society's 1:5,000,000 series of world maps.

In the latter half of the 1940s, the Society acted on a proposal by councilor Richard Upjohn Light, a neurosurgeon, to consider production of an atlas of diseases. Jacques M. May, a physician and nutritionist, was hired in 1948 to head the new department of medical geography established at the Society. His work investigating the distribution of diseases over the face of the earth was shaped by Briesemeister into maps (*Atlas of Distribution of Diseases*, seventeen sheets, 1950–55) first published in the *Geographical Review*. Each map—or maps, as a number of the sheets had multiple inset maps—contains an epidemiological sketch, historical routes of major pandemics, rates of incidence, and distribution of vectors (fig. 36). Many of the sheets use Briesemeister's elliptical equal-area projection, an elegant modification of the Lambert azimuthal equal-area projection; the blue,

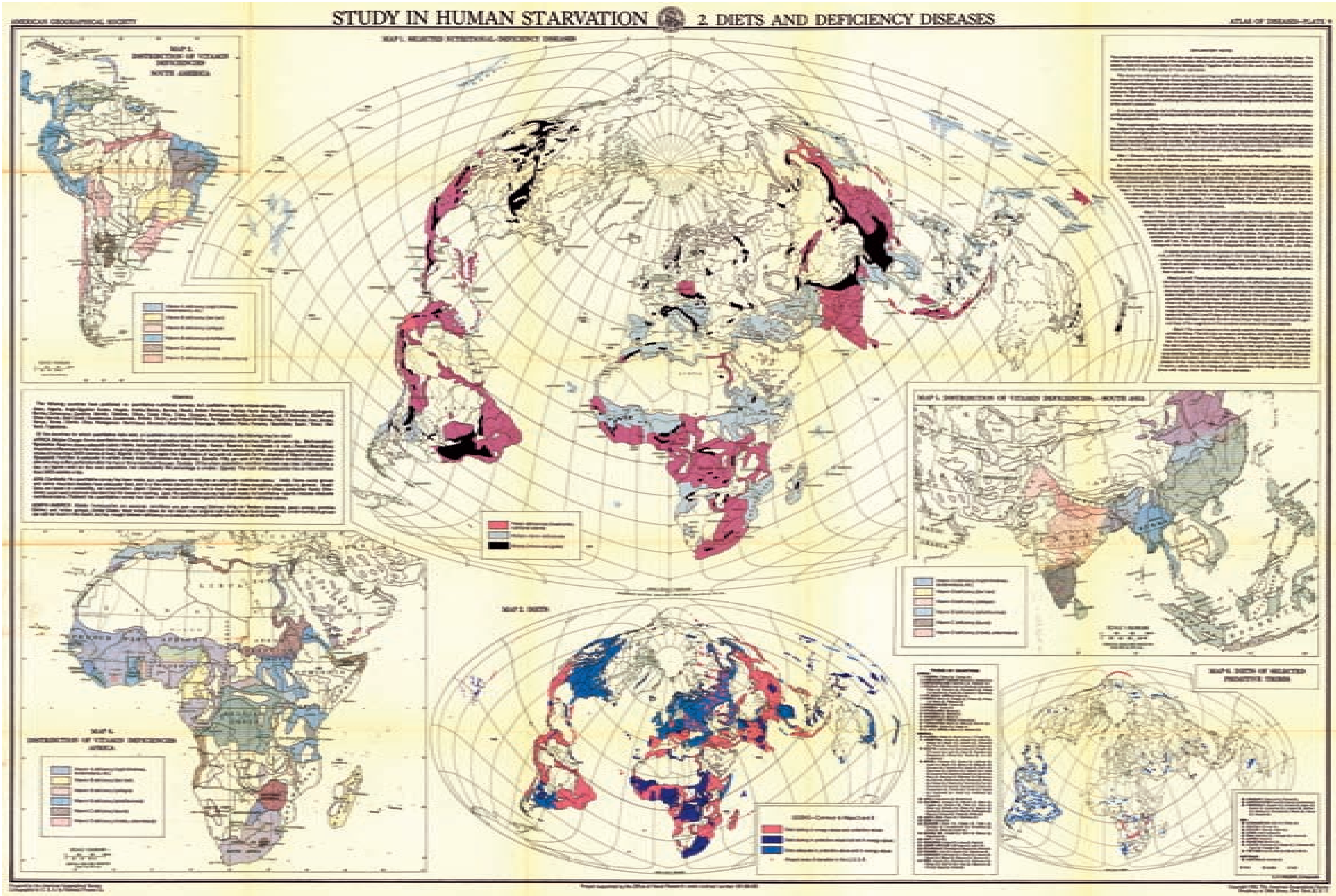

FIG. 36. *STUDY IN HUMAN STARVATION: 2. DIETS AND DEFICIENCY DISEASES*, 1953.
Size of the original: 63.4 × 96.4 cm. From *Atlas of Distribution of Diseases* (New York: The Society, 1950–55), pl. 9. Permission courtesy of the American Geographical Society, New York.

purple, and pink tints give the maps a sharp narrative impact.

This signaled a small parade of atlases. The *Serial Atlas of the Marine Environment* (twenty-four folios, 1962–74) was started in 1961, using the cartographic medium to bring together physical oceanographers and marine biologists. The *Antarctic Map Folio Series* (various scales, nineteen folios, 1964–75)—like the *Marine Environment* atlas, an idea of Hitchcock's, who had become the Society's director—contains cartographic analysis of the region and ancillary text to provide a summary of Antarctic knowledge.

Two additional atlas projects should be noted. *A Historical Atlas of South Asia* (Schwartzberg 1978) condenses and displays, in hundreds of orange-hued plates of conic and Miller cylindrical projections drafted at the Society, over fifty academic years of research in physical, historical, political, cultural, population, and economic geography, by the team assembled under Joseph E. Schwartzberg of the University of Minnesota. As for the *Ethnographic Atlas of Ifugao* (Conklin 1980), the meticulous cartographic detail of the region's terraced landscape—drawn by the Society's Miklos Pinther, some at a scale of 1:1500 and each a veritable storm of contour lines—is stunning (fig. 37). Combined with Harold C. Conklin's text, it is an exquisite, fully realized piece of regional geography à la Paul Vidal de la Blache.

FIG. 37. MAP SHOWING AMBAYAWWON PLOTS FROM HAROLD C. CONKLIN'S *ETHNOGRAPHIC ATLAS OF IFUGAO*.
Size of the entire original: 20.3 × 15 cm; size of the detail: ca. 8.4 × 11 cm. From Conklin 1980, 94 (pl. 46, 2a). Permission courtesy of Harold C. Conklin.

Perhaps the all-time best-selling map produced by the Society is A. W. Küchler's *Potential Natural Vegetation of the Conterminous United States* (1964). Küchler identifies 116 types of vegetation, keyed to colors and colored patterns stimulated by Henri Gaussen's beautiful vegetation maps. The 1:3,168,000 scale map, cast on an Albers equal-area projection, is a lovely phytogeographic mosaic, conjuring a landscape that might have been if not for the disrupting influence of humans. A descriptive manual, with photographs, served as a companion to the map.

The importance of the *Geographical Review* as the ongoing vehicle that brought the talents of the Society's cartographic department to bear on everyday geographical research cannot be stressed enough. During the first half of the twentieth century, when there were no cartographic journals being published, the *Review* was a—if not *the*—"principal source for newly issued maps, cartographic articles, and reviews of atlases and books on the subject" (Pinther 2001–2, 22, no. 1:17).

The Society has had its angels, but it has always had to negotiate the slippery slope of financial austerity. By the late 1960s, however, with governmental funding on the wane and a looming national economic recession giving even well-heeled contributors the collywobbles, austerity gave way to hardship, and hardship to retrenchment. The crack of doom sounded in 1974, when the cartography department was slashed in half. Unfinished projects scurried for alternative publishing venues. By the summer of 1976, there were no mapmakers left at the Society, and 125 years of cartographic activity came to a woeful close.

PETER LEWIS

SEE ALSO: International Map of the World; Miller, O(sborn) M(aitland); Paris Peace Conference (1919); Societies, Geographical: Canada and the United States; Wright, John K(irtland)

BIBLIOGRAPHY:

Anonymous. 1924. "Geography in Literature." *Geographical Review* 14:659–60.

Conklin, Harold C. 1980. *Ethnographic Atlas of Ifugao: A Study of Environment, Culture, and Society in Northern Luzon*. New Haven: Yale University Press.

Ogilvie, Alan G. 1922. *Geography of the Central Andes: A Handbook to Accompany the La Paz Sheet of the Map of Hispanic America on the Millionth Scale*. New York: American Geographical Society of New York.

Pinther, Miklos. 2001–2. "The History of Cartography at the American Geographical Society." *Ubique* 21, no. 3:1, 4, 14; 22, no. 1:1, 6–8, 13, 17; and 22, no. 2: 1, 6–8.

Schwartzberg, Joseph E., ed. 1978. *A Historical Atlas of South Asia*. Chicago: University of Chicago Press.

[Wright, John Kirtland?]. 1946. “The Map of Hispanic America on the Scale of 1:1,000,000.” *Geographical Review* 36:1–28.

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

Wrigley, Gladys M. 1951. “Isaiah Bowman.” *Geographical Review* 41:7–65.

Anaglyph Map. Derived from the Greek *ana* (upward, backward, or against) and *glyphein* (to hollow out, engrave, or carve), *anaglyph* originally referred to an embossed image, or bas-relief, but was later adopted to describe a method of three-dimensional viewing based on a pair of stereoscopic images superposed in different colors for viewing with glasses having lenses of chromatically opposite colors, usually red and cyan (fig. 38). Each eye thus sees the object from a slightly different vantage point, to simulate binocular viewing, whereby the eye-brain system can perceive all three dimensions. This approach, developed in Leipzig in 1853 by the German physicist Wilhelm Rollmann, has long been used in geovisualization (Rollmann 1853). Except for large-scale depictions, used mainly in architecture and landscape representation from the end of the nineteenth century onward, anaglyphs were not employed successfully in cartography until the 1930s, principally in Berlin.

Although anaglyph viewing of overlapping pairs of vertical aerial photographs predates the seminal book of Austrian geographer Hans Bobek (1941), the first use of an anaglyph map is not known with certainty. There are pre– as well as post–World War II examples of geomorphological diagrams rendered as anaglyph maps, but these produce essentially monochrome images insofar as color is used, in concert with colored glasses, only to provide each eye with a separate, slightly different image. Colored anaglyph maps, based on a shift of spectral colors, had become common by the end of the century, and were used in the United States at least as early as the 1970s in teaching college-level map reading and map interpretation (Westerback 1976).

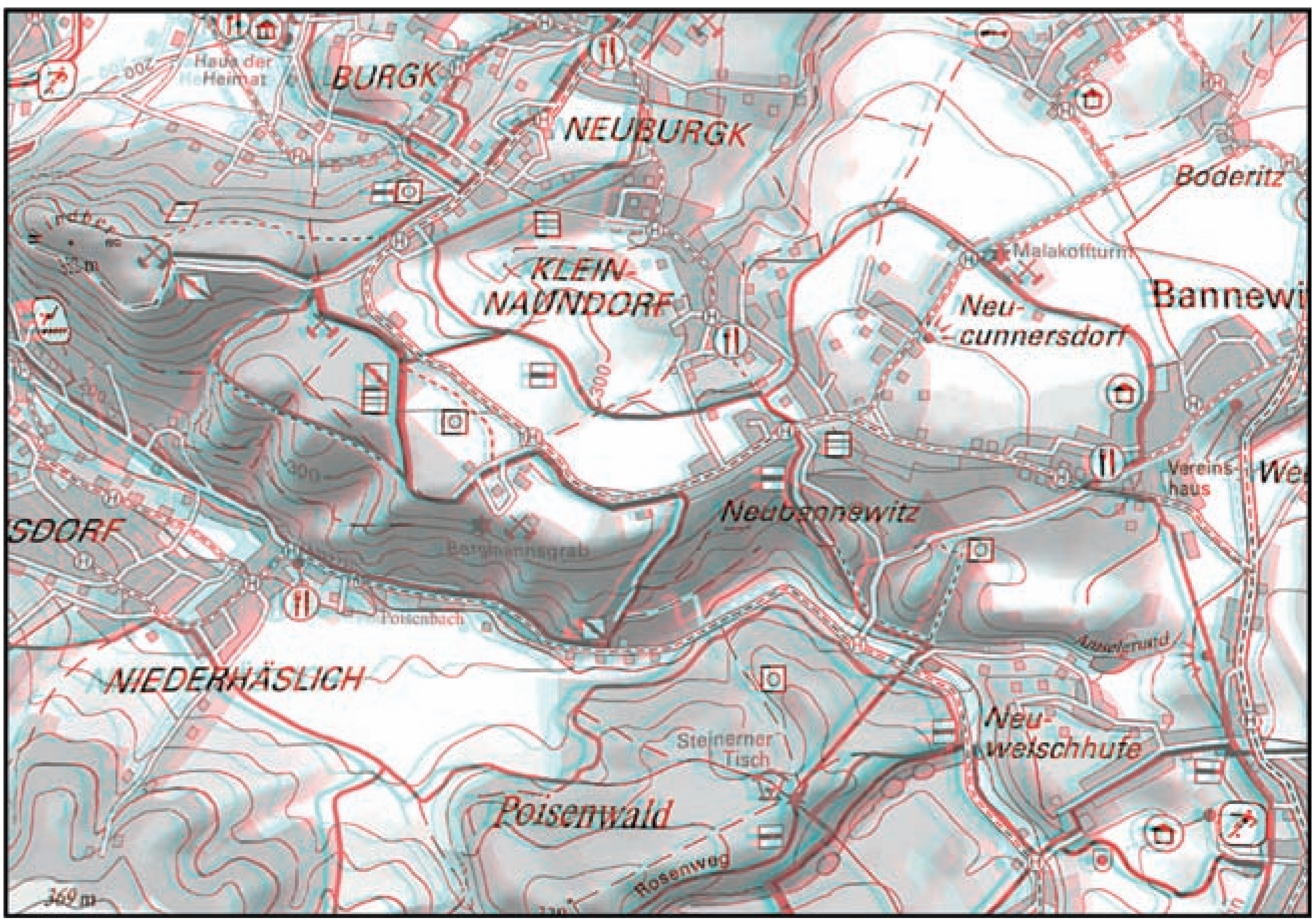

FIG. 38. CLASSICAL MONOCHROME ANAGLYPH MAP. Bannewitz area near Dresden, Germany. Image courtesy of Manfred F. Buchroithner.

Coordinated pairs of images can be captured with carefully calibrated stereo cameras or generated electronically using elevation data and software designed to produce the necessary offsets, with a given level of vertical exaggeration, for separate left-eye and right-eye images or line drawings. Anaglyph maps providing a nadir view of terrain impose rigid geometric conditions when a constant scale is intended to minimize distortion. Appropriate vertical exaggeration is particularly important if the viewer is to quickly comprehend the third dimension, but excessive vertical exaggeration can compromise clarity and obscure important details. Precise, high-resolution reproduction is equally essential. For these reasons fully realistic anaglyph maps with abstract cartographic symbols, rather than aerial imagery merely enhanced with scattered annotations, were rarely published. One of the few exemplars is the high-mountain map of the Dachstein Massif, Austria, by Manfred F. Buchroithner and Robert Schenkel (Buchroithner and Schenkel 1999; Buchroithner 2000), which nicely combines a three-dimensional representation of the land surface (instead of elevation contours) with symbolized information and hovering labels. Panoramic views are more common; one example is the anaglyph map of the north face of the Eiger, in Switzerland, which is based on a detailed geometric and textural model (Buchroithner 2002).

In the first decade of the twenty-first century Google Earth expanded the use of anaglyphs by supporting plug-ins with which an Internet browser could generate stereo image pairs of overhead images. Viewing options included the more easily viewable monochrome anaglyph; the color anaglyph with full-color viewing for scenes without bright primary colors; the half-color anaglyph, which offers a more reliable display of scenes with saturated colors; Dubois anaglyphs, which replace troublesome colors with more easily viewable ones; and yellow/blue anaglyphs with (special) glasses, for improved viewing of reds and greens. Internet cartography, high-resolution monitors, and special equipment developed for viewing three-dimensional motion pictures promise an increased role for anaglyph maps in the decades to come.

MANFRED F. BUCHROITHNER

SEE ALSO: Map: Images as Maps; Relief Depiction: Relief Map; Terrain Analysis and Cartography

BIBLIOGRAPHY:

Bobek, Hans, ed. 1941. *Luftbild und Geomorphologie*. Luftbild und Luftbildmessung, no. 20. Berlin: Hansa Luftbild.

Buchroithner, Manfred F. 2000. "Erste holographische Hochgebirgskarte." *Salzburger Geographische Arbeiten* 36:39–47.

———. 2002. "Creating the Virtual Eiger North Face." *ISPRS Journal of Photogrammetry & Remote Sensing* 57:114–25.

Buchroithner, Manfred F., and Robert Schenkel. 1999. "3D Mapping with Holography: Holographic Stereograms of the Austrian Alps." *GIM International* 13, no. 8:32–35.

Rollmann, Wilhelm. 1853. "Zwei neue stereoskopische Methoden." *Annalen der Physik und Chemie* 90:186–87.

Westerback, Mary E. 1976. "A Model to Aid Topo-Map Interpretation." *Science Teacher* 43, no. 6:42.

Analytical Cartography. Analytical cartography emerged as a distinct research focus within cartography in the latter half of the twentieth century. Its origin is generally attributed to the geographer Waldo R. Tobler, whose 1961 dissertation "Map Transformations of Geographic Space" explored the application of mathematical transformations to geographic and cartographic spaces. Tobler and various contemporaries sought to incorporate analytical theory into cartography. He equated analytical cartography with solving geographic problems using cartographic methods and saw its goal as an attempt "to capture this theory" (Tobler 1976, 29).

Robert B. McMaster and Susanna A. McMaster (2002, 318), in their history of American academic cartography, acknowledged Tobler's leadership. According to geographer Dalia E. Varanka (2005), the analytical approach also had a marked impact on cartographic activity within the U.S. government in the 1970s and 1980s. Analytical cartography, with its emphasis on concepts and theory, developed contemporaneously with geographic information systems (GIS), which emphasized technology. Geographic information science (GISci) arose much later, beginning about 1990, when Michael F. Goodchild strongly advocated including theory in GIS.

Analytical cartography originated in the history of map projection, starting with the transformation of a spherical earth onto a plane around the fifth century B.C. While early Greek geographers had to rely on geometry, a more sophisticated mathematics emerged in the seventeenth century, when Gottfried Wilhelm Leibniz and Isaac Newton invented calculus as a tool for codifying the laws of physics. In the late eighteenth century, Johann Heinrich Lambert first used calculus to develop map projections; from that time onward, calculus has remained the tool of choice. Tissot's indicatrix, devised in the late nineteenth century by Nicolas Auguste Tissot to describe both graphically and numerically the distortions of angles and area, proved an insightful analytical approach to map projection. Sometimes called mathematical cartography, these innovations strongly influenced the thinking of Tobler and his contemporaries.

In the early twentieth century the social sciences started to use quantitative analysis, especially statistics, and by the 1950s geography (the disciplinary home of academic cartography in English-speaking countries) became more quantitative as well, reinforcing the mathematical bent of analytical cartography. The Michigan Inter-university Community of Mathematical Geographers (MICMOG), founded in the early 1960s by Tobler and John D. Nystuen of the University of Michigan, William Bunge of Wayne State University, and quantitative geographers from Michigan State University, published a dozen Discussion Papers between 1963 and 1968, which as a group were influential in building the field of analytical cartography. (Edited by Nystuen, the Discussion Papers were accessioned by thirty research libraries, and the University of Michigan committed to providing them online in perpetuity.) This monograph series led to the founding of *Geographical Analysis*, an early journal in analytical geography and cartography.

Similar groups emerged in Europe and elsewhere in North America. In the 1950s geographer Arthur H. Robinson helped organize scholars from Northwestern University, the University of Wisconsin–Madison, and the University of Chicago. In the 1970s Stig Nordbeck and Bengt Rystedt formed a kindred group in Sweden, where they worked to extend analytical theory as it applied to mapping and GIS systems. Their NORMAP system (Nordbeck and Rystedt 1972) was one of the most sophisticated geospatial data systems in Europe at that time. It contained a number of powerful analytical components such as point-in-polygon and shortest-route analysis. At the same time, David P. Bickmore established the Experimental Cartography Unit (ECU) at the Royal College of Art, in England, and recruited David Rhind as an early collaborator. In a retrospective assessment, Rhind (1988) examined developments at the ECU under the leadership of Bickmore during the 1960s and 1970s as well as ECU relationships with spatial scientists in many other parts of the world.

Simultaneously, a few spatial scientists in an endeavor dubbed "social physics" independently became involved in the early roots of analytical cartography. One of the foremost was William Warntz, who in 1966 published his strategy for structuring the critical topological points and lines of a geographical surface—peaks, pits, ridges, valleys, passes, and pales—into a network. This network of topologically significant points and lines provided a topological skeleton of a surface that became known as a Warntz network. During the later stages of this work, Warntz became the director of the Laboratory for Computer Graphics, which Howard T. Fisher had founded at Harvard University in 1965 as a development center for computer mapping software. When Warntz arrived, he brought a more conceptual spatial view to the organization, as exemplified by work on the TIN (triangulated irregular network) model by Thomas K. Peucker (later Poiker) and colleagues as well as eclectic work on the network geometry of streams by Michael J. Woldenberg.

In the ensuing decades researchers strengthened the theoretical foundation for analytical and digital cartography. Key developments include the International Symposium on Computer-Assisted Cartography (Auto-Carto), a biennial conference initiated in 1974; the 1979 monograph on topological considerations by mathematician James P. Corbett of the U.S. Census Bureau; the first edition of Keith C. Clarke's textbook *Analytical and Computer Cartography* in 1990; a special issue of *Cartography and Geographic Information Systems* on "Analytical Cartography" in 1991; and a special issue of *Cartography and Geographic Information Science* on "The Nature of Analytical Cartography" in 2000 (both edited by Moellering).

Perhaps the most direct scientific results that arose from Tobler's 1961 doctoral dissertation and early work involved coordinate transformations. Although his initial work on planar and spherical coordinate transformations was a creative elaboration of the field's historical antecedents, Tobler later extended this work by looking at distortion on medieval map projections (1966) and the correspondence of geographic patterns (1965). In the late 1970s he used a least-squares framework that he called bidimensional regression (Tobler 1994) to compare planar forms with a number of landmarks and other point locations in common. His work on contiguous area cartograms in the 1970s extended the theory of map projections to the mapping of quantitative data (Tobler 2004). A typical objective was to distort the boundaries of a map's subdivisions so that each unit's area was proportional to its population. Tobler's early cartograms usually dealt with population counts represented by quadrilaterals bounded by meridians and parallels, while additional efforts addressed thematic zones such as states and voting districts. A transformed boundary map on which population density was equalized appealed to the larger scientific community, which appreciated the notion of a demographic base map for mapping disease, crime, and socioeconomic conditions. Tobler's work inspired a number of other workers, including Vladimir S. Tikunov and his Russian colleagues. Online cartogram computation sites became common in the late twentieth century, when a curious casual user could calculate area cartograms from stock sets of spatial data.

In the 1970s Tobler broadened his sense of the map as a mathematical transformation by proposing a conceptual model in which forward and inverse transformations link the world, raw data, the map, and the map viewer's mental image (Tobler 1979b). This concept, which was extended in the 1980s by geographers Phillip Muehrcke and Nicholas R. Chrisman, also struck a chord with Ohio State University geographer Harold Moellering, who worked closely with Tobler at the University of Michigan. Moellering (1980) proposed an expanded definition of the map based on two fundamental

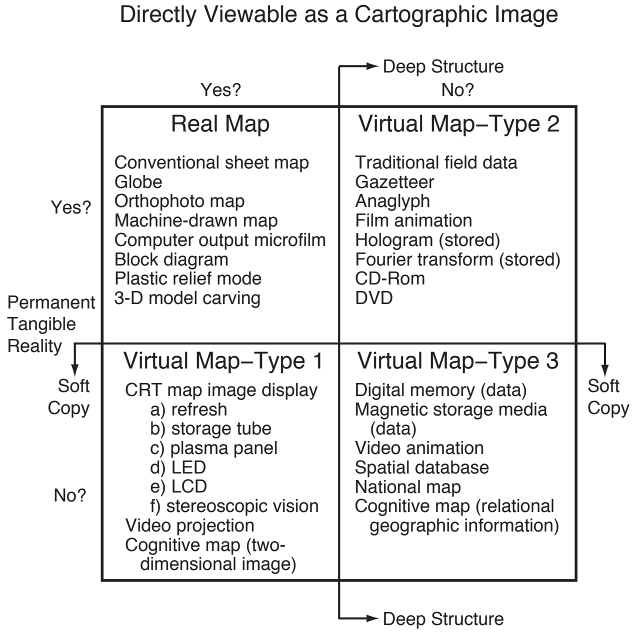

FIG. 39. THE SCIENTIFIC DEFINITION OF REAL AND VIRTUAL MAPS.
Enhanced from the version in Moellering 1980, 13.

characteristics: whether the map was directly visible as a map image, and whether it was fixed in hard copy on either paper or a similar more or less permanent medium. As shown in figure 39, these distinctions provide the basis for a four-way classification that includes the real map and three types of virtual map, which are fundamentally different from a hard copy real map. These four new classes of real and virtual maps encompass all cartographic products and can be transformed from one to another. For example, digital data (virtual map–type 3) can be transformed into an ephemeral electronic map (virtual map–type 1), an image stored on transportable magnetic media (virtual map–type 3), or into a hard-copy image on paper (real map). By contrast, conventional digitizing was a transformation that converted information stored as a real map into a virtual map–type 3, stored in a spatial database. Moellering identified sixteen real/virtual map transformations, which could be used to define any and all cartographic data/information processes, especially digital data systems, as shown in figure 40. The sixteen real/virtual map transformations also provided a conceptual tool for designing spatial data processing systems as well as a more concise statement of transformations addressed by Tobler.

In the late 1970s geographer Timothy L. Nyerges, who earned a PhD under Moellering at Ohio State, borrowed the concept of deep and surface structure from linguistics and used it to identify a conceptual domain containing relationships between cartographic objects that were not visually observable. Nyerges (1980) observed that spatial data that were visible and observable existed in the surface structure while nonvisible spatial data, information, and relationships resided in the deep structure. The notion of deep and surface structures enhanced the understanding of how spatial scientists define, handle, and process spatial data. Both Moellering and Nyerges identified a close relationship between real/virtual maps and deep/surface structure insofar as real maps and virtual maps–type 1 were part of surface structure, whereas cartographic products identified as virtual maps–types 2 and 3 resided below the surface. In this schema, spatial databases as well as Tobler's coordinate transformations reside in the deep structure.

Nyerges's dissertation also identified the need for an additional data level between the relationships among features in the real world and the relationships between the objects that made up the data model. This level, which he called canonical structure, was one of six data levels from the real world down to the machine encoding in the architecture of a computer (table 2). In this conceptual framework, information structure looked up at surface structure and the real world, while canonical structure looked down into the deep structure. Nyerges's information structure and canonical structure were somewhat similar insofar as information structure contains the relationships between features in the real world, while canonical structure translates those rela-

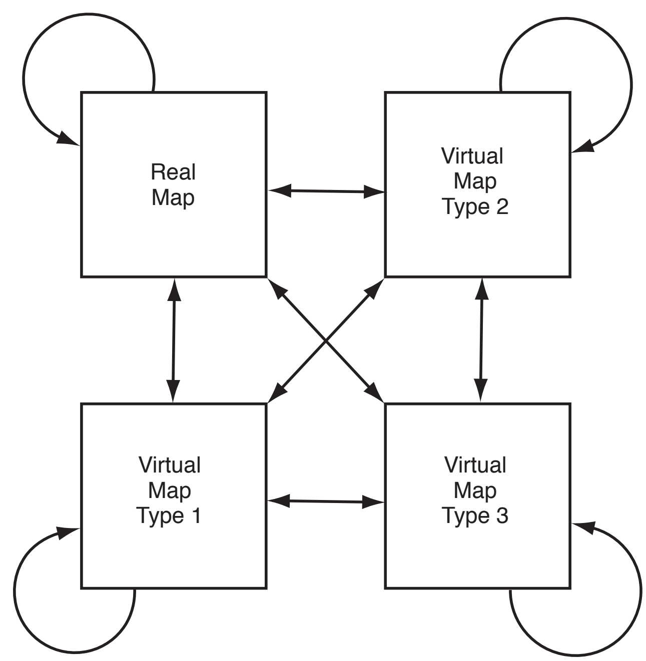

FIG. 40. SIXTEEN TRANSFORMATIONS BETWEEN REAL AND VIRTUAL MAPS.
Enhanced from the version in Moellering 1980, 14.

Table 2. Data levels identified by Timothy L. Nyerges (1980) as linking machine encoding (bottom) with the real world (top)

Data Reality—The data existing as ideas about geographical entities and their relationships that knowledgeable persons would communicate with each other using any medium for communication.

Information Structure—A formal model that specifies the information organization of a particular phenomenon. This structure acts as a skeleton to the canonical structure and includes entity sets plus the types of relationships that exist between those entity sets.

Canonical Structure—A model of data that represents the inherent structure of those data and hence is independent of individual applications of the data and also of the software or hardware mechanisms that are employed in representing and using the data.

Data Structure—A description elucidating the logical structure of data accessibility in the canonical structure. There are access paths that are dependent on explicit links. Those access paths dependent on links would be based on tree or plex structures such as network models. Those access paths independent of links would be based on tables as in relational models.

Storage Structure—An explicit statement of the nature of links expressed in terms of diagrams that represent cells, linked and contiguous lists, levels of storage media, etc. It includes indexing how stored fields are represented and in what physical sequence the records are stored.

Machine Encoding—A machine representation of data including specifications of addressing (absolute, relative, or symbolic), data compression, and machine code.

tionships onto the representations of spatial objects in data structure.

Another aspect of analytical cartography is the concept of digital filters and their inverses, pioneered in cartography by Tobler (1969) in the late 1960s, when he showed that a field of data represented by a uniform two-dimensional grid could be filtered by a smaller matrix (or kernel) of square-cell operator weights. The typical kernel was a square matrix with an odd number of rows and columns. To produce a new, transformed set of gridded data, the kernel was centered, in succession, over each cell in the original grid, so that a transformed value for the cell could be calculated by summing the products of the kernel's weights and the corresponding values of neighboring cells in the original grid. This form of raster-mode filtering proved useful for smoothing or detecting steep slopes in terrain elevation data; sharpening, blurring, or detecting edges in image data; and calculating plausible estimates for cells with missing data. Later researchers developed larger, more elaborate filters that performed several functions simultaneously. Stephen C. Guptill (1978), one of Tobler's graduate students, and Mark Monmonier (1983) developed a mathematical approach to filtering raster data representing land use or land cover.

Tobler also introduced the mathematical concept of the Sampling theorem (Moellering 2000, 210–11; Tobler 2000, 193) to analytical cartography. Although developed primarily for temporal sampling of linear, one-dimensional electronic signals, the theory was sufficiently robust to be expanded to two and three spatial dimensions. In the early 1970s Tobler adapted the Sampling theorem to two dimensions so that he could conduct spatial frequency analysis on a surface by experimenting with the effects of various sampling intervals. Applications included surface sampling, interpolation, and the fuller understanding of neighborhood operators and pixel resolution.

Tobler understood that a field of raster data could be conceptualized as a set of embedded spatial frequencies. That is, a researcher could analyze a surface in terms of its spatial frequencies, and apply the concepts of wave length, frequency, and amplitude used in mathematical formulations of Fourier transforms to decompose a set of raster data into a Fourier spectrum of some kind. Moellering and Tobler (1972) avoided the complexity of Fourier domain analysis by developing a two-dimensional least-squares approach to calculating a variance spectrum for a square-cell data set. Despite a requirement that the data array consist only of square cells, the dominant spatial frequencies could be ascertained handily.

Data format limited the applicability of these techniques insofar as most real-world spatial data are recorded for irregular zones, such as states, provinces, legislative districts, and census units. Prior to the 1970s it was common to interpolate data for irregular zones into uniform arrays of square cells with a consequent loss of information and reliability. Much effort was devoted to addressing this loss of fidelity by developing irregular cellular operators (conceptually akin to square-matrix kernels). Tobler early on worked on the idea of applying linear operators to areal data, with some success, and in the late 1970s and early 1980s several of his students developed irregular operators for their dissertations. In the early 1970s Moellering and Tobler (1972) developed an approach to calculate a variance spectrum in an irregular hierarchical spatial structure, here at the municipal, provincial, and regional levels. In 1984 Tobler addressed the vexing issue of how to assess the spatial resolution of an irregular cellular structure by introducing the concept of a resel (resolution element) as an irregular analog of the conventional square pixel. He developed a simple formula for calculating the average spatial resolution of a two-dimensional data set with irregular cells, and in 2000 he generalized this formula to any number of spatial dimensions.

Another key problem in analytical cartography was the interpolation of irregular point or cell data to a smooth, continuous three-dimensional surface with a volume that accurately represented the phenomenon portrayed. When the height of a surface represented population density, for example, the volume below the surface should represent the total number of people within the region, as Robinson had suggested in the 1950s. In the mid-1970s Tobler introduced smooth pycnophylactic interpolation (Tobler 1979a) as a mathematically elegant and robust method for transforming conventionally interpolated three-dimensional surfaces based on irregular data into smooth surfaces that not only met the continuity assumption but preserved volume under the surface as well. This transformation was a spatial tour de force and solved a major problem in surface analysis and spatial representation.

Terrain analysis and visualization was always a primary concern for cartographers and spatial scientists. Development of the Warntz network in the late 1960s was a significant advance because it enabled the design of the topological skeleton of a surface. Computer scientist John L. Pfaltz (1976) followed with his graph-theoretic extraction of the Warntz network, which delved further into deep structure and became known as a Pfaltz graph. In the 1990s computer scientist Shigeo Takahashi complemented Pfaltz's work by developing an efficient algorithm for extracting a surface network (Rana and Morley 2002). Another elaboration of Warntz's work was Peucker's pioneering procedure for generating a TIN model after first identifying a terrain surface's critical points and other detail points. The resulting interlocking network of irregular triangles was conceptually equivalent to a Warntz network and provided seamless coverage of the surface. Since the triangles were planar, the topological points and lines were preserved on the surface explicitly. TIN networks enabled the efficient computation of line-of-sight relationships basic to oblique views of three-dimensional surfaces and also to the intervisibility analysis used in military planning and in designing efficient networks of fire observation towers. TIN networks also fostered analytical hill shading, which reduced both the labor and the artist's role in making terrain maps. Computer-produced displays followed the early practice of H. Wiechel (1878), who shaded and illuminated the surface with gray tones. This approach continued into the 1970s, albeit with pen plotters and laser printers. Later work was usually produced in color.

Analytical cartography inevitably intersected numerical shape analysis, initiated in the early 1960s by quantitative geographers, whose measures typically involved arbitrarily defined single parameters. In the late 1970s Moellering and John N. Rayner (1982) developed a more sophisticated analytical model using Fourier components, which encouraged researchers to view two-dimensional shapes as assemblages of spatial frequencies.

Analytical cartography also intersected numerical approaches to cartographic generalization, which consisted of transformations of the shapes of spatial features. In the early 1970s David H. Douglas, collaborating with Peucker (1973), provided an operational strategy for generalizing lines with surface-structure geometry, and Tobler (1976) developed a digital filter approach to line generalization, basically a simplification of his two-dimensional digital filters for gridded data, but its application was limited insofar as most digital cartographic line data did not meet the requirements of the Sampling theorem. A. Raymond Boyle, Hans-Jörg Gottschalk, and Rhind, among others, pursued similar projects. A related expansion was Mark C. Shelberg's one-dimensional linear fractal algorithm, devised in collaboration with Moellering and Nina Siu Ngan Lam (1983) and based on ideas of the French mathematician Benoit B. Mandelbrot.

The 1970s ended with many researchers working on geometric line generalization. Geographers Robert B. McMaster and K. Stuart Shea (1992) summarized these largely one-dimensional solutions. In the 1980s researchers realized that features such as stream networks required not only the smoothing of linear sections but also the topological trimming of the network's lesser branches, an issue equally important in generalizing other kinds of networks, such as road networks. Geographer R. Weibel (1995) carried out more sophisticated generalization work in the 1990s, especially on mountainous terrain. As the century drew to a close, it was implicitly understood that effective numerical map generalization included work with elements of deep structure.

From the dawn of the digital age in the 1950s, spatial scientists tried to encode geographic reality into efficient, reliable spatial data structures. The early spatial data structures were pure geometry, usually with strings of encoded spatial coordinates, a strategy that worked satisfactorily with the simple computer systems of the 1950s and 1960s. But in the 1970s, more sophisticated problems like matching points or boundaries of polygons produced numerous errors unless the data were perfect. Vigorous debates at Auto-Carto meetings over the efficacy of data structures based only on geometry encouraged development of spatial data structures that included both geometry and topology, with the latter added to address adjacency and other neighborhood relationships. A 1975 article by Peucker and Chrisman led the way to spatial data structures based on both geometry and topology, and in the 1980s it became clear that most situations required data structures that integrated geometry and topology. A wider use of TIN models provided a realistic alternative to the simple square-cell structures of the 1960s, and because Tobler's resel-resolution approximation to the Sampling theorem worked well on triangulated surfaces, researchers could estimate the spatial resolution of the TIN data.

The U.S. Census Bureau was a prominent pioneer in the development of topological data structures. Encoding of various levels of hierarchically structured polygonal units attached to roadways and other boundaries proved to be an excellent challenge for such work. Their first attempt in the 1960s was a structure known as GBF/DIME (Geographic Base File/Dual Independent Map Encoding), rolled out for the 1970 Census. Corbett's 1979 monograph on cartography and topology provided a more detailed approach to the concepts and theory. For the 1990 U.S. census, the bureau designed a more robust and effective spatial data structure called TIGER (Topologically Integrated Geographic Encoding and Referencing). Many countries adopted a similar strategy.

By century's end, simple square-cell structures had become the preferred data structure for simple geometric situations, like remote sensing and deep space imagery, while complex boundaries and contiguity relationships required the richer, more complicated topological data structures such as TIGER for census and cadastral data and TIN models for terrain surfaces. Relational structures and object-oriented spatial data structures, brought in from other fields, were also in use. Because practicable application of analytical concepts and theory depended upon operational algorithms and computer software, cartographers owe much to researchers like W. Randolph Franklin (2000), who spent many years beginning in the 1970s with TIN model programming, and Alan Saalfeld (2000), who applied established concepts in computer science to complex cartographic problems such as map projection, graphic representation, and feature labeling. The impact of analytical cartography on mapmaking and geographic analysis reflects not only innovative theories and concepts, but also marked advances in computing technology.

HAROLD MOELLERING

SEE ALSO: Accuracy in Mapping; Cartogram; Cartometry; Exploratory Data Analysis; Interpolation; Mathematics and Cartography; Standards for Cartographic Information; Tobler, Waldo R(udolph); Warntz, William

BIBLIOGRAPHY:

Clarke, Keith C. 1990. *Analytical and Computer Cartography*. Englewood Cliffs: Prentice Hall.

Corbett, James P. 1979. *Topological Principles in Cartography*. [Washington, D.C.]: U.S. Department of Commerce, Bureau of the Census.

Douglas, David H., and Thomas K. Peucker 1973. "Algorithms for the Reduction of the Number of Points Required to Represent a Digitized Line or Its Caricature." *Canadian Cartographer* 10:112–22.

Franklin, W. Randolph. 2000. "Applications of Analytical Cartography." *Cartography and Geographic Information Science* 27:225–37.

Goodchild, Michael F. 1990. "Spatial Information Science." In *Proceedings of the 4th International Symposium on Spatial Data Handling*, 2 vols., ed. Kurt E. Brassel and H. Kishimoto, 1:3–12. Columbus: International Geographical Union IGU, Commission on Geographic Information Systems, Department of Geography, The Ohio State University.

Guptill, Stephen C. 1978. "An 'Optimal' Filter for Maps Showing Nominal Data." *Journal of Research of the U.S. Geological Survey* 6:161–67.

McMaster, Robert B., and Susanna A. McMaster. 2002. "A History of Twentieth-Century American Academic Cartography." *Cartography and Geographic Information Science* 29:305–21.

McMaster, Robert B., and K. Stuart Shea. 1992. *Generalization in Digital Cartography*. Washington, D.C.: Association of American Geographers.

Moellering, Harold. 1980. "Strategies of Real-Time Cartography." *Cartographic Journal* 17:12–15.

———. 2000. "The Scope and Conceptual Content of Analytical Cartography." *Cartography and Geographic Information Science* 27:205–23.

Moellering, Harold, and John N. Rayner. 1982. "The Dual Axis Fourier Shape Analysis of Closed Cartographic Forms." *Cartographic Journal* 19:53–59.

Moellering, Harold, and Waldo R. Tobler. 1972. "Geographical Variances." *Geographical Analysis* 4:34–50.

Monmonier, Mark. 1983. "Raster-Mode Area Generalization for Land Use and Land Cover Maps." *Cartographica* 20, no. 4:65–91.

Nordbeck, Stig, and Bengt Rystedt. 1972. *Computer Cartography: The Mapping System NORMAP: Location Models*. Lund, Sweden: Studentlitteratur.

Nyerges, Timothy L. 1980. "Modeling the Structure of Cartographic Information for Query Processing." PhD diss., Ohio State University.

Nystuen, John D., ed. 1962–68. *MICMOG Papers in Geography*. 12 issues. Online publication.

Peucker, Thomas K., and Nicholas R. Chrisman. 1975. "Cartographic Data Structures." *American Cartographer* 2:55–69.

Pfaltz, John L. 1976. "Surface Networks." *Geographical Analysis* 8:77–93.

Rana, Sanjay, and Jeremy Morley. 2002. *Surface Networks*. UCL Centre for Advanced Spatial Analysis, Working Paper 43. London: Centre for Advanced Spatial Analysis, University College London. Online publication.

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

Saalfeld, Alan. 2000. "Complexity and Intractability: Limitations to Implementation in Analytical Cartography." *Cartography and Geographic Information Science* 27:239–49.

Shelberg, Mark C., Harold Moellering, and Nina Siu Ngan Lam. 1983. "Measuring the Fractal Dimensions of Empirical Cartographic Curves." In *Proceedings of the Fifth International Symposium on Computer-Assisted Cartography (Auto-Carto): Environmental Assessment and Resource Management*, ed. Jack Foreman, 481–90. Falls Church: American Society of Photogrammetry and American Congress on Surveying and Mapping.

Tobler, Waldo R. 1961. "Map Transformations of Geographic Space." PhD diss., University of Washington.

———. 1965. "Computation of the Correspondence of Geographical Patterns." *Papers of the Regional Science Association* 15:131–39.

———. 1966. "Medieval Distortions: The Projections of Ancient Maps." *Annals of the Association of American Geographers* 56:351–60.

———. 1969. "Geographical Filters and Their Inverses." *Geographical Analysis* 1:234–53.
———. 1976. "Analytical Cartography." *American Cartographer* 3:21–31.
———. 1979a. "Smooth Pycnophylactic Interpolation for Geographical Regions." *Journal of the American Statistical Association* 74:519–36.
———. 1979b. "A Transformational View of Cartography." *American Cartographer* 6:101–6.
———. 1984. "Application of Image Processing Techniques to Map Processing." In *Proceedings of the International Symposium on Spatial Data Handling*, 2 vols., comp. and ed. Duane F. Marble et al., 1:140–44. Zurich: Geographisches Institut, Abteilung Kartographie/EDV, Universität Zürich–Irchel.
———. 1994. "Bidimensional Regression." *Geographical Analysis* 26:187–212.
———. 2000. "The Development of Analytical Cartography: A Personal Note." *Cartography and Geographic Information Science* 27:189–94.
———. 2004. "Thirty-Five Years of Computer Cartograms." *Annals of the Association of American Geographers* 94:58–73.
Varanka, Dalia E. 2005. "Analytical Concepts in Early Computer Cartography and Late National Topographic Mapping in the United States." In *Proceedings of the 22nd International Cartographic Conference*, in Theme 16. A Coruña, Spain: ICA. CD-ROM and online publication.
Warntz, William. 1966. "The Topology of a Socio-economic Terrain and Spatial Flows." *Papers of the Regional Science Association* 17:47–61.
Weibel, R. 1995. "Three Essential Building Blocks for Automated Generalization." In *GIS and Generalization: Methodology and Practice*, ed. J. C. Muller, J. P. Lagrange, and R. Weibel, 56–69. London: Taylor & Francis.
Wiechel, H. 1878. "Theorie und Darstellung der Beleuchtung von nicht gesetzmässig gebildeten Flächen mit Rücksicht auf die Bergzeichnung." *Der Civilingenieur*, n.f. 24:335–64.

Animated Map. Although animated maps drawn in sand to depict the movement of animals are perhaps as old as maps themselves, modern cartographic animation reflects the birth of the film industry in the early 1900s and the advent of studio-crafted animated maps in the late 1930s, when the typical movie theater supplemented its feature film with a newsreel and one or more cartoons. The invasions and advancing fronts of World War II was an obvious theme with box office potential. Experience in cartoon animation was also valuable, as exemplified in 1940 when the Disney studios released a short animation describing Germany's invasion of Poland the previous year. Arrows show the German army moving toward Warsaw and quickly encircling the city. As a part of a newsreel highlighting the tragic events unfolding in Europe, these early map animations were an effective propaganda tool for dramatizing Hitler's territorial ambitions.

The film metaphor continued to influence cartographic animation at the end of the century, when sophisticated software replaced the largely manual cel (short for celluloid) animation techniques. However helpful it was to animators, the software gave viewers little or no control over which frames made up the animation and how they were shown. Most cartographic animations included little more than the play/stop/forward/reverse controls found on the mass-produced videotape recorders introduced in the 1970s. The film/video metaphor still tied authors and viewers to a way of thinking about cartographic animation best described by the German word *Ablauf*, roughly translated as "an uninterrupted progression from beginning to end."

During the 1990s several research articles and computer programs challenged this limited view of cartographic animation. In an essay aptly titled "Animated Cartography/Thirty Years of Scratching the Surface," Craig S. Campbell and Stephen L. Egbert (1990) questioned why more had not been done with the technique since the seminal works by Norman J. W. Thrower (1961), who had discussed the development of animation in the American motion picture industry; Bruce Cornwell and Arthur H. Robinson (1966), who examined the potential of the cathode ray tube (CRT) as a drawing tool; Waldo R. Tobler (1970), who used a CRT to create an animated movie describing population growth in and around Detroit, Michigan; and Harold Moellering (1976), who experimented with animated maps as a tool for studying automobile accidents. In the late 1980s—more than a decade after Moellering's seminal article—computer programs for interactive cartographic animation began to emerge (Peterson 1993), and in 1995 Michael P. Peterson published a pioneering textbook, *Interactive and Animated Cartography*. Researchers who had begun to examine the potential of animation more systematically by defining the variables of animation and the range of applications included Alan M. MacEachren and David DiBiase (1991), who derived a strategy for mapping the diffusion of AIDS from existing cartographic data models; Daniel Dorling (1992), who presented an innovative analysis of election data that integrated statistical graphics and map animation; and Mark Monmonier (1989), who devised interactive and animated strategies for exploring spatial data.

Academic research revealed the need for a basic distinction between temporal and nontemporal cartographic animation (Dransch 1997). Temporal animation, the most common type, shows change over time, as when a time-lapse weather animation describes the movement of clouds or pressure cells. By contrast, nontemporal animation is exemplified by the fly-through, in which a coherent series of oblique views of a landscape displayed in quick succession creates the impression of flying over, past, or even through the terrain. The fly-through is usually constructed by draping a satellite image or aerial photographs over a digital elevation model (DEM), which encodes the terrain as a grid of elevation values.

In distinguishing between temporal and nontemporal animation, Doris Dransch (1997) differentiated between *Geoobjekte* (geo-objects) and *Animationsobjekte* (animation objects). In temporal animation, there is a change in the geo-objects relative to time. In nontemporal animation, there is a change in the animation objects relative to factors such as a change in the position of the "camera" or light source. Nonetheless, time is a part of all animations. According to Dransch, *Realzeit* (real time) is depicted as a time lapse in a temporal animation, and *Präsentationszeit* (presentation time) is the time actually used to show the animation, whether or not the animation depicts a temporal phenomenon. A fly-through and a historical animation might both have a presentation time of two minutes, but only the historical animation has a real time, which could be two months or two hundred years.

Many other types of nontemporal cartographic animations have been proposed. A *cartographic zoom*, for example, shows a series of maps at increasing or decreasing map scales. This form of animation has been the most difficult to automate because it involves all aspects of the cartographic abstraction process, especially the selection and simplification of features. In 2005, Google Maps implemented a version of cartographic zoom with up to twenty prescaled maps stored as individual tiles.

Another kind of nontemporal animation depicts different ways of classifying data. A *classification animation* might show the visual consequences of different methods for dividing data into categories; this approach is useful because the decision to use equal-interval breaks for a choropleth map rather than, for example, quantile or standard deviation breaks, can have a marked effect on the mapped pattern. Similarly, a *generalization animation* might explore the visual effect of holding the method of data classification constant while varying the number of categories. In addition, sound can be added to an animation to accentuate noteworthy changes in the display. The goal here is a less misleading view of the data than a static map relying on only a single classification.

By contrast, a spatial-trend animation depicts geographic change over time. An example would be an animation of the percentage of population in different age groups within a city (e.g., ages 0–4, 5–9, 10–14, etc.). This animation might reveal higher concentrations of older people closer to the city center and greater proportions of younger people, including families with children, near the periphery. The importance of physical features or boundaries can emerge, as in a spatial-trend animation for Omaha, Nebraska, that showed older populations generally closer to the older parts of the city along the Missouri River and younger populations farther out, in the western suburbs (Peterson 1993).

Another theoretical advance in the 1990s was the identification of "dynamic variables" useful in nontemporal animation (DiBiase et al. 1992). As explained by DiBiase and his colleagues at Pennsylvania State University, an appreciation of dynamic variables like *reordering* can suggest new ways of looking at data. Reordering, which involves presenting a temporal animation in a different order, can be particularly revealing. For example, in an animation depicting seismic activity, the frames could be ordered by the number of deaths caused by the earthquakes so that the more deadly events are shown first. Changing the pace of the animation can also highlight important attributes. In an earthquake animation, for instance, the duration of each scene in the animation could be made proportional to the magnitude of the earthquake or the number of deaths.

Animation can also be used in a very subtle way when a map is drawn initially or updated on the screen. The sequence in which the computer adds map elements or geographic features to the display becomes a short but potentially revealing animation even though it might only last a second or two (fig. 41). For example, an update sequence that presents the highest and lowest categories on a choropleth map first, before the other categories, focuses the viewer's attention on the extremes. This form of animation can be usefully informative to the map viewer who must wait while the software draws a large and complex map.

In addition to new forms of cartographic anima-

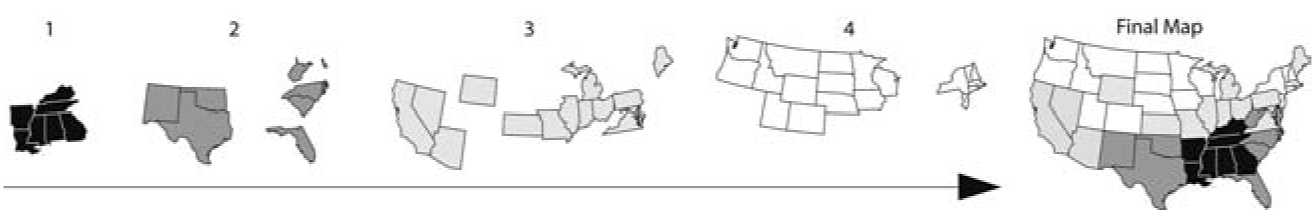

FIG. 41. ANIMATION IN THE MAP UPDATE PROCESS. A subtle form of animation that can occur in the second or two when the map is drawn on the screen of the computer. Image courtesy of Michael P. Peterson.

tion, the 1990s also witnessed new methods for adding interaction to an animated display. This enhanced flexibility was exemplified by MacChoro II, a software application that not only automated the production of individual frames but also generated an interactive display (Peterson 1993). Although limited to choropleth maps, which use shadings to depict values for areal units such as states or counties, MacChoro II used interactive dialogs to control the selection of variables and data classification methods. The individual maps were then constructed and stored in memory at a speed of approximately one map per second. The animation was then displayed and a pop-up control palette provided so that the viewer could change the speed and direction of the animation. Further enhancements for viewing cartographic animations on the World Wide Web were developed using JavaScript, a scripting language that increased the power and flexibility of Netscape, Internet Explorer, and other browsers (Peterson 1999).

These methods of animation were closely linked with cartographic visualization, an analytical form of cartography intended to help individuals, or groups of individuals, think spatially. In contrast to the traditional view of the map as a form of presentation for mass or specialized audiences, cartographic visualization, also known as geographic visualization, was promoted in the late twentieth century as a highly interactive form of map use customized for individual viewers (MacEachren and Kraak 1997; Hallisey 2005). Although the distinction between "maps for analysis" and "maps for presentation" is not easily defined, cartographers previously had considered animation more a presentation medium than an analytical tool. Nonetheless, map use is, by definition, an inquisitive process that incorporates varying levels of analysis. Every map can be used for analysis, even maps on paper or animations that are supposedly designed for presentation. Although a cartographic animation is a presentation that exploits time as a visual variable, like any other map presentation, it becomes more valuable when used for analysis.

In sum, cartographic animation during the twentieth century was limited by the difficulty of constructing and distributing animations and by a continued fixation on static maps. Even so, the animated map could be particularly useful in revealing spatial-temporal patterns, and computer technology was making it possible not only to create different types of cartographic animations but also to distribute them efficiently to a wider audience. Experience with animated maps during the century indicated that their continued development would depend on the extent to which interaction was incorporated in their creation and use.

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SEE ALSO: Cinema and Cartography; Interactive Map; Narrative and Cartography; Time, Time Geography, Temporal Change, and Cartography; Visualization and Maps

BIBLIOGRAPHY:

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

Cornwell, Bruce, and Arthur H. Robinson. 1966. "Possibilities for Computer Animated Films in Cartography." *Cartographic Journal* 3:79–82.

DiBiase, David, et al. 1992. "Animation and the Role of Map Design in Scientific Visualization." *Cartography and Geographic Information Systems* 19:201–14.

Dorling, Daniel. 1992. "Stretching Space and Splicing Time: From Cartographic Animation to Interactive Visualization." *Cartography and Geographic Information Systems* 19:215–27.

Dransch, Doris. 1997. *Computer-Animation in der Kartographie: Theorie und Praxis*. Berlin: Springer.

Hallisey, Elaine J. 2005. "Cartographic Visualization: An Assessment and Epistemological Review." *Professional Geographer* 57:350–64.

MacEachren, Alan M., and David DiBiase. 1991. "Animated Maps of Aggregate Data: Conceptual and Practical Problems." *Cartography and Geographic Information Systems* 18:221–29.

MacEachren, Alan M., and M. J. Kraak. 1997. "Exploratory Cartographic Visualization: Advancing the Agenda." *Computers & Geosciences* 23:335–43.

Moellering, Harold. 1976. "The Potential Uses of a Computer Animated Film in the Analysis of Geographical Patterns of Traffic Crashes." *Accident Analysis and Prevention* 8:215–27.

Monmonier, Mark. 1989. "Geographic Brushing: Enhancing Exploratory Analysis of the Scatterplot Matrix." *Geographical Analysis* 21:81–84.

Peterson, Michael P. 1993. "Interactive Cartographic Animation." *Cartography and Geographical Information Systems* 20:40–44.

———. 1995. *Interactive and Animated Cartography*. Englewood Cliffs: Prentice Hall.

———. 1999. "Active Legends for Interactive Cartographic Animation." *International Journal of Geographical Information Science* 13:375–83.

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

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

Antarctica

Antarctica. Antarctica is the highest, driest, and coldest of earth's landmasses. Nearly twice the size of Australia, Antarctica is almost completely covered by a nearly 12,000,000 square kilometer ice cap. With an average thickness of over 2,200 meters, this ice cap contains 90 percent of the planet's freshwater. Numerous books have chronicled the continent's early exploration and scientific significance (e.g., Fogg 1992; McGonigal and Woodworth 2001; *Antarctica* 1985).

Mapmakers hypothesized an Antarctic landmass long before explorers confirmed its existence. Although the elaborate coastlines and feature names on an anonymous ca. 1530 hand-drawn world map in the Vatican library are nothing more than "pure invention" (Van Duzer 2007, 207), Gerardus Mercator, Abraham Ortelius, and other prominent sixteenth-century mapmakers offered similarly hypothetical renderings of a fictitious southern continent (Richardson 1993). Although James Cook is sometimes credited with having discovered Antarctica when he ventured beyond the Antarctic Circle on his three voyages of discovery, 1768–79, he was deterred by fog and floating ice and never sailed closer than about 120 kilometers. Explorers did not set foot on the continent until 1821, and then only briefly. Subsequent voyages in search of the south magnetic pole in the 1830s and for whales throughout the nineteenth century resulted only in widely spaced sightings, and it remained unclear whether Antarctica was a continuous landmass or merely a group of islands.

Antarctica remained an enigma on the world map until the twentieth century, with its existence as a continent still largely conjectural, deduced from rock samples collected from the surrounding southern ocean by the oceanographic research vessel HMS *Challenger* in 1873–74. The Sixth International Geographical Congress, held in London in 1895, unanimously passed a resolution that recognized lack of knowledge of the region as "the greatest piece of geographical exploration still to be undertaken" (International Geographical Congress 1896, 176). This limited contemporary cartographic knowledge of Antarctica was evident in maps of the Antarctic regions published by John George Bartholomew in 1898 (fig. 42).

The International Geographical Congress prompted a series of expeditions from Belgium, Sweden, Germany, Britain, Japan, Norway, France, and Australia during what is often called the Heroic Era of Antarctic exploration. These efforts included coastal charting expeditions in areas accessible by ship, for example, the Charcot expeditions to the Antarctic Peninsula, as well as inland probes to locate the south geographic and geomagnetic poles by explorers such as Robert Falcon Scott, Ernest Henry Shackleton, and Douglas Mawson. These expeditions only documented limited areas of features visible to the immediate flanks of their sledging journeys and did little to improve the overall cartographic representation of the inland continent. In 1902 Scott and Erich von Drygalski separately attempted to observe and photograph the continent from tethered balloon flights, but their ships were too far from land features to produce information useful for mapping. The maps produced during this era were typically included in expedition reports rather than as stand-alone cartographic products (Amundsen 1912; Mawson 1915; Scott 1905; Shackleton 1909).

Antarctica's cartographic unveiling began in 1928, when Sir George Hubert Wilkins flew from a Norwegian whaling base on Deception Island for a ten-hour flight along the eastern side of the Antarctic Peninsula. This mission demonstrated the huge potential of aircraft for Antarctic exploration but also exposed the limitations of relying solely on aerial observation. Wilkins misinterpreted several transverse glaciers for ice-filled channels cutting through the peninsula (Nasht 2005).

Richard Evelyn Byrd further developed the use of aircraft for exploration during three expeditions to Little America on the Ross Ice Shelf. In his 1928–30 expedition, Byrd made a successful long-distance flight over the South Pole. His 1933–35 and 1939–41 expeditions included aerial exploration of large areas in West Antarctica, the Transantarctic Mountains, and the region between the Ross Sea and the Weddell Sea (Byrd 1935). In 1929, the American Geographical Society published the first Antarctic map to include information from aircraft observation (fig. 43). Produced at a scale of 1:20,000,000, the map included Byrd's new discoveries and perpetuated Wilkins's errors. A similar map, produced by the National Geographic Society and released as a supplement in its October 1932 magazine, charts the flight lines of Wilkins and Byrd as well as those of Mawson and his fellow pioneer aviator Lars Christensen on the other side of the continent.

Mawson undertook two ship voyages to the coast of East Antarctica in 1929–30 and 1930–31. These voyages along the edge of the ice connected the disparate sightings of the previous century to reveal a continuous coastline (Price 1962). This work resulted in the map *Antarctica* published in 1939 by the Commonwealth of Australia at a scale of 1:10,000,000 (Bayliss and Cumpston 1939). In the 1930s, Christensen, a Norwegian whaling magnate as well as an aviator, combined his East Antarctica whaling fleet operations with reconnaissance aerial photography for mapping (Christensen 1938). This effort resulted in the Hansen series of eleven 1:250,000 charts from 20°E to 80°E published in 1946 by the Whalers Assurance Association in Sandefjord. In 1937–38 the private British Graham Land Expedition, led by John Rymill, demonstrated an integrated approach to exploration and mapping by using a small ship, light plane, and dog sled teams to explore the Antarctic Peninsula and correct Wilkins's earlier misinterpretations (Rymill and Stephenson 1938).

In January 1939 a German expedition shot extensive aerial photography in Queen Maud Land from ship-launched Dornier Wal flying boats, but mapping from that expedition was not based on ground control and contained substantial errors of position (Burke 1994).

The first half of the twentieth century witnessed territorial claims on the Antarctic continent by Argentina, Australia, Chile, France, New Zealand, Norway, and the United Kingdom. These claims were based largely on the sector theory, whereby meridians converging at the pole

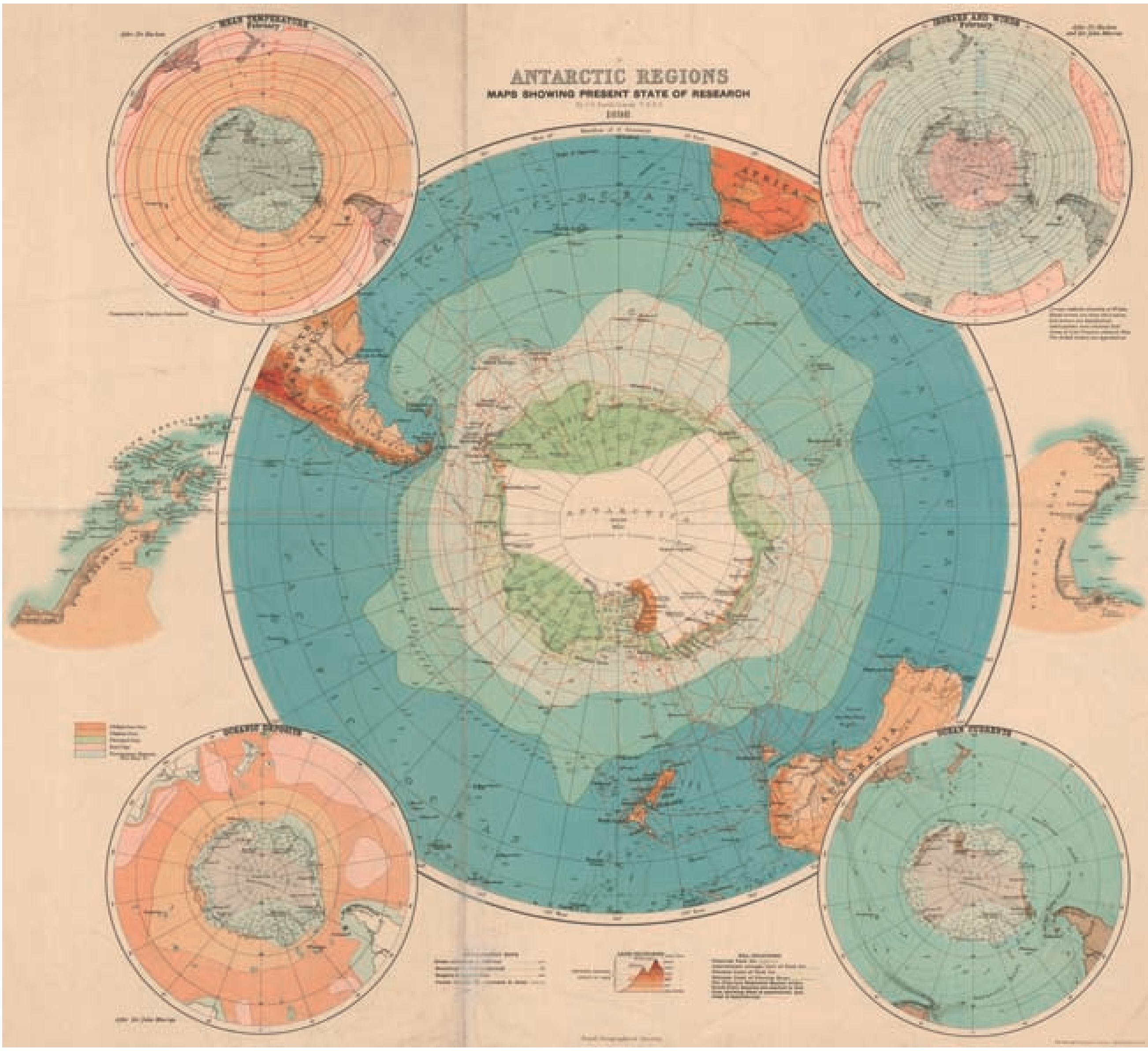


FIG. 42. *ANTARCTIC REGIONS: MAPS SHOWING PRESENT STATE OF RESEARCH*, PRODUCED BY J. G. BARTHOLOMEW, SEPTEMBER 1898. Made for the Royal Geographic Society for special circulation, the map shows the state of research and the composite extent of cartographic knowledge of the Antarctic continent at the start of the twentieth century.
Size of the original: 48.8 × 53.8 cm. Image courtesy of the National Library of Scotland, Edinburgh.

carved out pie-like slices of territory, rather than on discovery or effective occupation. Moreover, the claims of the United Kingdom, Chile, and Argentina overlapped in the Antarctic Peninsula. Neither the United States nor the Soviet Union recognized these claims. Germany had planted flags on the coast and dropped others inland during its 1939 mapping expedition, but no other country recognized this potential claim, which evaporated with the Nazis' defeat in World War II. The seven remaining territorial claims were set aside under the Antarctic Treaty of 1959, a consequence of the international cooperation inspired by the International Geophysical Year, 1957–58. These claims remain dormant while the Antarctic Treaty is in place. Dormant perhaps, but neither erased nor forgotten: the claim boundaries were shown on the Australian 1:10 million map series of Antarctica, such as the seventh edition published in 1986 (fig. 44), and in the early twenty-first century Argentina continued to advertise its sector, "Antártida Argentina," on national maps and atlases.

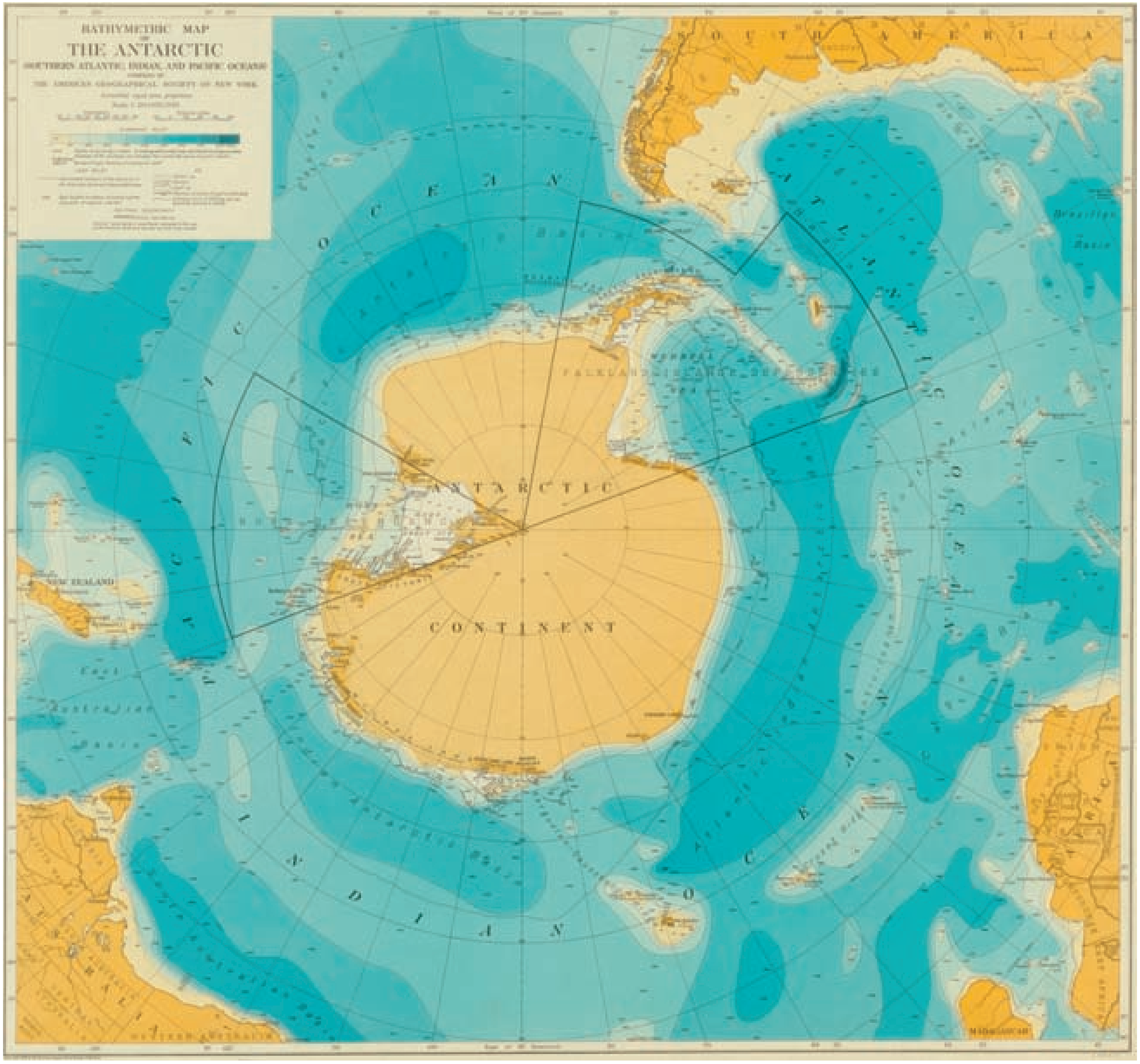


FIG. 43. *BATHYMETRIC MAP OF THE ANTARCTIC*, 1929. Azimuthal equal area projection with sea ice and political boundaries at a scale of 1:20,000,000. Relief shown by soundings, bathymetric tints, spot heights, and contours. Compiled by the American Geographical Society of New York, it includes the first information gathered from aircraft flights. Size of the original: 55.6 × 59.5 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries. Permission courtesy of the American Geographical Society, New York.

Antarctic activity changed after World War II as large national agencies began to dominate exploration and mapping. Operation Highjump, the massive U.S. Navy expedition in 1946–47, took some 65,000 aerial photographs of nearly half of the Antarctic coastline with trimetrogon cameras. The mission was supported by thirteen ships, a submarine, seaplanes, a C-47 aircraft, and over 4,000 men. Yet without the requisite ground control, this immense amount of data was of little immediate use to careful cartographers (Rose 1980).

In the early 1950s the United Kingdom formed the British Antarctic Survey and began establishing control for 1:200,000 mapping along the Antarctic Peninsula. Operation Deep Freeze, an American mapping project that operated from 1955 to 1959, took aerial photographs of nearly 4,000,000 square kilometers of

FIG. 44. *ANTARCTICA, 1:10,000,000*, 7th EDITION, 1986. Polar stereographic projection with contours and hill shading showing the boundaries of the dormant territorial claims. Produced by the Division of National Mapping, Department of Resources and Energy, Canberra, in association with the Antarctic Division, Department of Science, Kingston, Tasmania. Uses topographic information provided by member countries of the Scientific Committee on Antarctic Research.
Size of the original: 82.5 × 74 cm. Map courtesy of the Australian Antarctic Division © Commonwealth of Australia 1986.

coastal and inland features poleward of 70°S and used astrofix ground control (positioning by celestial navigation methods) to begin a series of 1:250,000 maps of the Transantarctic Mountains and West Antarctica. The Soviet Antarctic Expedition of 1955–56 explored East Antarctica using extensive aerial photography, astrofixes, and over-ice traverses for inland ice cap elevations. Japan established Syowa Base on Ongul Island and produced a 1:5,000 map of the area in 1957.

While exploratory flights acquired vast numbers of aerial photographs, they were only converted to maps slowly because photogrammetric techniques required extensive ground control in mountainous areas, and it was difficult to bridge the featureless ice cap between rock features. Astronomic fixes were the only techniques available for ground control, and these were often unreliable because of problems with refraction and the difficulty of getting precise time from radio signals affected by magnetic storms. Electronic distance measuring equipment introduced in 1959 enabled accurate geodetic networks in areas of exposed rock such as the Prince Charles Mountains (by Australia), the Transantarctic Mountains (by the United States), and the Antarctic Peninsula (by the United Kingdom). However ambitious, this attempt to produce regional geodetic frameworks was limited to continuous mountain areas and needed extensive helicopter support to transport survey parties to high-elevation triangulation sites with unobstructed line-of-sight intervisibility.

Establishment of permanent scientific bases led to increased cartographic activity, which was accelerated when the International Council of Scientific Unions (ISCU) approved an International Geophysical Year (IGY) program for 1957–58 that focused on Antarctica. In 1958 the twelve nations involved in the IGY formed the Special (later Scientific) Committee on Antarctic Research (SCAR) under the auspices of the ISCU. The following year the Working Group on Cartography was established after it became clear that topographic mapping and charting were essential for planning and recording scientific results. The working group's name was changed to Geodesy and Cartography in 1961, and to Geodesy and Geographic Information in 1988, to better reflect its broadening scope of activity. Australia chaired the working group from 1961 until 2002, when the unit was split into separate working groups focused on geodesy and geographic information.

SCAR coordinated international Antarctic mapping efforts since its inception. The working group actively promoted cartographic products and first-surface, topographic mapping (in contrast to the mapping of ice thickness and other subsurface phenomena); provided guidelines on scale, content, and projections through a number of standing resolutions; and encouraged standardization of topographic symbols through a published set of standards. SCAR also published *Catalogue of Maps and Charts of Antarctica* as a series from 1960 and introduced the free exchange of cartographic products among Antarctic mapping centers. In 1992 the SCAR working group addressed the question of duplicate names for geographic features advocating a principle of "one feature one name." While there is considerable duplication of names of features on early maps, the issue is complex because of inaccurate feature descriptions and the large number of languages involved. Because of this, Italy produced and maintained an online composite gazetteer of all member-approved geographic names as a reference to avoid further duplication. This composite gazetteer is available from the Australian Antarctic Division's website.

Free exchange of maps and data fostered production of several atlases, and the United States produced an extensive map folio series (fig. 45). In 1966 the Soviet Union released the massive *Atlas Antarktiki*, complemented by a Russian-language descriptive summary published in 1969. The beautiful cartography of the atlas's 225 plates took ten years to produce, and the two-volume set, which covered the complete continent with large-scale maps of rock areas and thematic map information on weather and geophysical phenomena, successfully summarized scientific knowledge of Antarctica at the time of its publication (fig. 46). In 1978 the Geographical Survey Institute of Japan, Kokudo chiriin 国土地理院, published *Magnetic Maps 1975 of the Antarctic*, an atlas of eight maps. Another large-format publication, *Antarctica: Glaciological and Geophysical Folio* (Drewry 1983), produced by the Scott Polar Research Institute at the University of Cambridge, offered further insights about the interior of the continent and the land beneath the ice.

In the late 1960s, low-resolution images from weather satellites began to be applied to mapping. Initially used to monitor the extent and shape of the large ice shelves, this technology took a big step forward in 1972 with the launch of the Earth Resources Technology Satellite (ERTS, later renamed Landsat 1), which enabled a single-format image to cover the same area as 1,000 aerial photographs. With an 80-meter pixel resolution and multispectral layers (bands), Landsat 1 was used extensively to revise planimetric positions on existing maps, some of which were more than 100 kilometers in error. Satellite imagery quickly revolutionized mapping at scales of 1:250,000 and smaller. The Soviet Union also employed small-scale photographs from its Soyuz manned satellites in the 1970s for photogrammetric mapping over Antarctic regions. Continued improvements in the resolution of imagery through the SPOT (Système Probatoire d'Observation de la Terre) and Landsat series of satellites encouraged mapping at scales of 1:25,000 and larger (fig. 47).

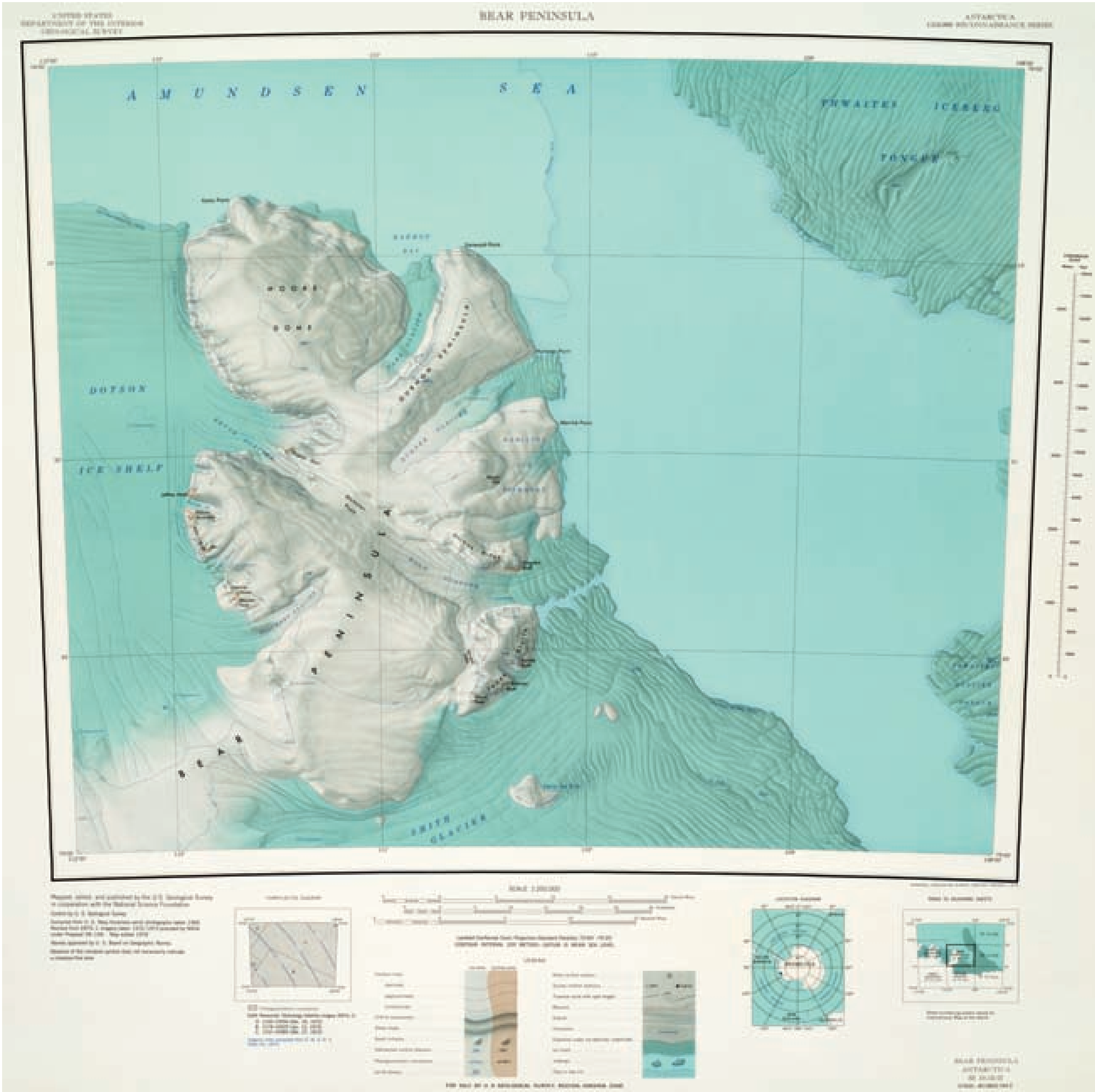


FIG. 45. *BEAR PENINSULA*, ANTARCTICA, 1:250,000, 1978. The Topographic Reconnaissance Map series was the primary source for the planning, logistic support, and multidisciplinary investigations of the U.S. Antarctic Research Program. Produced by U.S. Geological Survey (USGS), in cooperation with the National Science Foundation, Washington, D.C. Polar stereographic projection, with contour interval of 200 meters and shaded relief from satellite imagery.
Size of the original: 60.5 × 60.3 cm.

By 1980 the application of satellite technology to mapping had been supplemented by improved geodetic positioning from satellites. Initially using fixed cameras to photograph satellites against star backgrounds for space triangulation, this technique was replaced in the early 1970s by mobile Doppler-based systems from satellites. As satellite positioning systems improved, SCAR tested the Global Positioning System (GPS) in 1988, and when GPS provided a reliable instantaneous approach to positioning, ground control was no longer a serious impediment. In 1992 the SCAR Working Group created the Geodetic Infrastructure of Antarctica (GIANT) project to establish a core network of highly accurate points using continuous transmission of GPS data by satellite to

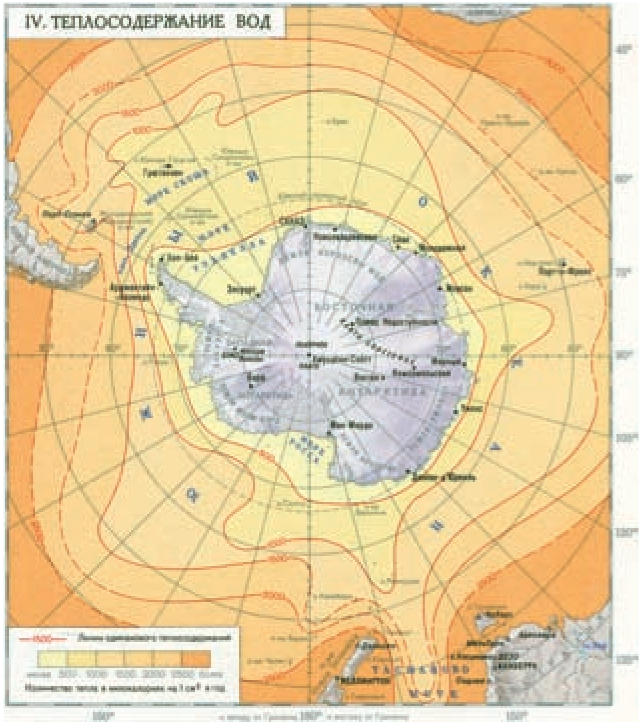


FIG. 46. *TEPLOSODERZHANIYYE VOD*, HEAT CONTENT OF WATER, BY V. G. KORT, 1:80,000,000. The map shows distribution of heat reserves accumulated in the waters of the Southern Ocean during the summer season. The lines of equal heat content and the color scale show heat from less than 500 to more than 2,500 kilocalories/cm^2/year. Data come from expeditions of the RRS *Discovery* and *Discovery II* (1925–51) and the RV *Ob'* (1955–58) (*Atlas of Antarctica, Vol. I, Moscow, 1966* [*Soviet Geography: Review & Translation* 8, nos. 5–6] [1967]: 394).
Size of the original: 14.7 × 12.9 cm. From *Atlas Antarktiki*, 2 vols. (Moscow: Glavnoye Upravleniye Geodezii i Kartografii, 1966–69), vol. 1, pl. 109 IV.

scientific agencies worldwide. This framework allowed the crustal movement of the sites to be monitored and provided a common foundation for all geodetic control points in Antarctica.

By the mid-1980s mapping of the continent was reasonably complete. With digital satellite data readily available, the emphasis turned to digital maps, supplemented by hard copy products only when necessary. Countries began making their data available in digital formats. In 1993 SCAR released the Antarctic Digital Database (ADD), which became the premier source of vector topographic data for the entire continent. The British Antarctic Survey (BAS) published the data on CD-ROM and in 2000 version 4.1 was made available at the SCAR website.

By the end of the century the availability of satellite imagery had revolutionized the cartography of Antarctica. The *Atlas of Antarctica*, which includes 136 topographic maps derived from satellite radar altimetry, is a good example of the use of satellite data (Herzfeld 2004). Each map is presented together with a description of glaciological and topographical features. Integrating the massive volume of geophysical data from other scientific disciplines became a new cartographic focus for SCAR, within which various specialist groups coordinated the compilation of geophysical databases and cartographic products such as ADGRAV (Antarctic Digital Gravity Synthesis) for gravity data, ADMAP (Antarctic Digital Magnetic Anomaly Project) for geomagnetic data, BEDMAP (Antarctic Bedrock Mapping Project) for bedrock topography, and the high-resolution Radarsat Antarctic Mapping Project (RAMP) and its associated digital elevation model (DEM) (Liu et al. 2001). The DEM incorporates topographic data from satellite radar altimetry, airborne radar surveys, the ADD, and large-scale topographic maps from the U.S. Geological Survey (USGS) and the Australian Antarctic Division (fig. 48).

By the twenty-first century, many national governments throughout the world had adopted the online national atlas as a common cartographic strategy for integrating topographic, remote sensing, and other thematic data and making the information readily accessible worldwide. As Antarctica had no official inhabitants or national government, SCAR coordinated national approaches by countries involved in Antarctic cartography. Several nations make their Antarctic data available on national websites such as the USGS. The Australian Antarctic Division makes a wide range of data and products readily available for web mapping at its online Australian Antarctic Data Centre.

JOHN MANNING

SEE ALSO: Arctic, The; Boundary Disputes; Geographic Names: (1) Applied Toponymy, (2) Gazetteer; Geopolitics and Cartography; International Geophysical Year; Scientific Discovery and Cartography

BIBLIOGRAPHY:

Amundsen, Roald. 1912. *The South Pole: An Account of the Norwegian Antarctic Expedition in the "Fram," 1910–1912*. Trans. Arthur G. Chater. London: John Murray.

Antarctica: Great Stories from the Frozen Continent. 1985. Surry Hills: Reader's Digest Services.

Bayliss, E. P., and J. S. Cumpston. 1939. *Handbook and Index to Accompany a Map of Antarctica*. Canberra: L. F. Johnston, Commonwealth Government Printer.

Burke, David. 1994. *Moments of Terror: The Story of Antarctic Aviation*. Kensington, N.S.W.: NSW University Press.

Byrd, Richard Evelyn. 1935. *Discovery: The Story of the Second Byrd Antarctic Expedition*. New York: G. P. Putnam's Sons.

Christensen, Lars. 1938. *My Last Expedition to the Antarctic, 1936–1937*. Oslo: Johan Grundt Tanum.

Drewry, D. J., ed. 1983. *Antarctica: Glaciological and Geophysical Folio*. Cambridge: Scott Polar Research Institute, University of Cambridge.

Fogg, G. E. 1992. *A History of Antarctic Science*. Cambridge: Cambridge University Press.

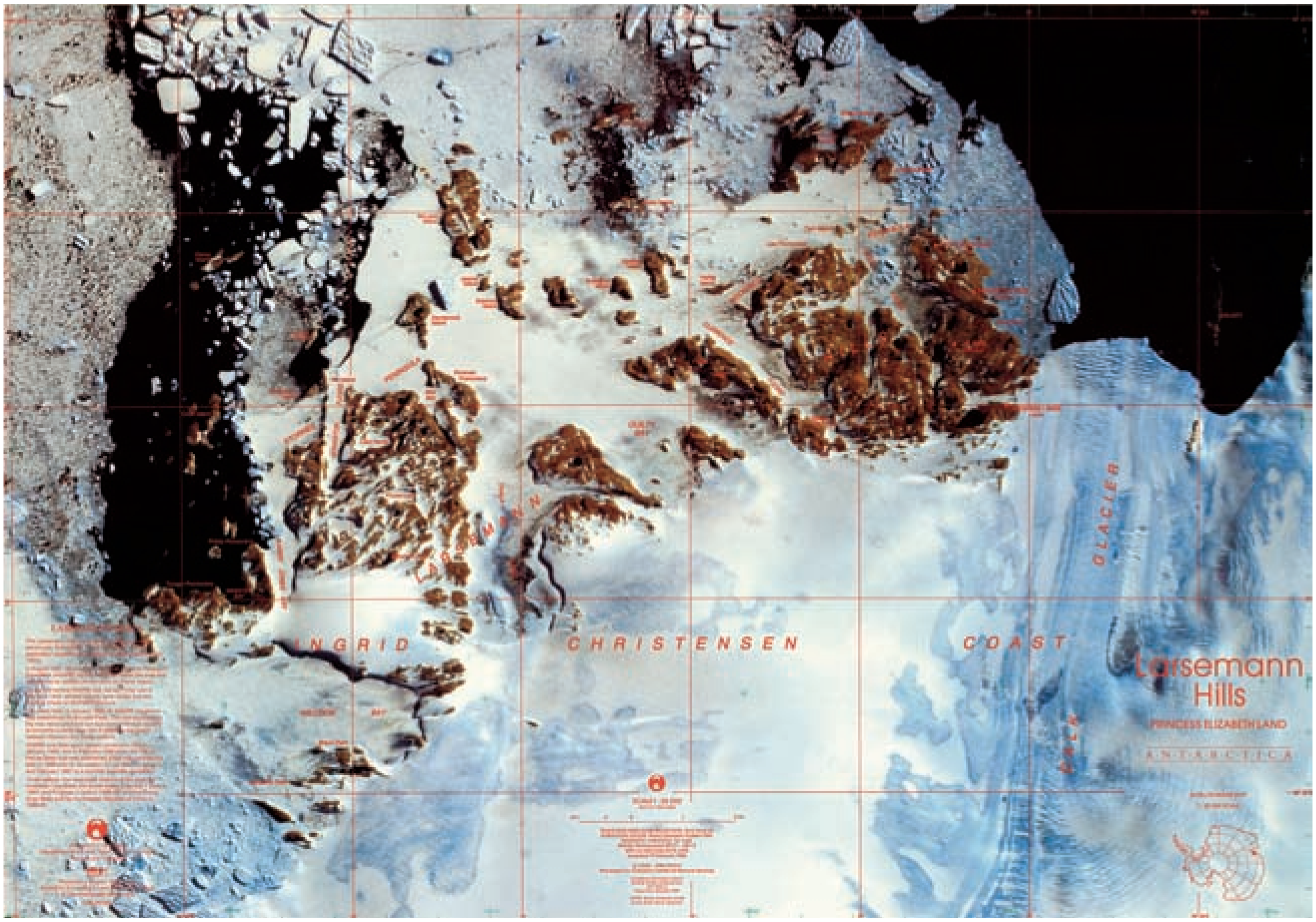


FIG. 47. *LARSEMANN HILLS–PRINCESS ELIZABETH LAND*, 1:25,000, 2d ED., 1990. Satellite image map with topographic map on the reverse side, on a Universal Transverse Mercator projection. Produced by the Australian Surveying and Land Information Group for the Australian Antarctic Division from 1988 multispectral SPOT imagery processed by the Australian Centre for Remote Sensing; digitally enhanced and direct digital techniques used in printing.
Size of the original: 70 × 101 cm. Map courtesy of the Australian Antarctic Division © Commonwealth of Australia 1990.

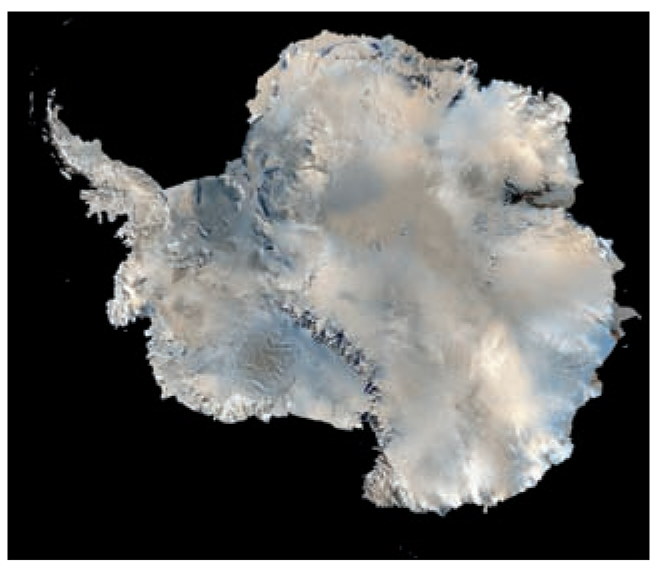


FIG. 48. RADAR SATELLITE IMAGE MOSAIC OF ANTARCTIC ICE SHEET. Made using Advanced Very High Resolution Radiometer (AVHRR) images collected between 1980 and 1994. Original digital mosaic corrected into polar stereographic projection by the National Remote Sensing Center, United Kingdom. Image base modified by USGS and available online from USGS National Mapping Center and as a hardcopy USGS 1-2560 at a scale of 1:5,000.
Size of the original: 98 × 137 cm. From Richard S. Williams and Jane G. Ferrigno, eds., *State of the Earth's Cryosphere at the Beginning of the 21st Century: Glaciers, Global Snow Cover, Floating Ice, and Permafrost and Periglacial Environments*, Satellite Image Atlas of Glaciers of the World, 1386A (Washington, D.C.: U.S. G.P.O., 2012), fig. 6A. Image courtesy of the U.S. Geological Survey.

Herzfeld, Ute Christina. 2004. *Atlas of Antarctica: Topographic Maps from Geostatistical Analysis of Satellite Radar Altimeter Data*. Berlin: Springer.

International Geographical Congress. 1896. *Report of the Sixth International Geographical Congress, Held in London, 1895*. London: John Murray.

Liu, Hongxing, et al. 2001. *Radarsat Antarctic Mapping Project Digital Elevation Model Version 2*. Boulder: National Snow and Ice Data Center. Online publication.

Mawson, Douglas. 1915. *The Home of The Blizzard: Being the Story of the Australasian Antarctic Expedition, 1911–1914*. 2 vols. London: Heinemann.

McGonigal, David, and Lynn Woodworth. 2001. *Antarctica: The Complete Story*. Auckland: Random House New Zealand.

Nasht, Simon. 2005. *The Last Explorer: Hubert Wilkins, Australia's Unknown Hero*. Sydney: Hodder.

Price, A. Grenfell. 1962. *The Winning of Australian Antarctica: Mawson's B.A.N.Z.A.R.E. Voyages, 1929–31, Based on the Mawson Papers*. Sydney: Angus and Robertson.

Richardson, W. A. R. 1993. "Mercator's Southern Continent: Its Origins, Influence and Gradual Demise." *Terrae Incognitae* 25:67–98.

Rose, Lisle A. 1980. *Assault on Eternity: Richard E. Byrd and the Exploration of Antarctica, 1946–47*. Annapolis: Naval Institute Press.

Rymill, John, and A. Stephenson. 1938. *Southern Lights: The Official Account of the British Graham Land Expedition, 1934–1937*. London: Chatto and Windus.

Scientific Committee on Antarctic Research (SCAR). 1988. *Antarctica: A Catalogue of Maps & Charts*. 5th ed. Belconnen, ACT: Australian Surveying and Land Information Group, Department of Administrative Services.

Scott, Robert Falcon. 1905. *The Voyage of the "Discovery."* 2 vols. London: Macmillan.

Shackleton, Ernest Henry. 1909. *The Heart of the Antarctic: Being the Story of the British Antarctic Expedition, 1907–1909*. 2 vols. London: William Heinemann.

Van Duzer, Chet A. 2007. "Cartographic Invention: The Southern Continent on Vatican MS Urb. Lat. 274, Folios 73v–74r (*c*.1530)." *Imago Mundi* 59:193–222.

Antiquarian Maps and Grand Larceny. Although there have been many stories of map theft throughout history, particularly in the context of military reconnaissance, political intrigue, and colonial aggrandizement, the theft of antiquarian maps from public and private institutional collections for resale and personal profit gained national and international attention during the last three decades of the twentieth century, continuing into the first decade of the twenty-first. While these thefts have focused on major university, urban public, and privately endowed libraries in the Northeastern and Midwestern United States, institutions in Canada and Europe have also been victimized. During this time, at least a dozen people have been arrested and convicted of stealing antiquarian cartographic materials. These individuals include Michael Huback, Stephen Chapo, Andrew P. Antippas, Charles Lynn Glaser, Robert M. Willingham Jr., Fitzhugh Lee Opie, William Charles McCallum, Daniel Spiegelman, Gilbert Bland Jr., and E. Forbes Smiley III, who primarily preyed on American libraries, while Peter Bellwood, Melvin Nelson Perry, and Ian Hart operated in various European countries (Tony Campbell, personal communication, 2007; Finnegan 2005; Harvey 2000).

Several related factors explain why these crimes have occurred at this time and in these places. These include the establishment of collections of rare books, atlases, and maps for the public beginning in the mid to late nineteenth century; the rise of map librarianship as a profession with a strong emphasis on publishing cartobibliographies and disseminating cataloging records through online databases; and the widespread development of map collecting as a popular hobby and investment, with the concurrent rise of the sale of antiquarian maps and atlases as a profitable business.

While the collecting of rare books and cartographic materials has a long tradition in Europe, the establishment of privately endowed and publicly funded urban and university libraries with departments specializing in manuscripts, rare books, atlases, and maps became increasingly prevalent in the United States during the last decades of the nineteenth century. Libraries such as the George Peabody (Johns Hopkins University), Newberry (Chicago), James Ford Bell (University of Minnesota), Beinecke (Yale University), and Houghton (Harvard University) were established and funded by late nineteenth- and twentieth-century philanthropists. Public institutions, including the Library of Congress, New York Public Library, Boston Public Library, and Free Library of Philadelphia built similar collections of antiquarian materials. As these collections grew and prospered, curators continued to make their materials more readily available to scholars and the public, initially through published book and map bibliographies, and by the last third of the century, through electronic and online databases (Kandoian 2007; Wolf 1986).

Aided by these bibliographic publications and a growing body of literature on the history of cartography that discussed the importance or rarity of individual maps or various cartographic genres, map collecting became a popular hobby and a lucrative investment among private individuals, primarily in North America and Europe (Clancy and Harvey 2005). Evidence of this growing popular interest in map collecting can be seen in the establishment of an international map society (International Map Collectors' Society) and numerous regional map societies and map fairs supported by map collectors and enthusiasts in the United States and Canada (Grim 1996). Concurrently, a number of popular periodicals promoting map collecting were published, notably the *Map Collector*, *Mercator's World*, *IMCoS Journal*, the *Portolan*, and *MapForum*.

The rise of map thefts and their increased publicity have forced map and rare book librarians to address these issues. For most institutions, it has meant increased attention to security—registration of readers with photo identification, individual retrieval slips for each item examined, staff and camera surveillance while rare materials are examined, lockers for researchers to store personal belongings, books tagged with metal strips, and the installation of metal detectors. Librarians have realized the need to comprehensively inventory and catalog their collections, along with marking single maps and maps in books or atlases with a library stamp. An increasingly important process that aids librarians in detecting missing items and reclaiming stolen materials is making reference surrogates (photostats, photographs, microfilm, and digital images). These reproductions have been utilized successfully to record and identify a map's fingerprint or individual peculiarities that cannot easily be removed (annotations, folds, stains, wormholes, tears, repairs). In order to deter sales of stolen maps and to aid in their recovery, libraries have begun to compile lists of missing items, which are being shared online (John Woram, personal communication, 2006).

The impact of map thefts goes beyond the damage to a particular institution's collections. These crimes also directly affect curators, dealers, and collectors. From the librarian's perspective, portions of the cultural and historical heritage, which has been entrusted to their care for public use, have been damaged and in some cases, entirely lost. The integrity and provenance of books, atlases, and personal collections have been severely diminished by these losses. Dealers, who bought and resold these materials, suffer financially as the stolen items are returned to their respective institutions. Likewise, collectors, who unknowingly purchased stolen items, were often requested to return maps to dealers and institutions, thus diminishing the size and value of personal collections and their respect for the dealers and the institutions.

What is clear is that the entire map community has a vested interest in reporting and prosecuting thieves as well as developing innovative ways to secure collections, reducing opportunities for those who steal and damage cultural artifacts. Through the cooperative efforts of institutions, curators, collectors, and dealers by the beginning of the twenty-first century, not only are offenders being caught in the act of removing maps from volumes and collections, but they are being prosecuted, convicted, required to make restitution, and sent to prison. It is equally clear that these crimes are serious breaches of trust within the map community, and those who violate that trust will be identified and punished.

RONALD E. GRIM

SEE ALSO: Collecting, Map; Libraries, Map; Libraries and Map Collections, National

BIBLIOGRAPHY:

Clancy, Robert, and Jenny Harvey. 2005. "Whither the Collecting of Maps (or Looking Back to the Future)." *MapForum*, no. 7:18–21.

Finnegan, William. 2005. "A Theft in the Library: The Case of the Missing Maps." *New Yorker* 17 October, 64–80.

Grim, Ronald E. 1996. "Map Societies in the United States." Philip Lee Phillips Society *Newsletter* 1, no. 1:14–17.

Harvey, Miles. 2000. *The Island of Lost Maps: A True Story of Cartographic Crime*. New York: Random House.

Kandoian, Nancy A. 2007. "Cartobibliography for Catalogers: Reference Materials to Support the Identification of Early Printed Maps." *Journal of Map and Geography Libraries* 3:45–78.

Wolf, Eric W. 1986. "Cartobibliography: Whither and Why." *Bulletin*, Special Libraries Association, Geography and Map Division, no. 144:28–34.

Arctic, The. General knowledge of the terrestrial geography of Arctic regions was largely complete by the end of the twentieth century, although much detailed undersea survey remained to be done, a fact readily apparent in atlas maps that portrayed the Arctic Ocean as a blank area, often labeled "unexplored." As in preceding centuries, mapping of the Arctic proceeded principally by exploration. After all, a region cannot be mapped until it is known. Until quite recently, mapping on the often featureless and constantly moving ice of the Arctic Ocean was a considerable challenge to cartographers. On land, and even using aerial survey, the vast unbroken distances made mapping difficult; as late as 1996 the A-5 sheet of the *World Aeronautical Chart*, published by the Canadian government, contained a caveat at the northeastern tip of Ellesmere Island warning that "Greenland is up to 5 nautical miles out of position relative to Canada" (fig. 49).

From 1898 to 1902 the Norwegian explorer Otto Neumann Sverdrup led an expedition to explore the last major part of the Arctic: the area west of Ellesmere Island. With a team that included cartographer Gunnerius Ingvald Isachsen, Sverdrup methodically mapped for the first time some 250,000 square kilometers and 2,800 kilometers of coastline of what are now the Sverdrup Islands. One of the recurring themes of Arctic cartography is the use of maps to claim sovereignty, and Sverdrup's maps provide a good but hardly extreme example of this tendency (Sverdrup 1904).

Sverdrup precipitated a controversy by claiming the land for Norway. His claim created a problem for the Canadian government, which regarded most of the Arctic north of North America as Canadian territory inherited from Britain, which had been highly active in the Arctic during the nineteenth century. It was a Canadian senator, Pascal Poirier, who in 1907 seems to have invented the "sector principle," which divided the Arctic into pie-sliced shapes meeting at the North Pole. This principle, still espoused by Canada, has been supported

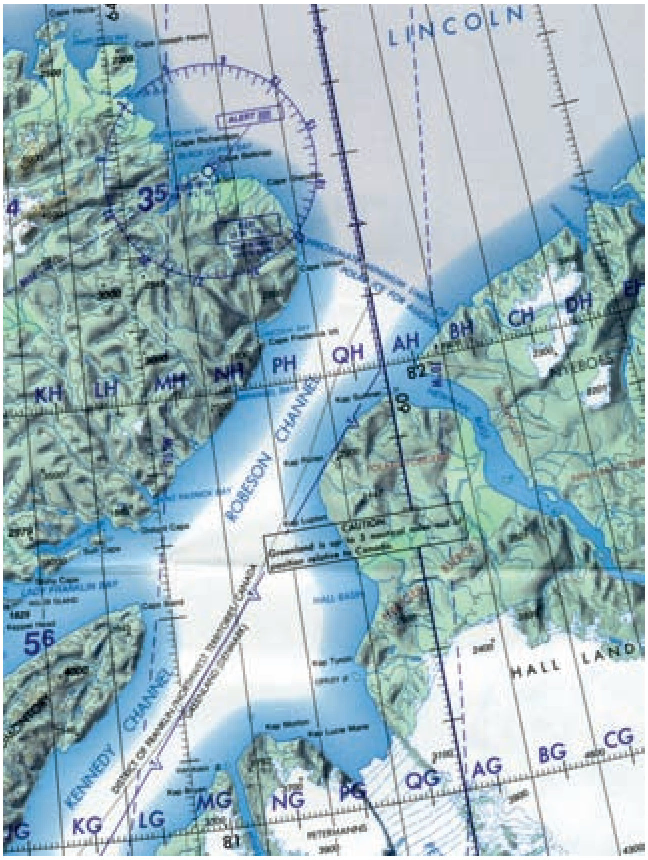


FIG. 49. DETAIL BETWEEN CANADA AND GREENLAND FROM THE *WORLD AERONAUTICAL CHART*, 1996. WAC A-5, 5th edition, produced by Geomatics Canada, Department of Natural Resources, Ottawa.
Size of the entire original: 51.8 × 130.2 cm; size of detail: ca. 21.9 × 16.5 cm.

by most, but not all, countries with land bordering the Arctic Ocean. In 1925 Canada formally claimed the territory, both land and water, "right up to the Pole" (Hayes 2003, 165). Meridians provided a convenient framework for claiming territory without any necessary knowledge of what was actually there to be claimed.

In the wake of Sverdrup's survey, Canada sent out a number of expeditions, including three led by Joseph-Elzéar Bernier, whose purpose was to map the islands, place copies in cairns, and thereby—it was hoped—claim sovereignty. In 1930 the Canadian government purchased Sverdrup's maps and diaries for $67,000, thus somehow achieving the retroactive fiction that Sverdrup was employed by Canada when he made his discoveries and thus ensuring Canadian sovereignty. By a strange twist of fate, these maps, though not the diaries, appear to have been lost (Hayes 2003, 156).

Sverdrup had played a wider role in Arctic cartography. He had been captain of the *Fram*, the ship of fellow Norwegian Fridtjof Nansen that had drifted across the Arctic Ocean between 1893 and 1896, locked in the ice. In 1907 Nansen published the first attempt at a comprehensive bathymetric map of the Arctic, based on his own observations as well as those of Sverdrup. Although necessarily quite generalized, the map correctly described the basic features of the Arctic seafloor (Nansen 1907).

A 1907 map, compiled and printed by the J. N. Matthews Co., Buffalo, New York, epitomized the nationalism that pervaded Arctic mapping by describing explorations toward the pole and along coastlines with carefully color-coded lines representing the nationality of the explorer. A reissue of the map in 1909 was hastily overprinted with both Frederick Albert Cook's and Robert E. Peary's claimed routes to the pole (fig. 50). The following year, yet another version, under the byline of Gilbert Hovey Grosvenor of the National Geographic Society, accompanied Peary's 1910 book, *The North Pole*, and showed only Peary's claim.

Between 1903 and 1906 the Northwest Passage was transited for the first time with a ship. (The British explorer Robert John Le Mesurier McClure had done it in 1850–54 without his ship, completing the journey with a sledge party that rescued him from the other direction.) Norwegian explorer Roald Amundsen sailed his tiny ship *Gjøa* along the northern coast of North America, mapping his route as he went. Cook and Peary both claimed to have reached the North Pole, in 1908 and 1909 respectively, but their claims have long been bitterly contested. Cook claimed to have discovered new land between 83° and 85°50′N, Crocker Land and Bradley Land, which appeared on his maps. That they could have been Arctic mirages or some other place raises further questions about his exploration claims.

Between 1914 and 1917 the Canadian Vilhjalmur Stefansson explored the Arctic islands, correcting the positions of some and adding several new ones, including Borden, Mackenzie King, and Meighen, all named after Canadian prime ministers. From 1910 to 1915, the Russian Arctic Ocean Hydrographic Expedition mapped Poluostrov Taymyr (Taymyr Peninsula) and the southern part of what is now Severnaya Zemlya. In 1930–32 a Soviet expedition under Georgiy Alekseyevich Ushakov further charted the coast of Severnaya Zemlya, along with several smaller islands (Hayes 2003, 167).

Another expedition of note is that of Amundsen and the 1922–25 drift of the *Maud*, a ship Amundsen had designed with a rounded bottom to lift up with the ice instead of being crushed. Trapped for three years, the crew of the *Maud* collected considerable amounts of valuable oceanographic, meteorological, and magnetic data.

The obvious strategy for mapping the Arctic, once the technology had become sufficiently reliable, was by air.

FIG. 50. *THE ARCTIC REGIONS SHOWING EXPLORATIONS TOWARDS THE NORTH POLE* (BUFFALO: J. N. MATTHEWS, 1909). Diameter of the original: 45 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

The pioneer was the unfortunate Swedish engineer Salomon August Andrée, who was lost over Kvitøya (White Island) in a silk hydrogen balloon in 1897. The wreckage was located in 1930 and Andrée's diaries and maps with it. Also found was undeveloped film, and thirty photographs were still printable. The first use of an airplane in the Arctic was in 1914, when Russian navy lieutenant Yan Iosifovich Nagurskiy flew a seaplane on five separate flights (Hayes 2003, 170–71).

The persistent Amundsen was the first to propose the use of airplanes for high Arctic exploration and mapping. In 1923, on flights over Svalbard (Spitsbergen) intended to set up a refueling depot for Amundsen, the Swiss photographer Walter Mittelholzer took the first aerial photographs of the Arctic and devised a way to convert them into maps by overlaying them with a perspective grid on two-kilometer squares. By this crude but effective method, Mittelholzer produced the first maps of the Arctic using aerial photographic survey (Hayes 2003, 171).

In 1925 Amundsen made an epic flight to within 26 kilometers of the North Pole. The following year Richard Evelyn Byrd and Floyd Bennett flew a three-engine monoplane to the North Pole and back in another Arctic expedition that has been questioned repeatedly; Byrd's navigation, which involved much dead reckoning because he broke his sextant, was examined and charted by a committee of the National Geographic Society and proclaimed accurate. At the same time as Byrd flew, the airship *Norge* was waiting to take off. The airship was designed by the Italian aviator Umberto Nobile and also carried the redoubtable Amundsen and his colleague Lincoln Ellsworth. In May 1926 they flew from Svalbard right across the pole, landing at Point Barrow, Alaska. This was the first *uncontested* achievement of the North Pole. Two years later, Nobile crashed while piloting another airship, the *Italia*, to the pole. Amundsen joined the search and was never seen again (Hayes 2003, 179).

These attempts are significant from a mapping point of view because they created broad channels of mapped territory on each side of the route visible from the plane or airship. They showed nothing of note except ocean ice, but that fact was important at the time because fictitious lands had previously been shown on maps. Atlas maps of the era typically show a white area marked "Unexplored," separated by these straight "explored" paths to the pole.

In 1931, a large German airship, the *Graf Zeppelin*, mapped Severnaya Zemlya as two islands, not one, as it had been mapped before. The airship was also used for an aerial survey of the islands of Franz Josef Land, reaching Rudolph Island, the northernmost island, only 800 kilometers from the pole.

After World War II, aerial survey was the main tool for mapping the Arctic. More reliable long-range aircraft and radio communications made the job much safer than previously. The Royal Canadian Air Force put some of its planes and pilots to work mapping the Canadian Arctic. In 1948, returning from a photographic mapping survey of northern Baffin Island, one plane's crew discovered a large island in Foxe Basin. Named Prince Charles Island, it covered 9,500 square kilometers and was the last large piece of land in the Arctic to be found and mapped (Hayes 2003, 183).

In 1948 the Russians began a program of scientific reconnaissance of the Arctic using drifting research stations from which numerous types of observation could be made, including important bathymetric ones, allowing the seabed of the Arctic Ocean to be mapped in some detail. A similar American station set up in 1952 on an ice island—ice platforms broken off from an ice shelf—floated around the Arctic Ocean for twenty-five years.

The end of the Soviet era facilitated more information sharing. A new *Arctic Meteorology and Climate Atlas*, released in 2000 on CD-ROM by the National Snow and Ice Data Center in Boulder, Colorado, was based on data from the United States and Russia as well as several other countries. One important use of this atlas is for forecasting ice conditions, a practice that had begun in 1939 using charts of current ice conditions and weather forecasts. Satellite remote sensing, which revolutionized many different types of mapping in the Arctic, was of particular use in ice forecasting because of the facility for repetitive coverage of wide areas as well as comprehensive, single-time pictures of ice conditions.

The Canadian government used Radarsat satellite images as the basis for maps by simply overprinting them with a grid of coastlines and geographic names. Differences in color distinguish the multiyear ice pack from the single-year pack (fig. 51). These maps were combined with earlier data to construct maps in the *Sea Ice Climatic Atlas, Northern Canadian Waters, 1971–2000*, released in 2002 by Environment Canada.

The first contour map of the Arctic Ocean seabed was made in 1958, after the nuclear submarine USS *Nautilus* took sonar scans under the ice. Long-range side-scanning multibeam sonar, developed in the 1960s, enabled the imaging of vivid three-dimensional maps of the seabed with a sensor towed by a submarine. This method led to the publication in 2001 of version 1.0 of the *International Bathymetric Chart of the Arctic Ocean* (IBCAO) (fig. 52).

One consequence of this newfound knowledge of the Arctic seafloor is the discovery of previously unknown submarine ridges. The Lomonosov Ridge, first discovered in 1948 but now known to extend farther toward North America than at first thought, has been used by Russia to claim an extended outward boundary of its maritime territory, based on the Law of the Sea as it applies to the continental shelf. Although Russia's claim to a large portion of Arctic seabed was still under development at the end of the century, the new data challenged Canada's sector-based claims.

With climate-change predictions that include a widening of the Northwest Passage as well as the disappearance of the polar ice cap, the Arctic seems poised to assume greater importance internationally. Oil exploration is planned for the Beaufort Sea. The Arctic nations are committing more and more resources to understand-

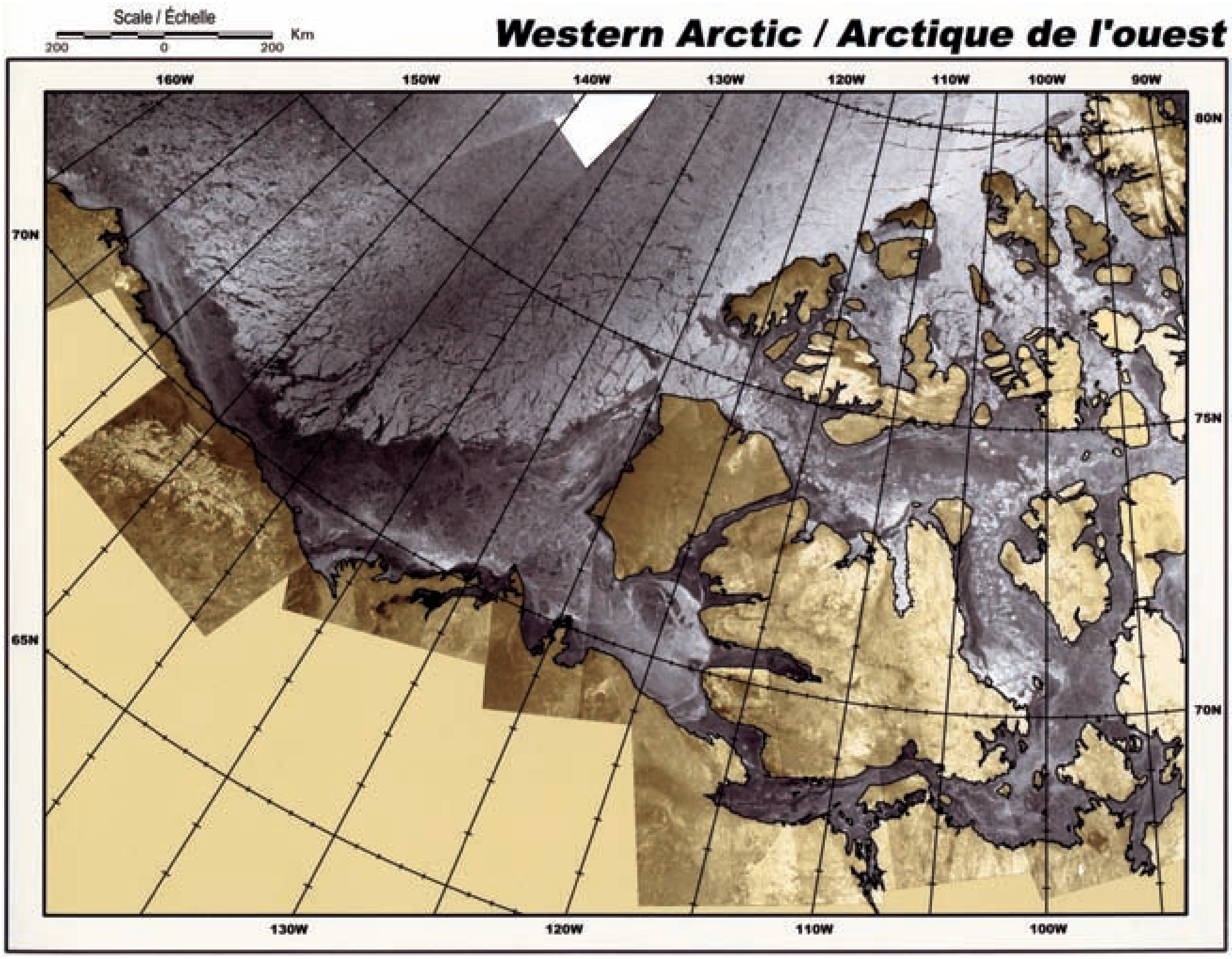


FIG. 51. *WESTERN ARCTIC/ARCTIQUE DE L'OUEST*, 2001. A Radarsat (earth observation satellite developed by Canada and launched in 1995) satellite image of the western Canadian Arctic showing the state of sea ice between 31 January and 4 February 2001. The difference in coloration between multiyear pack (lighter gray) and single-season ice (darker gray) is immediately evident.

Size of the original: 21.4 × 27.6 cm. From *Annual Arctic Ice Atlas—Winter 2001 = Atlas annuel des glaces de l'Arctique—Hiver 2001* (Ottawa: Canadian Ice Service = Service Canadien des Glaces, 2001), 11. RADARSAT-1 data © 2001 Canadian Space Agency. RADARSAT is an official mark of the Canadian Space Agency. © Environment Canada, 2001.

ing their northlands, an understanding that will surely require more detailed mapping of the region.

DEREK HAYES

SEE ALSO: Antarctica; Boundary Disputes; Geophysics and Cartography; Geopolitics and Cartography; International Geophysical Year; Law of the Sea; Oceanography and Cartography; United Nations

BIBLIOGRAPHY:

Canadian Ice Service/Service canadien des glaces. 2002. *Sea Ice Climatic Atlas: Northern Canadian Waters, 1971–2000 = Atlas climatique des glaces de mer: Eaux du Nord Canadien, 1971–2000*. Ottawa: The Service = Le Service.

Hayes, Derek. 2003. *Historical Atlas of the Arctic*. Vancouver: Douglas & McIntyre.

Jakobsson, Martin, et al. 2008. "An Improved Bathymetric Portrayal of the Arctic Ocean: Implications for Ocean Modeling and Geological, Geophysical and Oceanographic Analyses." *Geophysical Research Letters* 35:L07602.

Leier, Manfred. 2001. *World Atlas of the Oceans: With the General Bathymetric Chart of the Oceans (GEBCO) Published by the Canadian Hydrographic Service*. Toronto: Firefly Books.

Mittelholzer, Walter, et al. 1925. *By Airplane towards the North Pole: An Account of an Expedition to Spitzbergen in the Summer of 1923*. Trans. Eden Paul and Cedar Paul. London: G. Allen & Unwin.

Nansen, Fridtjof. 1907. *Bathymetrical Chart of North Polar Seas*. In "On North Polar Problems," *Geographical Journal* 30:469–87, 585–97, map follows 487.

Peary, Robert E. 1910. *The North Pole: Its Discovery in 1909 under the Auspices of the Peary Arctic Club*. New York: Frederick A. Stokes.

Sverdrup, Otto Neumann. 1904. *New Land: Four Years in the Arctic Regions*. 2 vols. Trans. Ethel Harriet Hearn. London: Longmans, Green.

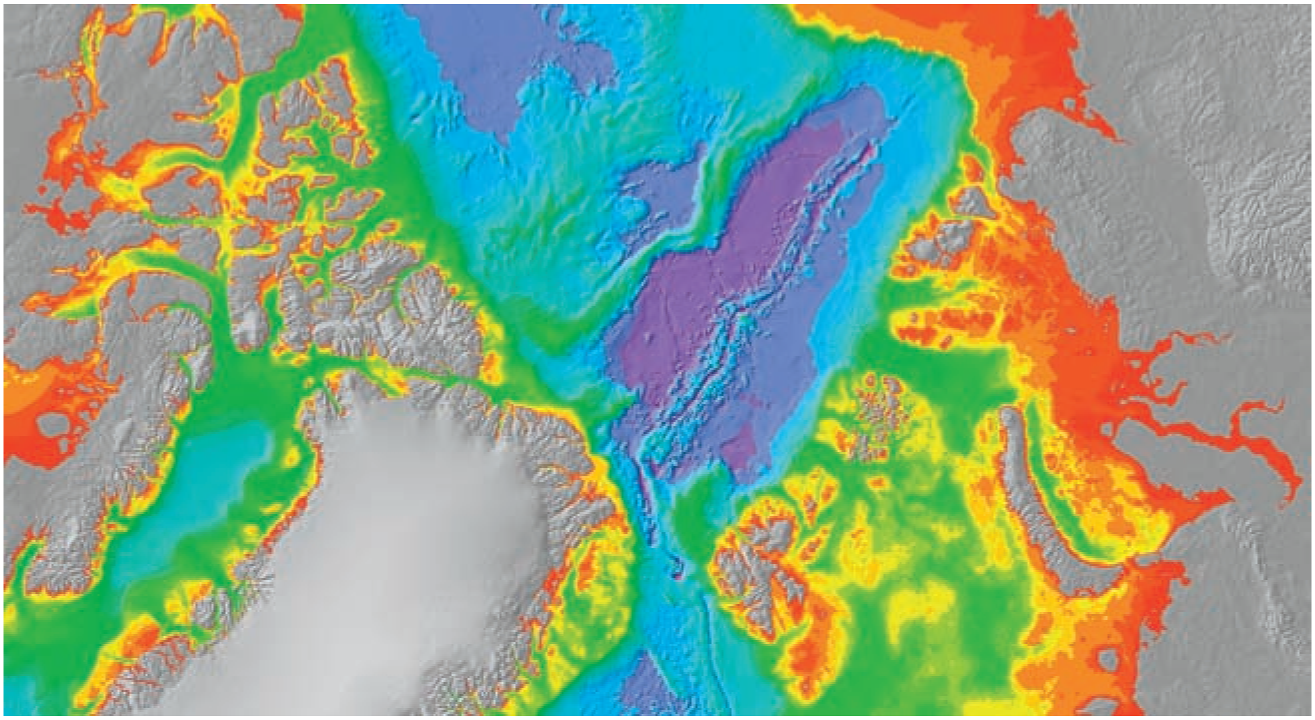


FIG. 52. DETAIL FROM THE *INTERNATIONAL BATHYMETRIC CHART OF THE ARCTIC OCEAN* (IBCAO), 2001 (VER. 1.0). Available online and digitally constructed and updated, IBCAO is intended as a summary of the most up-to-date information on the topography of the Arctic seabed. Covering the area north of 64°N, information is contributed by eight countries: Canada, Denmark, Germany, Iceland, Norway, Russia, Sweden, and the United States. The scale goes from purple (deepest) to red (shallowest). The Lomonosov Ridge is shown diagonally in green in the top center; Greenland is in the lower left. Image courtesy of the National Geophysical Data Center, NOAA.

Art and Cartography. During the twentieth century artists and cartographers participated in a dialog exploring core questions in both fields. Map art, as used here, refers to aesthetic objectives involving ways of seeing the map as a visual object, as a narrative of place and geographic processes, and as a means for people to express ideas about the world or their environment. The definition of cartography as a representation of spatial relations in the world draws on previous definitions (Andrews 1996). Those concepts changed during the twentieth century as artists and cartographers challenged one another's meanings and used one another's strengths to facilitate or convey their objectives. During the century, cartographers consciously opposed their practice to art, while at the same time appropriating the visual skills and conceptual discipline developed by artists. Artists challenged the objectivity of mapping but used map art to build connections to the world. The relations among the concepts, practices, and objectives of art and cartography were manifested in discussions by critics and theoreticians and in historical events.

Artistic cartography, map images in art, and mutual influences between art and cartography were known for hundreds of years (Woodward 1987), but the interplay between maps and modern and postmodern art took unique shape during the twentieth century. Around 1900, modernism as a cultural movement involved a reexamination of earlier spheres of interest and conflicting processes of thought and representation in reaction against realism, romanticism, and naturalism in art and culture of the nineteenth century (Butler 1994). Greater complexity emerged in artistic expressions of the time, in response to changing technology, social order, and politics. Developments in those realms such as industrialization, problems of colonialism, and modern warfare turned twentieth-century thinkers toward a critical regard of the future (or their fears of it). Individual and subjective thought and expression along with the acceptance of and interaction with the current age found their way into art. One important development was that perspective fell away as the necessarily accepted method of representing three-dimensional objects and places, and the two-dimensional plane, resembling geographical projections, formed the background for artistic exploration.

The known corpus of map art by artists who embedded maps in their work was created by modern art movements during and immediately after World Wars

I and II and again by the postmodern art movement, which began in 1960. From about 1977 exhibitions of map art inspired comparative studies, followed by more formal literature on map art after 1980. Early works of critical cartography advanced the inclusion of map art as a cartographic form. After 1985, cartographic literature on map art formed theoretical and critical interpretations of the genre.

Cartography's predominant design legacy, based on a combination of scientific empiricism, materialist outlook, and demographic and utilitarian ideals, was a simplified general style, purposely intended to suppress strongly individual or diverse perspectives. A long-standing debate in cartographic theory was whether cartography is a science or an art (Woodward 1987). Mapping science typically involved empirical data, statistical manipulations, concern with accuracy and standardization, and precision instruments and techniques. The "art" of cartography was considered to be human creativity and judgment, invoked where rules were vague, such as in generalization and design. It was argued that such subjectivity was necessary, but should be subservient to scientific objectives (Krygier 1995, 4).

Although cartographers resisted subjectivity in mapping, they often added decoration, and along with it, its dimensions of rhetorical or political social semantics, to scientific-styled mapping. Conventional cartography incorporated elements of graphic design and pictorial realism. Pictures and maps, including propaganda maps, appeared together in illustrative or popular art intended for general dissemination. Maps themselves were often pictorial, for example, the maps of Ernest Dudley Chase and Charles Hamilton Owens (Cosgrove and della Dora 2005) (fig. 53). Such maps involved the semiotic manipulation of color, scale, pictures, and other elements to directly address political interests and thus undermine

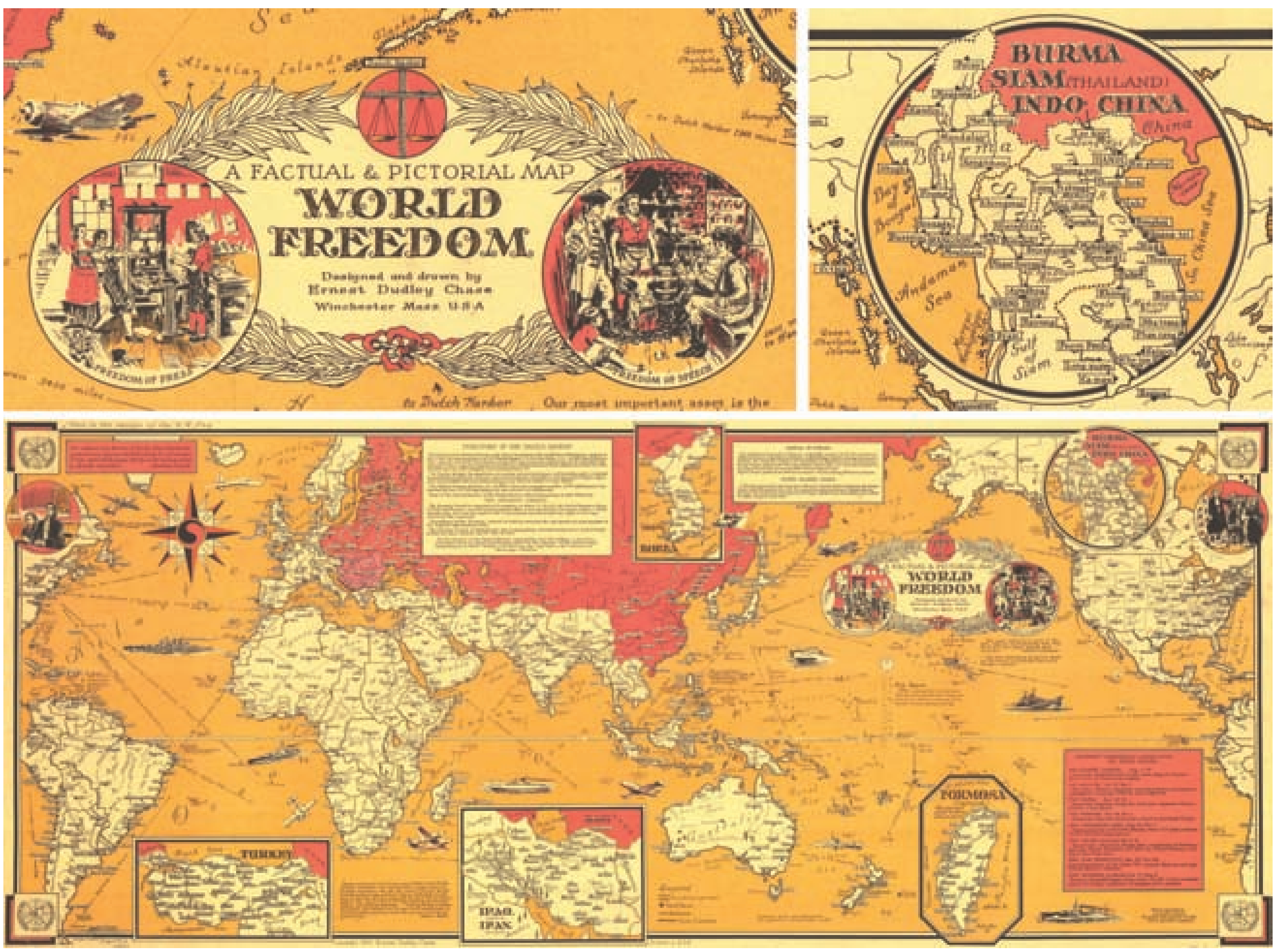


FIG. 53. ERNEST DUDLEY CHASE, *A FACTUAL & PICTORIAL MAP WORLD FREEDOM* (WINCHESTER, MASS., 1950). Photolithographic print. Colored a menacing pinkish-red, Cold War–era China and the Soviet Union are shown encircled by planes and ships, the watchful sentinels of the United Nations, whose foundation in 1945 this map honors.
Size of the entire original (bottom): 37.2 × 89.4 cm; size of details: 9.2 × 18 cm and 9.2 × 10.5 cm.

scientific-style objectivity. Propagandistic and emotive cartographies were in competition with scientific-style cartography before the twentieth century.

That schism between art and cartography narrowed significantly as the theoretical foundations of map art as a cartographic form took shape during the twentieth century (Krygier 1995; Harley 2001). John Krygier postulated that cartographic theory and practice are distinctive in that visual design and communication are an innate part of the science. He concluded that the dualism of art and science is overly simplistic. Scientific work resembles the creative process of art, while art practices often involve empirical and systematic investigations resembling science. Krygier suggested that other perspectives, such as epistemology or literary criticism, would offer a more productive theoretical foundation. The viewpoint that maps are propositions about the world involving varying methods and intents, as well as different ontologies shaping and shaped by the cultural, social, and economic context within which they are situated, brings the art and science in cartography into rapport. Art, science, and cartography, he argued, share aesthetic and technical issues and have human experience and nature in common. Focusing on what the two have in common makes it apparent that both build hypothetical constructions and modify them in light of further experience. Both processes at times strive for "fit," a new expression of reality that makes sense and solves problems. Both depend on understanding how ideas and concepts are shaped and clarified.

FIG. 54. MARCEL DUCHAMP, *ALLÉGOIRE DE GENRE*, 1943. Playing on the ambiguity of visual imagery, the artist has created a profile portrait of George Washington looking to the right. When turned on its side it is a quilted map of the United States, its batting tacked in place by gold stars.
Size of the original: 54.8 × 42.7 × 7 cm. CNAC/MNAM/Dist. Réunion des Musées Nationaux/Art Resource, New York.

Artists started exploration of the interrelationship of art and cartography early in the twentieth century. Marcel Duchamp's "found art" style strove to attack the privileged status of traditional art and make the everyday the object of cultural regard (fig. 54). For Duchamp, mapping served as an intermediary between cerebral idea and object form that expressed the connection to others (Shearer 1997). The incorporation of readymade objects in art expanded the theoretical underpinnings for map art throughout the twentieth century. Modernist rejection of traditional paradigms accelerated in reaction to World War I, broadening the scope of its subject matter. Some artists influenced by Surrealism produced map art in the period leading up to and during World War II; they included Jind ich Štzrský, Salvador Dalí, Max Ernst, and Joseph Cornell (fig. 55). Duchamp continued to draw inspiration from maps, and maps appeared in the Latin American modern art of Joaquín Torres-García (Wood 2006a, 6). It has been suggested, though not widely demonstrated, that early maps, either pictorial or in publications, inspired or influenced the meaning of map art objects. Certainly maps served as sources for collaged map art.

Broader innovations in modern art in the early twentieth century gradually expanded the visual vocabulary of graphic communication to bridge the gap between the theoretical foundations of art and cartography. Cubism introduced the use of text in art. Its dialectic between art and the common symbols of the public allowed the mutual interchange of ideas between art and graphic design, including cartography. Movements such as purism, orphism, and concretism led to studies of color, patterns of shape, and multiple viewpoints in three-dimensional space. Constructivist artists connected art and graphic design. Rising interest in the purely visual elements of art led to greater examination of color, form, and limits of abstraction, bringing art closer to cartographic concerns of scale, viewpoint, and temporal and spatial change. Such exploration in art concepts and practices formed a broader framework shaping art and cartography.

In the years after World War II, obstacles to the resolution of the theory of art and of cartography remained. They included the rejection of art within cartography and a reaction on the part of the artist against postwar

FIG. 55. JOSEPH CORNELL, UNTITLED (SOAP BUBBLE SET), 1936. Mixed media construction. The formal arrangements of found objects in Cornell's shadow boxes evoke nostalgia; here the soap-bubble pipe, juxtaposed with an egg, a glass, a doll's head and a French map of the moon raise questions about the ephemerality of existence.
Size of the original: ca. 39.4 × 36 × 13.8 cm. Wadsworth Atheneum Museum of Art/Art Resource, New York.

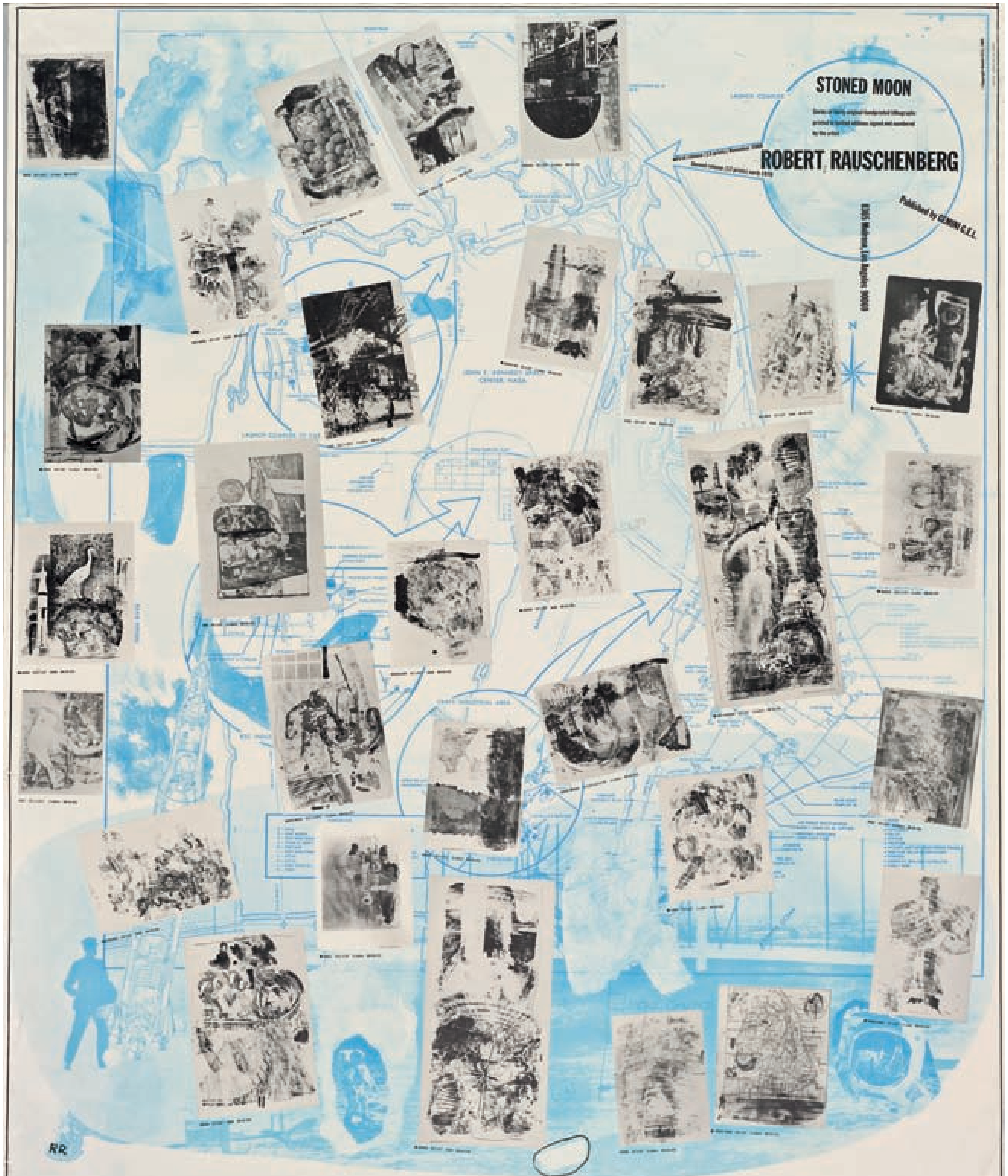


FIG. 56. ROBERT RAUSCHENBERG, *STONED MOON*, 1969. Offset lithographic print. Scientific maps, charts, and photographs of Apollo 11 were furnished by NASA to Rauschenberg, who witnessed the launch in 1969, and formed the basis for a print series. The mixture of techniques and subject matter celebrate the collaboration of man and technology. Size of the original: 99.7 × 82.5 cm. Image courtesy of the San Francisco Museum of Modern Art, Gift of Andrea Comel di Socebran. © Estate of Robert Rauschenberg/Licensed by VAGA, New York.

consumer and military culture, in which maps were perceived to play a role. By the end of the century, artists and cartographers would move toward acceptance of a postmodern relationship between art and cartography.

Map art in the 1950s built foundations that would endure even after the proliferation of map art after 1960 (Wood 2006b). Maps became an integral strategy and expression of psychogeography, arising with the letterists in the early 1950s and continuing into the twenty-first century (Cosgrove 2005, 39–41; Kanarinka 2006, 26–39). Early works by Robert Rauschenberg and Jasper Johns led to seminal versions of map art as explorations of American symbols (fig. 56). Beginning in the 1960s, pop artists drew directly from commercial art and graphic design, including maps. Conceptual art focusing on empirical experience accepted maps as its documentation, as was true for earth art created outside of the studio or gallery, such as work by Robert Smithson or Christo's representation of the environmental processes as art.

Literature on map art gained prominence with a special issue of *artscanada* ("On Maps and Mapping," 1974) devoted entirely to the subject. The Museum of Modern Art exhibit titled "Maps," organized by Richard Marshall, was perhaps the earliest group show of map art (1977). Three exhibits devoted to map art accompanied by published catalogs occurred between 1980 and 1983. An increasing number of group exhibits and shows of individual artists followed from the 1990s through the end of the century (Wood 2006a, 7). The preparation of exhibits by curators and their analysis by critics marked the beginning of the comparative study of the map art movement's body of work with appraisals of its meaning.

Later map art, arising roughly concurrently with postmodern theory in cartography, used the map form to challenge the hierarchical values of conventional cartography. Often motivated by rejection of the geography reproduced by cartography, artists rearranged the signs employed on the flat plane to bring forward what they saw to be most essential (Wood 2007). Studies of the relationship between art and cartography postulated that the demise of the apparent scientific objectivity of cartography expanded the range of concepts and allowed artists to engage with the map form. The map also represented the expression of individual inner geographies; psychological aspects in map art included memories and emotions, yet were still visually experimental in execution (Varanka 2006). Often the map form provided a vehicle for particular perspectives on the world, which may have been individual or representative of entire populations.

Artistic embrace of industrialism and new political movements created a bridge to art for map designers. The embrace of new spatial interaction technologies, such as those in transportation and communication, spurred the demand for geographical knowledge. Cartographic practices, including air photography, geographical filmmaking, and multispectral remote sensing, captured images that inspired artists and provided them with material, as did the related popular culture of travel, exploration, exoticism, and the cosmos.

The debate in modern art about the relationship between art and its public, and art and society, continued through the postmodern period. Maps were used in art as political statements. Affecting those developments were rapid innovations in technology that altered the materials and audiences with which cartographers could work. The ubiquity of maps made possible by the technological infrastructure of printing and digital technology brought about new realization of the extent to which maps could absorb other ideas and affect the public. Their proliferation offered artists ample opportunity to analyze their nuances.

Postmodern critiques of cartography after 1980 enabled an acceptance of artistic principles that had been rejected throughout the earlier part of the century. The primary works of geographical literature about map art appeared after 2000. Volume 53 of *Cartographic Perspectives*, which appeared in 2006, was the first issue of a disciplinary journal of cartography devoted to map art; discursive responses from critical theorists in the field followed in volume 55 (Denil 2006).

As a recently emerged form of expression, map art offers scope for further study of its twentieth-century origins as a way of understanding its cultural context and building the conceptual foundations for its further development. The examples cited here are mainly from the United States, and attention also needs to be given to map art developments in Europe and worldwide. Twentieth-century topics deserving historical exploration include the persistence and significance of the categorization of map-art creators into artist versus cartographer (Denil 2006), the influence of modern and postmodern art practice and concepts on map design, and the intersection of the art-cartography divide with the late-century appropriation of mapping by geographic information system science.

DALIA E. VARANKA AND JOHN KRYGIER

SEE ALSO: Color and Cartography; Decoration, Maps as; Reproduction of Maps: Reproduction, Design and Aesthetics

BIBLIOGRAPHY:

Andrews, J. H. 1996. "What Was a Map? The Lexicographers Reply." *Cartographica* 33, no. 4:1–11.

Butler, Christopher. 1994. *Early Modernism: Literature, Music, and Painting in Europe, 1900–1916*. Oxford: Clarendon Press.

Cosgrove, Denis E. 2005. "Maps, Mapping, Modernity: Art and Cartography in the Twentieth Century." *Imago Mundi* 57:35–54.

Cosgrove, Denis E., and Veronica della Dora. 2005. "Mapping Global

War: Los Angeles, the Pacific, and Charles Owens's Pictorial Cartography." *Annals of the Association of American Geographers* 95:373–90.

Denil, Mark. 2006. "Denis Wood's Article 'Map Art.'" *Cartographic Perspectives* 55:4–5.

Harley, J. B. 2001. *The New Nature of Maps: Essays in the History of Cartography*, ed. Paul Laxton. Baltimore: Johns Hopkins University Press.

Kanarinka. 2006. "Art-Machines, Body-Ovens and Map-Recipes: Entries for a Psychogeographic Dictionary." *Cartographic Perspectives* 53:24–40.

Krygier, John. 1995. "Cartography as an Art and a Science?" *Cartographic Journal* 32:3–10.

"On Maps and Mapping." 1974. *artscanada* 31, nos. 188–89.

Shearer, Rhonda Roland. 1997. "Marcel Duchamp's Impossible Bed and Other 'Not' Readymade Objects: A Possible Route of Influence from Art to Science, Part I." *Art & Academe* 10, no. 1:26–62.

Varanka, Dalia E. 2006. "Interpreting Map Art with a Perspective Learned from J. M. Blaut." *Cartographic Perspectives* 53:15–23.

Wood, Denis. 2006a. "Map Art." *Cartographic Perspectives* 53:5–14.

———, comp. 2006b. "Catalogue of Map Artists." *Cartographic Perspectives* 53:61–67.

———. 2007. "A Map Is an Image Proclaiming Its Objective Neutrality: A Response to Denil." *Cartographic Perspectives* 56:4–16.

Woodward, David, ed. 1987. *Art and Cartography: Six Historical Essays*. Chicago: University of Chicago Press.

Astrophysics and Cartography. In the twentieth century, astrophysics—the application of physics and chemistry to the study of extraterrestrial phenomena—dramatically expanded and changed humanity's understanding of the universe and the bodies within it. In past centuries, astronomers relied on cartography primarily to locate celestial bodies within a coordinate system of two dimensions. Knowledge of the heavens depended on careful observation of light in the visible wavelengths, which was aided first by telescopes and, by the end of the nineteenth century, photography. Although astrometry remained an important pursuit, astrophysics (a word that only came into common usage in the twentieth century) gained importance and dominated the field of astronomy by the end of the century. As astronomy's focus changed, new theories about the nature of space and time as well as the origin of the universe developed and eventually achieved widespread acceptance. Astrophysicists also began to depend on increasingly more sophisticated tools for observing. Large telescopes perched atop mountains and orbiting observatories allowed them to look deeper into space across a wider spectrum of wavelengths while electronic detectors provided increasingly more sensitive means for recording the data. Advances in computing power made it possible to analyze the incredible body of information returned by these instruments. As a result of these shifts, by the end of twentieth century astrophysical maps attempted to represent a universe of much greater scale in three dimensions. In addition, they needed to accommodate more complex spatial and temporal assumptions than in earlier periods as well as multiple wavelengths of light.

The interconnected history of developments within astrophysics and their cartographic expression does not lend itself to a strict chronological retelling. The story becomes clearer when one starts at the beginning of the twenty-first century with a map of the observable universe published by a group of astronomers as a summary of recent discoveries (Gott et al. 2005). Much of what the map contains was unknown, even unimagined, when the century began, and one can also read the chart as a demonstration of how notions of space-time, geophysics of bodies outside the earth's solar system, and theoretical conceptions of the universe came to form a coherent picture of the cosmos (fig. 57). The map presents a slice of the universe as a vertical column with the earth's core and the future visibility limit, the line past the Big Bang that will always lie beyond our view due to the expansion of the universe, on opposite ends. In between, scientists plotted a representative sample of objects within the equatorial slice. By using a logarithmic scale, they could display each of the different phenomena in a size large enough to show sufficient detail. Nearer to the bottom of the column (and the earth), both the moon and the earth's artificial satellites—the numerous GPS (Global Positioning System) satellites, the Hubble Space Telescope, and other well-known orbiting observatories—are identified. Traveling upward, one finds the planets, asteroids, and comets in our solar system, and then, at a farther distance, stars, including many that are known to have planets of their own. The galaxies that make up the Local Group lie beyond the boundary of the Milky Way. Moving further still, one sees the large-scale structures formed by the clustering of galaxies. Beyond the webs of galaxies, a solid line marks the distance in time and space to the cosmic microwave background, and a second line, slightly further along the column, indicates the Big Bang. Finally, one reaches the limits of observation.

The immense scope of the 2005 map of the universe was nearly unthinkable at the beginning of the twentieth century. Although the possibility of other star systems outside our galaxy had been proposed much earlier, most famously by Immanuel Kant with his theory of "island universes," astronomers knew little about the size and shape of the Milky Way, our position within it, or its relationship to other objects in the universe. Observations made during the first three decades of the century resolved these questions. Henrietta Swan Leavitt contributed a crucial discovery in 1912, when she identified a proportional relationship between periodicity and luminosity in Cepheid variable stars. A few years later, in 1918–19, Harlow Shapley combined his earlier research on determining the distance and brightness of eclipsing binary stars with Leavitt's observation and developed a distance scale for Cepheid variables. He then used this method to calculate the distance to several globular clusters, which lie at the edge of the Milky Way. He determined that they formed a flattened spherical system with the center more than 50,000 light years away from our solar system. The Milky Way was much larger than previously estimated, and our position was far from the center. The recognition of the great size of the galaxy did not, however, settle the question about the location of the spiral nebulae, and Shapley argued that such a vast galaxy must include these other objects. Edwin Powell Hubble settled the debate in 1925, when he announced his discovery of a Cepheid variable in the Andromeda Nebula. He calculated its distance and demonstrated that the nebula was far outside the limits of the galaxy as defined by Shapley's observations. Hubble's observations demonstrated that the universe extended beyond the Milky Way Galaxy and was populated by analogous extragalactic nebulae, which are now also known as galaxies (Longair 2006).

These discoveries opened a whole new realm of study for astronomers and astrophysicists, which they explored to increasingly greater depths in the decades that followed. Because of the interest in distant reaches of the universe, astronomers required additional coordinate systems, which, unlike the equatorial coordinate system, did not change with the earth's equator and shifting equinox. William Herschel had suggested a galactic coordinate system in 1785, but astronomers had not adopted a common system. The publication of the *Lund Observatory Tables* in 1931 established the first set of standard galactic coordinates using the galactic plane with a zero point for longitude at the intersection of the plane and the celestial equator for the equinox 1900.0 (the reference system at the beginning of the year 1900). The International Astronomical Union revised them in 1958, when new data demonstrated the need to shift the standard location of the galactic pole (Blaauw et al. 1960). Coordinate systems of even greater scale, such as supergalactic latitude and longitude based on the plane of the local supercluster of galaxies, came into use as observations stretched deeper into space. Another system, comoving coordinates, allowed objects to maintain the same coordinates in an expanding universe.

The last coordinate system reflected another revolutionary shift in theories of space and time that occurred during the first half of the twentieth century. With his general theory of relativity, which was published in 1915, Albert Einstein united space and time into a single concept and predicted that, rather than being fixed, spacetime was distorted through the effects of gravity on matter. As a consequence, he suggested that the universe was not a static, infinite plane, but was either expanding or contracting. In response to the theory of relativity, astronomers dramatically revised their ideas about the origin of the universe and its dynamism. Hubble's second great contribution to astronomy came in 1929, when he demonstrated that the universe was expanding and answered a question left open in Einstein's theory. Hubble recognized that redshifts—the amount that spectral lines are shifted toward lower wavelengths—were proportional to distance. Galaxies at a greater distance had greater redshifts, or velocities; they were receding at a faster rate than closer objects (Hubble 1936). His use of redshifts would also become an important tool in later decades when astronomers mapped the universe in three dimensions.

Hubble was the first to identify the Local Group of galaxies, which includes the Milky Way; however, he did not predict the existence of large galaxy clusters. But as astronomers surveyed the sky with new tools and theories, they discovered the large-scale structure of the cosmos. Using contour maps based on photographs taken at Lick Observatory, C. D. Shane and C. A. Wirtanen (1954) concluded that galaxies occur in clusters. The National Geographic Society–Palomar Observatory Sky Survey (POSS I) of the northern sky, conducted in the 1950s with the 48-inch Schmidt telescope at Palomar Observatory, yielded even more extensive catalogs of galaxies and clusters as well as maps of their distribution (Abell 1958; Zwicky 1961–68).

Such efforts showed the relationship of galaxies in two dimensions, and they formed the basis for later efforts to map the galaxies in depth using redshift. Although astronomers collected samples of galaxy redshifts in the 1950s and 1960s, the introduction of digital detectors in the 1970s greatly increased the efficiency of making these measurements. Astronomers first analyzed selected regions of the sky, for example, areas that seemed empty of galaxies on a two-dimensional map. They quickly recognized patterns in the three-dimensional distribution of the galaxies. Their maps showed voids that lacked galaxies and dense groupings of galaxies that astronomers dubbed great walls. More extensive surveys across the sky followed in the 1980s, including a survey conducted by a group of astronomers at the Harvard-Smithsonian Center for Astrophysics (CfA). Some of the most innovative maps came from a second survey conducted by the CfA from 1985 to 1995 and led by John P. Huchra and Margaret J. Geller. To show the relationship between the different galaxies, they plotted them on a fan-shaped slice with the earth at its apex and the galaxies represented as dots at varying redshift distances (fig. 58) (Geller and Huchra 1989). This method for plotting galaxies in three dimensions has become standard in astrophysics. Two more ambitious surveying projects that will observe at greater redshift distances—the Sloan Digital

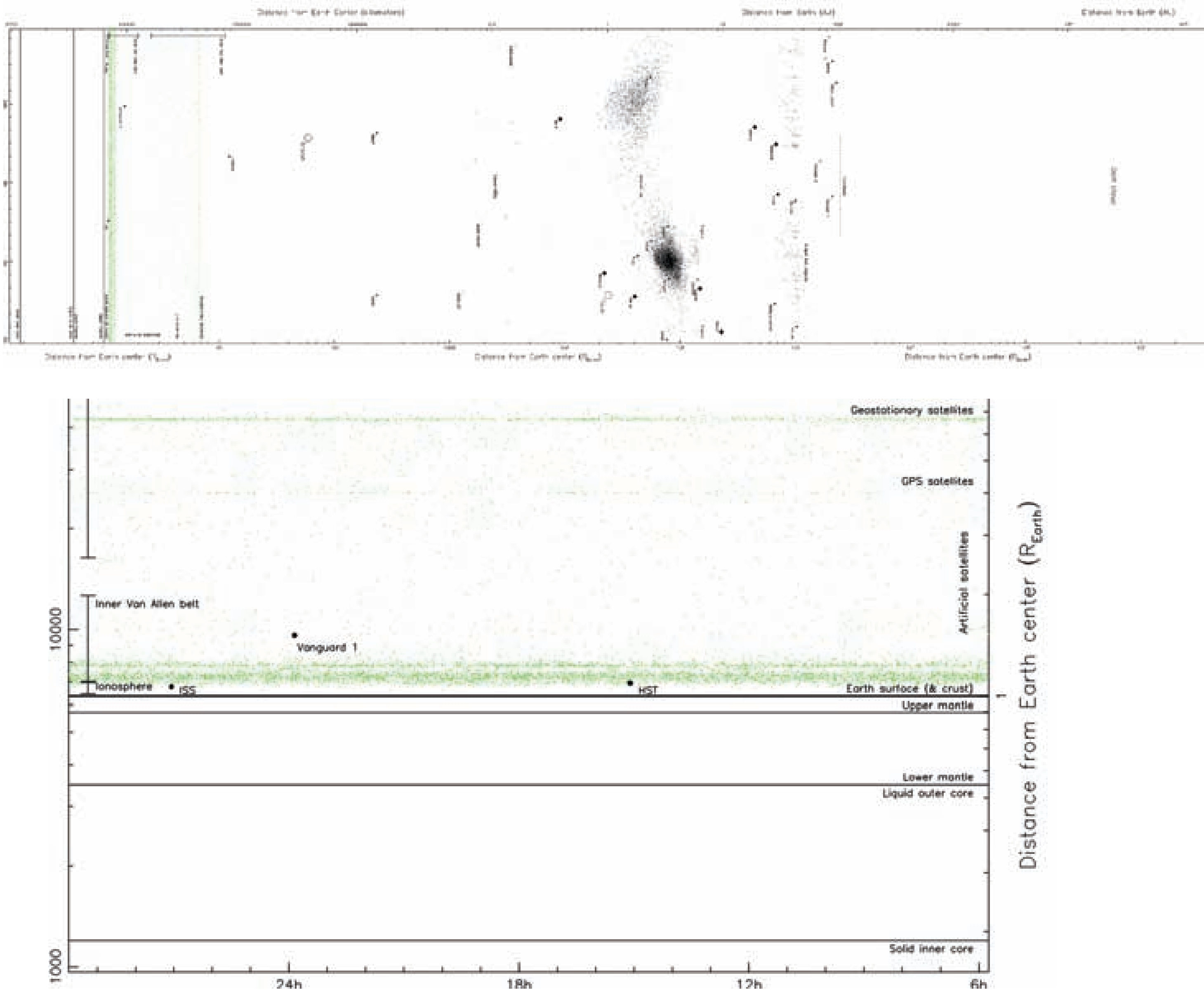
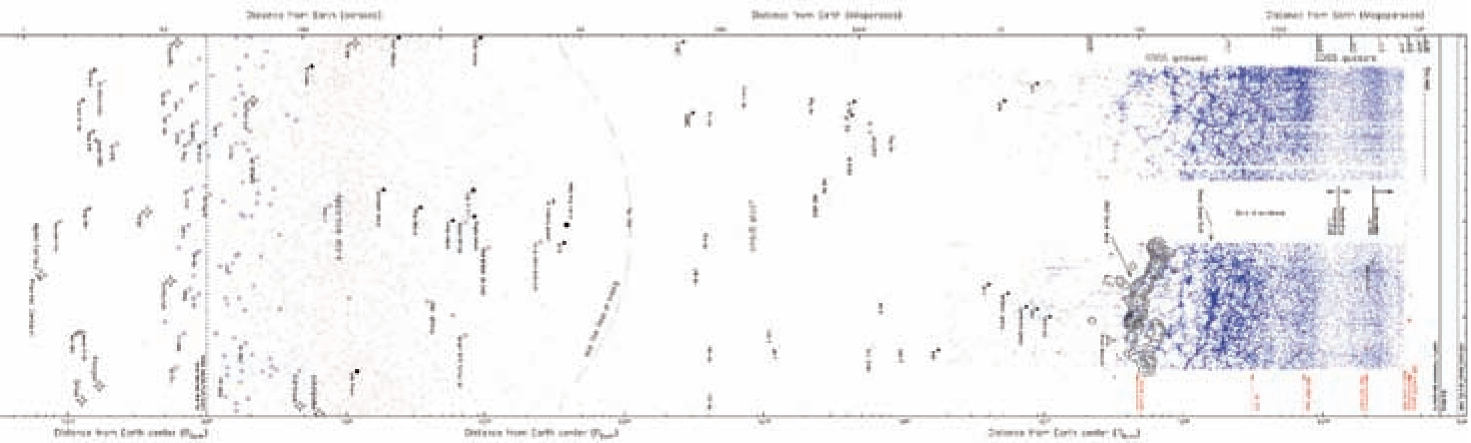
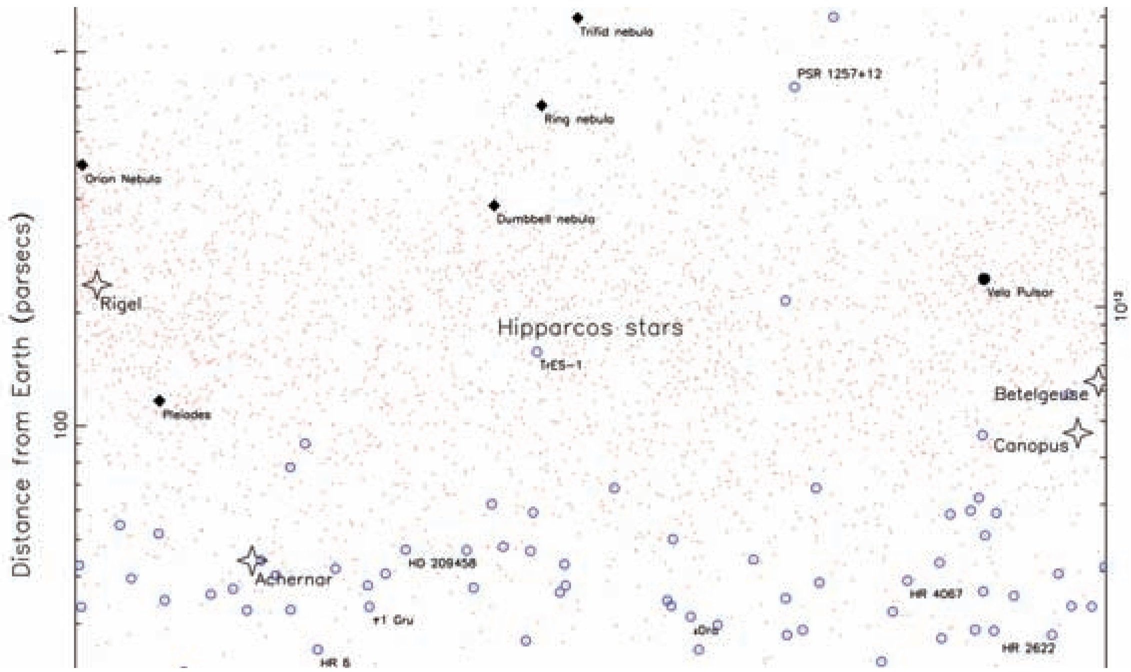


FIG. 57. MAP OF THE UNIVERSE BY J. RICHARD GOTT ET AL., 2005. To represent the observed universe from the earth's center (top left) to beyond the Big Bang (top right), astronomers used a conformal map that preserved shapes locally, but also showed the full range of astronomical scales. Two details (rotated 90°) are shown below the full map. Size of the entire original: 13.2 × 90.5 cm; size of each detail: ca. 7.6 × 13.2 cm. Copyright © J. Richard Gott and Mario Juric.

Sky Survey, which began in 1998 and will measure the redshifts of more than one million galaxies and quasars over one quarter of the northern sky, and the Two-Degree Field, or 2dF, Galaxy Redshift Survey, collecting data for the southern sky—both make use of these types of maps (Colless, Staveley-Smith, and Stathakis 2005, 77–104, 129–39).

In addition to mapping the universe in multiple dimensions, observations of the sky in wavelengths outside the optical range expanded during the twentieth century, a development that occurred largely after World War II and often benefited from military applications or industrial research. In 1933, Karl G. Jansky, an engineer at Bell Telephone Laboratories who was researching possible interference sources for radio transmissions, determined that the Milky Way Galaxy emitted radio waves. In 1944 Grote Reber, an amateur astronomer and radio buff, published the first cartographic representation of these emissions: contour maps on a flattened globe showing the intensity of radio emissions in the portion





of the Milky Way visible in the northern hemisphere (fig. 59) (Reber 1944). Concerns about interference with radar transmissions during World War II helped scientists to first identify and later map discrete sources of radio emissions. Observations with radio telescopes by Jan Hendrik Oort and his colleagues in the 1950s also led to confirmation that the Milky Way Galaxy had spiral arms like those observed in other galaxies (Oort, Kerr, and Westerhout 1958).

Interest in radio waves intersected with new explanations of how the universe was formed. In 1948 George Gamow proposed what came to be known as the Big Bang theory to explain the distribution of chemical elements through the universe. He asserted that they were created through nucleosynthesis in the hot, dense moments of the early universe. Mapping radio waves provided support for this view of the universe's formation. Astronomers, including Gamow, predicted the existence of cosmic microwave background, a remnant of the original energy that set the universe in motion. This en-

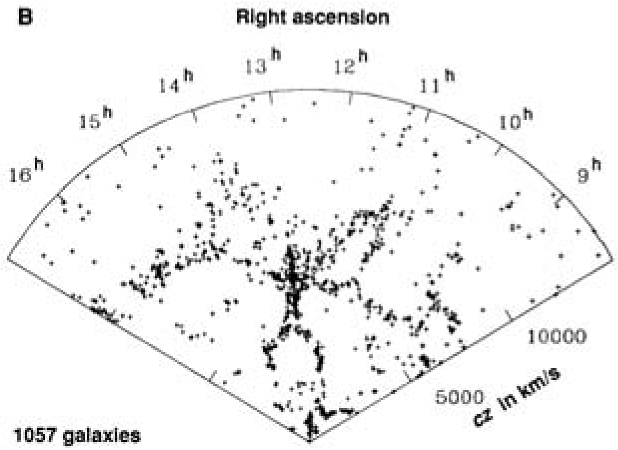


FIG. 58. CENTER FOR ASTROPHYSICS REDSHIFT SURVEY SLICE, 1989. When astronomers began using redshifts to map galaxies in three dimensions, they discovered patterns in their distribution, including a structure that resembles a stick figure in this early slice.
From Geller and Huchra 1989, 899 (fig. 3B). Permission courtesy of the American Association for the Advancement of Science, Washington, D.C.

ergy coming from every direction was first observed in 1965 by Arno A. Penzias and Robert Woodrow Wilson, also of Bell Telephone Laboratories. In 1989 the National Aeronautics and Space Administration (NASA) launched the Cosmic Background Explorer (COBE) to measure the diffuse microwave radiation. The observations were presented as a map of the temperature fluctuations shown using galactic coordinates in a Mollweide projection (fig. 60). Scientists believed that the subtle shifts led to the large-scale structures of the universe plotted in other maps. Another NASA mission, the Wilkinson Microwave Anisotropy Probe (WMAP), launched in 2001, provided a similar temperature map, but of higher resolution, sensitivity, and accuracy.

While telescopes can detect radio waves from the earth, observations of ultraviolet, X-rays, and gamma rays require orbiting instruments. Germany's rocket program, which was transplanted to the United States after World War II, encouraged the first observations in these areas of the spectrum, but extensive research coincided with the space race in the 1960s. Until the 1970s, the data remained too limited in scope to produce substantive cartographic representations. NASA's UHURU X-ray observatory, launched in 1970, led to a catalog and map that plotted the location and variety of X-ray sources in the sky. A more complete survey, conducted by the German ROSAT observatory, resulted in a catalog of 150,000 X-ray objects and enabled more precise study with other instruments. Satellites for detecting gamma rays, notably the European COS-B satellite in 1975 and NASA's Compton Gamma Ray Observatory in 1991, returned data that astronomers translated into increasingly more detailed maps of the gamma ray sky. Similarly, ultraviolet data from satellites were made into maps in the 1980s, including an atlas of the ultraviolet sky in 1988 (Henry et al. 1988). Broader surveys in all three wavelengths were ongoing at the end of the century (McLean et al. 1998).

Unlike other parts of the wavelength spectrum, infrared radiation was observed during the nineteenth century, but astronomers at that time primarily focused their attention on the sun. The twentieth century saw increased attention to mapping the presence of infrared radiation in nebulae and extragalactic objects. As they had done with other parts of the spectrum, astronomers first made infrared cartographic representations of discrete objects and the Milky Way, exemplified by the contour maps of the galaxy's center published in 1968 (Becklin and Neugebauer 1968). With advances in telescopes and detectors, surveying projects that produced maps and catalogs of the infrared sky followed. Projects like the Two Micron All Sky Survey (2MASS) used ground-based telescopes to observe in the near-infrared from 1993–2001. Far-infrared mapping required satel-

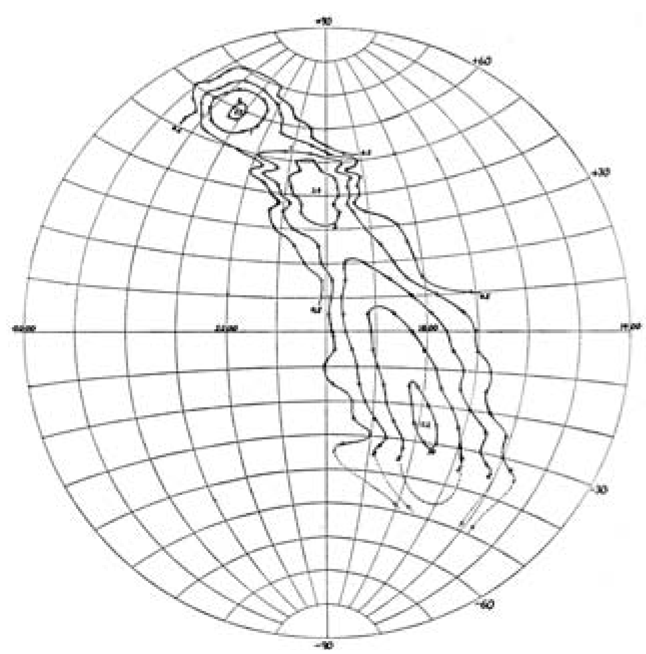


FIG. 59. MAP OF RADIO WAVE EMISSIONS, 1944. Relying on observations from instruments he built in his backyard in Wheaton, Illinois, Grote Reber made the first contour maps of radio waves in the Milky Way. This example shows right ascension two hours to fourteen hours.
Diameter of the original: 8.5 cm. From Reber 1944, 285 (fig. 4, left). Reproduced by permission of the American Astronomical Society.

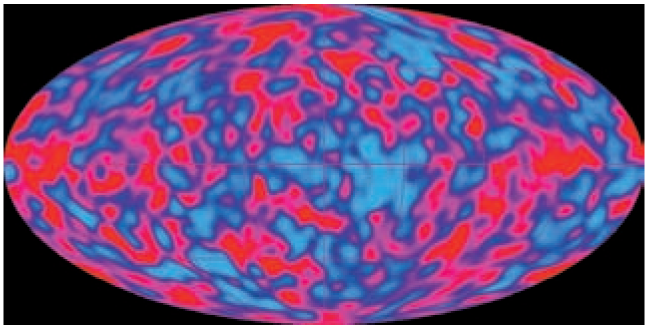


FIG. 60. COSMIC MICROWAVE BACKGROUND, 1992. The Cosmic Background Explorer (COBE) measured radiation from the early universe, and astronomers then used color to map temperature fluctuations on a Mollweide projection in geocentric ecliptic coordinates.
Image courtesy of NASA Goddard Space Flight Center, Greenbelt.

lites like the Infrared Astronomical Satellite (IRAS), a cooperative venture of the Netherlands, the United States, and the United Kingdom that was launched in 1983 and surveyed the entire sky.

By the end of the twentieth century, most astronomical observations were made with electronic detectors, typically charged-couple devices, which had a much higher sensitivity to light than other electronic detectors. In addition, their adoption resulted in a common digital format for all data. While a printed map that contained such a wealth of information would require significant effort, astronomers could combine and juxtapose the data more easily in an electronic format. Websites such as SkyView, operated by NASA but accessing data from an international array of observatories, allowed users to select a set of coordinates for a region of the sky and one or more wavelengths to create a custom map of the universe in a matter of seconds that easily fits in the space of computer screen.

Such ease of assembly in some ways diminishes the incredible expansion of humanity's understanding of the cosmos and the complex ways in which cartography illustrates astrophysical concepts and theories. The 2005 map of the universe that began this entry offers a clearer picture of the history of astrophysics and cartography in the twentieth century. In addition to demonstrating the expanded knowledge of the universe, it combines different cartographic innovations from the period. It also provides a compelling experience of scale. In order to show these objects in detail, the map must fill several pages or screens of a computer. A viewer cannot see and understand the universe in a single glance, but must in this format scroll through it in careful steps, readjusting to the scale and system of cartography used in each local region.

ELIZABETH A. KESSLER

SEE ALSO: Geodesy: Geodetic Surveying for the Planets; Geophysics and Cartography; Lunar and Planetary Mapping; National Aeronautics and Space Administration (U.S.); Star Chart

BIBLIOGRAPHY:
Abell, George O. 1958. "The Distribution of Rich Clusters of Galaxies." *Astrophysical Journal Supplement* 3:211–88.
Becklin, E. E., and G. Neugebauer. 1968. "Infrared Observations of the Galactic Center." *Astrophysical Journal* 151:145–61.
Blaauw, Adriaan, et al. 1960. "The New I.A.U. System of Galactic Coordinates (1958 Revision)." *Monthly Notices of the Royal Astronomical Society* 121:123–31.
Colless, Matthew, Lister Staveley-Smith, and Raylee Stathakis, eds. 2005. *Maps of the Cosmos: Proceedings of the 216th Symposium of the International Astronomical Union*. San Francisco: On behalf of the IAU by Astronomical Society of the Pacific.
Geller, Margaret J., and John P. Huchra. 1989. "Mapping the Universe." *Science* 246:897–903.
Gingerich, Owen, ed. 1984. *Astrophysics and Twentieth-Century Astronomy to 1950*. Cambridge: Cambridge University Press.
Gott, J. Richard, et al. 2005. "A Map of the Universe." *Astrophysical Journal* 624:463–84.
Henry, Richard C., et al. 1988. *Atlas of the Ultraviolet Sky*. Baltimore: Johns Hopkins University Press.
Hubble, Edwin Powell. 1936. *The Realm of the Nebulæ*. New Haven: Yale University Press.
Longair, M. S. 2006. *The Cosmic Century: A History of Astrophysics and Cosmology*. Cambridge: Cambridge University Press.
McLean, Brian J., et al. 1998. *New Horizons from Multi-Wavelength Sky Surveys: Proceedings of the 179th Symposium of the International Astronomical Union*. Dordrecht: Kluwer.
Oort, Jan Hendrik, Frank J. Kerr, and Gart Westerhout. 1958. "The Galactic System as a Spiral Nebula." *Monthly Notices of the Royal Astronomical Society* 118:379–89.
Reber, Grote. 1944. "Cosmic Static." *Astrophysical Journal* 100: 279–87.
Shane, C. D., and C. A. Wirtanen. 1954. "The Distribution of Extragalactic Nebulae." *Astronomical Journal* 59:285–304.
Turner, Michael Stanley, and J. Anthony Tyson. 1999. "Cosmology at the Millennium." In *More Things in Heaven and Earth: A Celebration of Physics at the Millennium*, ed. Benjamin Bederson, 245–77. New York: Springer; American Physical Society.
Zwicky, F. 1961–68. *Catalogue of Galaxies and of Clusters of Galaxies*. 6 vols. Pasadena: California Institute of Technology.

Atlas.

ELECTRONIC ATLAS
FACSIMILE ATLAS
HISTORICAL ATLAS
HISTORICAL-BOUNDARIES ATLAS
NATIONAL ATLAS
REGIONAL ATLAS
SCHOOL ATLAS
SUBSCRIPTION ATLAS
THEMATIC ATLAS
WORLD ATLAS

Electronic Atlas. Electronic atlases, also referred to as digital or multimedia atlases, are systematic collections of digital maps and associated information designed for distribution online or as electronic media such as a compact disc. Some electronic atlases display and enable interactive analysis of information. Maps can be manipulated through panning and zooming, switching layers on and off, moving the cursor to highlight particular features, and using hyperlinks to summon additional information. The relatively small screens used with most electronic atlases require efficiently structured data, carefully designed menus, and selective, rule-based displays. Many atlases use animation to display time-dependent phenomena, or employ sound for voice-over narration, local pronunciation of geographic names, or music clips with cultural content. Analytical functions include database queries, selection of class intervals, and simulation modeling. Depending on the range of functions, electronic atlases can be categorized as read-only, user-created, or analytical. While this last category incorporates functions common to geographic information systems, an electronic atlas is distinguished by its coherent collection of maps.

Development of electronic atlases began in the 1980s. One of the first prototypes of an interactive analytical atlas was *Electronic Atlas Mark 1* (1982), intended to modernize *The National Atlas of Canada* (fig. 61). Another prototype was the *PC-Atlas* (of Sweden) (1985). Early comprehensive digital mapping systems with user-created maps include the *BBC Domesday Project* of the United Kingdom (1986), which introduced the concept of user participation in the collection of information, and the TIGER Map Service, which the U.S. Census Bureau developed for creating maps from the 1990 census. Examples of early read-only atlases were the *Electronic Atlas of Arkansas* (1986), marketed by ElectroMap, and the *Digital Atlas of the World* (1986), developed by DeLorme.

In the 1990s many countries produced national or regional electronic atlases with general purpose or thematic content and distributed them on CD-ROMs and later on the Internet. The World Wide Web provided new opportunities for publication, marketing, and distribution of electronic atlases and for development of atlas information systems. Increasingly the products were multimedia, dynamic, and interactive. Examples of atlases from this period include the *CD-Atlas de France* (1991); *Territorial Evolution of Canada* (1992), first published on CD-ROM and later on the Internet; National Geographic's *Picture Atlas of the World* (1993); Canada's web-based *National Atlas Information System* (1993); *Atlas Nacional de España* (1994); *Atlas of Switzerland* (1997); and *National Atlas of the United States* (1997). By the end of the century electronic atlases were widely used, particularly in the educational community.

The accessibility of electronic atlases has been strongly influenced by the evolution of electronic media. Even rare historical atlases such as Mercator's world atlas have been converted to a digital format (Octavo edition) and thus made available to wider audiences. This trend has continued into the twenty-first century. Another development was the integration of electronic atlases into multimedia encyclopedias (such as *Grolier's Multimedia Encyclopedia*) or into digital libraries (such as Microsoft Encarta Reference Library). With the steady growth of geospatial information, electronic atlases have begun to serve as gateways to National Geospatial Data Infrastructure (NGDI) programs.

FIG. 61. RULE-BASED AUTOMATIC GENERALIZATION IN THE CANADIAN *ELECTRONIC ATLAS MARK 1*, AN EARLY ELECTRONIC ATLAS PROTOTYPE SYSTEM. The system was able to automatically convert area symbols into point symbols when, during the scale reduction process, an area became too small for acceptable legibility standards. This detail is from a Lexidata 3400 computer display.
Image courtesy of Eva Siekierska.

EVA SIEKIERSKA

SEE ALSO: Electronic Cartography: Electronic Map Labeling; Interactive Map

BIBLIOGRAPHY:

Köbben, Barend, Ferjan Ormeling, and Timothy F. Trainor, eds. 1997. *Proceedings of the Seminars on Electronic Atlases II*. Enschede: International Cartographic Association.

Siekierska, Eva. 1983. "Towards an Electronic Atlas." In *Auto-Carto Six: Automated Cartography, International Perspectives on Achievements and Challenges*, 2 vols., ed. Barry S. Weller, 2:464–74. [Canada]: Steering Committee of the Canadian National Committee for the Sixth International Symposium on Automated Cartography. Reprinted in *Auto-Carto Six: Selected Papers*, ed. David H. Douglas, Monograph 32–33, *Cartographica* 21, nos. 2–3 (1984):110–20.

Siekierska, Eva, and D. R. F. Taylor. 1991. "Electronic Mapping and Electronic Atlases: New Cartographic Products for the Information Era—The Electronic Atlas of Canada." *CISM/Journal ACSGC* 45:11–21.

Spiess, Ernst. 1995. "Some Problems with the Use of Electronic Atlases." *European Research Libraries Cooperation: The LIBER Quarterly* 5:235–44.

Facsimile Atlas. Well established as a cartographic genre by 1900, the facsimile atlas attained prominence as a printed product during the 1960s and held on to its distinctive role at century's end in multiple electronic formats. A trio of monumental works marked its rise in the nineteenth century: Edme-François Jomard's *Les monuments de la géographie; ou, Recueil d'anciennes cartes européennes et orientales* (1842–62), Manuel Francisco de Barros e Sousa, Visconde de Santarém's *Atlas composé de mappemondes, de portulans et de cartes hydrographiques et historiques depuis le VI^{e} jusqu'au XVII^{e} siècle* (1849), and A. E. Nordenskiöld's *Facsimile-Atlas to the Early History of Cartography with Reproductions of the Most Important Maps Printed in the XV and XVI Centuries* (1889). As their titles suggest, all were collections of early maps, intended to promote the study of map history by scholars lacking ready access to large map collections. Although hand-drawn facsimiles had been produced in the sixteenth century, the genre's prominence in the late nineteenth and early twentieth centuries reflects improved techniques for reproducing large images, notably the collotype process, which could support editions of several thousand copies; the large-format camera; and photographic lithography, a less expensive, more efficient process, which allowed even larger editions (Ristow 1967). Notable examples from the early twentieth century include *Monumenta cartographica Africae et Aegypti* (1926–51), five volumes in sixteen parts edited by Egyptian prince Yūsuf Kamāl and Frederik Caspar Wieder, and the six-volume *Portugaliae monumenta cartographica* (1960), by Armando Cortesão and A. Teixeira da Mota, with an accompanying text in both Portuguese and English (Yonge 1963, 440–41, 445).

Largely intended for historians interested in early maps or historical geographers interested in past landscapes, facsimile atlases have also catered to a more general audience of history buffs and map aficionados. Atlases well received by lay readers include Andrew M. Modelski's *Railroad Maps of North America: The First Hundred Years* (1984) and J. B. Post's *Atlas of Fantasy* (1973), a collection of fictional frameworks like the treasure map from Robert Louis Stevenson's *Treasure Island* (1883) and the map of Middle-earth from J. R. R. Tolkien's *The Lord of the Rings* (1954–55). Although most facsimile atlases were collections of diverse maps focused on a particular region, time period, or phenomenon, some were more or less exact reproductions of entire atlases, intended to meet an increased demand for originals that were in short supply (Ristow 1967). Numerous late nineteenth-century subscription atlases of U.S. counties have been reprinted, and in 1973 Dover Publications, which specializes in out-of-copyright classics, rolled out a facsimile of Nordenskiöld's *Facsimile-Atlas*. Concern for graphic quality led map historian C. Koeman (1964, 87) to identify four types of facsimile atlases, ranging from those sufficiently similar to "look like a forgery" to books intended "only for reference, without aiming at any graphic quality." The latter were often smaller than the original, with image quality further degraded by the dot screens used in halftone printing.

J. B. Harley questioned the assumed importance of facsimile atlases to the study of map history. Writing with M. J. Blakemore, he acknowledged that "facsimile publishing [enjoyed] a special place within the history of cartography" but argued "it cannot in itself be regarded as a barometer of progress" in the field and "clearly do[es] little to advance the serious study of early maps" (Blakemore and Harley 1980, 42–43). In particular, facsimiles ignored important aspects of the originals, such as binding and watermarks, and were often studied without ready reference to important related materials. In the first volume of *The History of Cartography*, Harley conceded "the value of the scholarly commentaries that accompanied them (epitomizing the geographical contribution to the study of early maps)" but noted that "these atlases have today declined in relative importance within the subject as a whole" (Harley 1987, 19).

In the 1990s the facsimile atlas attained new prominence online as well as on compact disc. Prominent Internet collections, supported by high-capacity fiber-optic connections and efficient compression/decompression software, include the David Rumsey Historical Map Collection, which features high-resolution digital images focused on North America in the eighteenth and nineteenth centuries; the various digital map collections of the U.S. Library of Congress; and extensive heritage collections of town and city maps developed in the Netherlands (Alkhoven 2005–6). In 2000, Octavo, a California firm specializing in electronic reprints of rare books, released a two-disc version of Gerardus Mercator's *Atlas sive cosmographicæ meditationes de fabrica mundi et fabricati figura* (1595) with a viewer that allowed 300 percent enlargement and a comprehensive commentary by map historian Robert W. Karrow. Harley's criticism does little to contradict Nicholas Crane's assessment (2001, 164) that this "first complete translation into English of Mercator's *Atlas* [is] a significant study-aid to sixteenth-century cartography [that] bring[s] a rare, beautiful and historic edition to every computer-user's desk." More questionable is the lifespan of compact discs and the electronic software needed to access them.

MARK MONMONIER

SEE ALSO: Atlas: Subscription Atlas; Cartobibliography; Historians and Cartography; Historical Geography and Cartography; Histories of Cartography; Photography in Map Design and Production; Reproduction of Maps: Photomechanical Processes

BIBLIOGRAPHY:

Alkhoven, Patricia. 2005–6. "Is It Real or Is It Virtual? Digital Facsimile Maps and Atlases in the Netherlands." *Journal of Map & Geography Libraries* 1:85–96; 2:5–35.

Blakemore, M. J., and J. B. Harley. 1980. *Concepts in the History of Cartography: A Review and Perspective*. Monograph 26, *Cartographica* 17, no. 4.

Crane, Nicholas. 2001. Review of *Gerardus Mercator, Atlas sive Cosmographicæ meditationes de fabrica mundi et fabricati figura (Duisberg, 1595)*, trans. David Sullivan. *Imago Mundi* 53:164.

Hameleers, Marc. 1992. "Kaarten in facsimile: Mogen er eisen aan gesteld worden?" *Caert-Thresoor* 11:11–16.

Harley, J. B. 1987. "The Map and the Development of the History of Cartography." In *HC* 1:1–42.

Koeman, C. 1964. "An Increase in Facsimile Prints." *Imago Mundi* 18:87–88.

Ristow, Walter W. 1967. "Recent Facsimile Maps and Atlases." *Quarterly Journal of the Library of Congress* 24:213–29.

Ruitinga, Lida. 1993. "Facsimile Maps and Atlases and Their Function in the Map Collection of the University Library of the Vrije Universiteit in Amsterdam." *LIBER Quarterly* 3:77–89.

Yonge, Ena L. 1963. "Facsimile Atlases and Related Material: A Summary Survey." *Geographical Review* 53:440–46.

Historical Atlas. Defined as a coherent set of maps created to depict earlier places and events, the historical atlas evolved significantly as a genre during the twentieth century. Historian Jeremy Black (1997, 81–225) identified several characteristics common to most twentieth-century historical atlases. For instance, political boundaries and military affairs were the most frequent subjects, and world atlases were strongly Eurocentric (fig. 62). National historical atlases usually reflected themes in the country's schoolbooks and in the outlook of its dominant group (e.g., the Nazis in pre–World War II Germany), and they seldom gave much attention to indigenous people and minorities, such as American Indians and African Americans in the United States. Outside Europe and North America nearly all historical atlases were published after World War II. The topics in historical atlases—and the techniques used to map them—multiplied as the scope of historical scholarship expanded to reflect developments like a heightened appreciation of population diversity since the 1960s and economic globalization since the 1980s.

Student atlases published on both sides of the Atlantic were usually organized into two or three parts. Although an index is essential for efficient use, not all atlases had one. At the turn of the century, maps and text were in separate parts, an arrangement reflecting the cost and technique of printing maps as color plates (black-and-white maps were few) and tipping them into the binding. Supporting text provided historical information for students as well as suggestions for teachers regarding student exercises and classroom use of the maps; information about sources of data or how the maps were constructed was rare.

The standard for scholarly historical atlases was set in 1932 by Charles Oscar Paullin's *Atlas of the Historical Geography of the United States* (Black 1997, 117–23; Wright 1965). Much of the data came from original research by leading historians, and sources and methods were fully documented. Most of the maps were designed as references, emphasizing locational aspects of single topics such as population distribution and boundary lines proposed in treaty negotiations. In his introduction Paullin encouraged readers to interpret the data by correlating maps to discover relationships among topics. In a similar fashion, reference maps of European states and empires at various dates contributed to the notable longevity of some student atlases like *F. W. Putzgers historischer Schul-Atlas zur alten, mittleren und neuen Geschichte*, by Friedrich Wilhelm Putzger, first published in 1877 and still in print 120 years later.

In the late twentieth century, the search for ways to handle previously unmapped phenomena and to improve on conventional but dated treatments of standard topics gave birth to innovative cartographic techniques and treatments. Inspired by editors of historical documents, Lester Jesse Cappon's scholarly *Atlas of Early American History* (1976) gave readers edited and redrawn eighteenth-century city plans (Wiberley 1980). Historian Helen Hornbeck Tanner compiled individual Indian settlements and their locations and mapped them in Cappon's atlas as well as in her own *Atlas of Great Lakes Indian History* (1987), with maps by Miklos Pinther, and *The Settling of North America* (1995), prepared with several associate editors. Tanner discredited both the idea that Indians were nomadic and the conventional use of vaguely shaped colored areas to depict where they lived (fig. 63).

By the 1960s offset photolithography had reduced the cost of color printing enough to make it economical to combine extensive text and colored images on a single page; this opened the way to the creation of a new type of publication for general readers: the popular historical atlas. An outstanding exemplar (possibly the first of its kind) was *The American Heritage Pictorial Atlas of United States History* (1966). American Heritage Publishing Company was founded after World War II to popularize and spread the latest historical scholarship in the United States. For marketing, American Heritage claimed to be heir to the standards of Paullin's work, but while the index was comprehensive, there was no information about contributors, sources, or methods of compilation. The subject matter of the atlas was organized in two-page spreads with each topic presented by means of one or more new, colorful maps and one or more illustrations or a reproduction of a contemporaneous map, all tied together by a lively text that was long enough to explain the topic and succinct enough not to lose the reader's interest. Combining the historical narrative with the historical map maximized the effect of both, and each

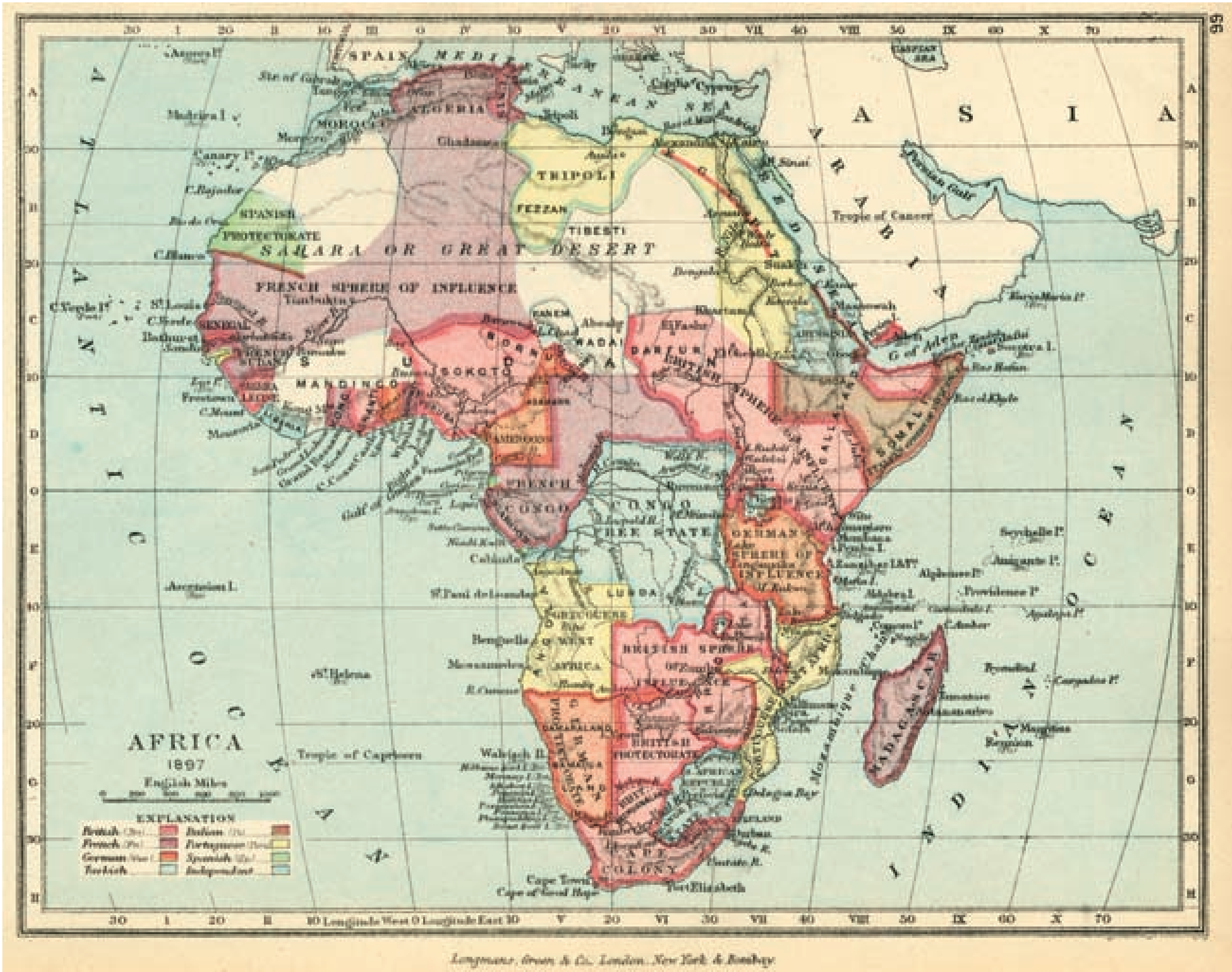


FIG. 62. *AFRICA 1897*. The place-names on this map tell less about Africa and Africans than about the interests and attitudes of various European nations, especially Great Britain, thus illustrating the Eurocentrism typical of Western historical atlases at the start of the twentieth century. Size of the original: 14.0 × 18.1 cm. From Samuel Rawson Gardiner, ed., *A School Atlas of English History*, new impression (London: Longmans, Green, 1902), pl. 66.

turn of the page dished up an attractive serving of history that made even the most hackneyed topic look fresh.

Following that formula for success, tens—perhaps hundreds—of popular historical atlases were published in the closing decades of the twentieth century. Malcolm Swanston and associates, who had originally provided cartographic services but became book packagers, helped create many popular atlases (Black 1997, 140–42), including the most successful of all, *The Times Atlas of World History*. First published in 1978 and edited by Geoffrey Barraclough, it was reprinted often and in several languages, sold more than one million copies (Black 1997, 144), and became the basis for a twenty-six-part television series viewed by millions worldwide (Reilly 1985). By 1990, when Clockwork Software released *Centennia Historical Atlas* under its original name, *Millennium*, it had become feasible to market an electronic student atlas with animated historical maps (Black 1997, 235).

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SEE ALSO: Education and Cartography: Teaching with Maps; Historians and Cartography

BIBLIOGRAPHY:

Black, Jeremy. 1997. *Maps and History: Constructing Images of the Past*. New Haven: Yale University Press.

Reilly, Kevin. 1985. Review of *The World: A Television History*, by Nicholas Barton. *History Teacher* 18:435–38.

Wiberley, Stephen E. 1980. "Editing Maps: A Method for Historical Cartography." *Journal of Interdisciplinary History* 10:499–510.

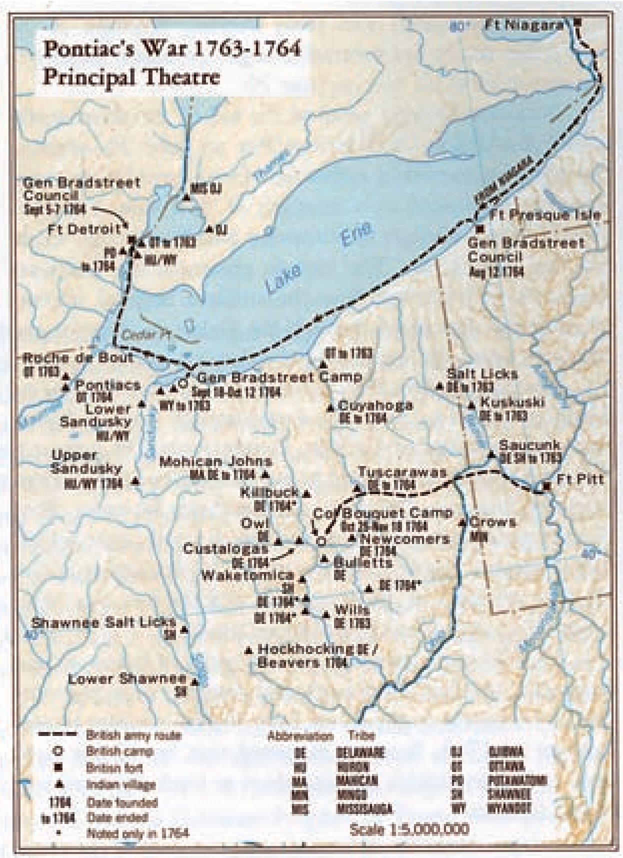


FIG. 63. *PONTIAC'S WAR 1763–1764: PRINCIPAL THEATRE*. Helen Hornbeck Tanner treated Indian towns as similar to European settlements, a radical change from the common practice before her work. The resulting map image makes clear that the Indians had a strong interest in the region where they fought the British.
Size of the original: 11.6 × 8.3 cm. From Helen Hornbeck Tanner, ed., *Atlas of Great Lakes Indian History*, cartography by Miklos Pinther (Norman: University of Oklahoma Press, 1987), 50.

Wright, John Kirtland. 1965. "J. Franklin Jameson and the Atlas of the Historical Geography of the United States." In *J. Franklin Jameson: A Tribute*, ed. Ruth Anna Fisher and William Lloyd Fox, 66–79. Washington, D.C.: Catholic University of America Press.

Historical-Boundaries Atlas. An atlas of historical boundaries is a set of maps that outline data-gathering areas for statistical maps or portray the boundary history of geographic units like counties or electoral districts by depicting the scope and context of their jurisdiction or operations. Interest in these atlases has been particularly strong in the United States, where counties and equivalent units, which serve many functions, have averaged four to five boundary changes since their formation.

In 1906 Illinois's secretary of state published *Counties of Illinois*, which depicts the evolution of the state's counties by plotting past and "present" boundaries together, a technique adopted by genealogists William Thorndale and William Dollarhide in their *Map Guide to the U.S. Federal Censuses, 1790–1920* (1987) as well as by the historians who created the digital *Atlas of Historical County Boundaries* (2010). Between the world wars, historical boundary atlases were published for five American states: California (1923), Indiana (1933), Louisiana (1939), Mississippi (1942), and Wisconsin (1942). The authors, all archivists, saw historical boundary maps as essential to understanding the scope and relevance of county records; they complemented the maps with the legal boundary descriptions. More state historical boundaries were published after World War II. A notable example is John Parr Snyder's prize-winning *The Story of New Jersey's Civil Boundaries, 1606–1968* (1969).

In the 1970s historians Stanley B. Parsons and William W. Beach, aiming to provide a resource for studying voting in the years before the regular publication of congressional district maps, used session laws to compile *United States Congressional Districts, 1788–1841* (1978) and *United States Congressional Districts and Data, 1843–1883* (1986), which outlined the districts and their constituent counties and added population statistics and other information. Geographer Kenneth C. Martis built upon a huge, incomplete 1930s federal undertaking to create the district networks in *The Historical Atlas of United States Congressional Districts, 1789–1983* (1982).

In 1909 the U.S. Department of Agriculture first issued a set of maps outlining American counties for every federal census from 1840 onward. (Each map was entitled *Outline Map of the United States*, and a new map was added each decade through 1960; the Census Bureau assumed publication in 1950.) In 1943 the source materials for the early years were reported lost. At the University of North Carolina, geographers Stephen S. Birdsall and John William Florin compiled *A Series of County Outline Maps of the Southeastern United States for the Period 1790–1860* (1973). A decade later, at the University of Maryland, Baltimore County, geographer Carville Earle and a team led by cartographer Thomas D. Rabenhorst redrew the Department of Agriculture maps and published them anew (Rabenhorst 1984). As a convenience to statistical cartographers, they added a very small-scale version of each map as a base for sketching. Earle continued working on the Department of Agriculture maps, and by early 1997, after he joined the faculty at Louisiana State University (LSU), the LSU Geoscience Publications program advertised expanded and digitized versions for sale as *Historical United States County*

FIG. 64. TWO COUNTY BOUNDARY MAPS BY PEGGY TUCK SINKO, 1996. "Knox Boundaries, 1 Sep 1814–31 Jan 1816" (left) shows the setting of Knox Co., Indiana, during seventeen months, 1814–16; the solid line depicts the boundary line at the time, in comparison to the dashed lines that portray the 1990 state and county boundaries. The county outline map "Indiana Territorial Census 1815" (right) depicts Indiana's county network at the time of its territorial census of 1815. It is designed for the reader interested in making a statistical map based on data from that enumeration.
Size of the originals: 15.1 × 9.7 cm (left); 17.9 × 11.6 cm (right). From Peggy Tuck Sinko, *Indiana: Atlas of Historical County Boundaries*, ed. John H. Long (New York: Charles Scribner's Sons, 1996), 180 and 344. © Copyright the Newberry Library, Chicago.

Boundary Files (HUSCO), 1790–1970 (and later editions to 1990 and 1999).

Historians on the Newberry Library's Atlas of Historical County Boundaries project (1987–2010) scoured session laws to make boundary maps as references for each county's history and as outlines for statistical mapping (fig. 64); they compiled all boundary changes from the 1630s to 2000, including noncounty areas and county attachments, and published twenty-four states in nineteen volumes before abandoning the printed atlas for an electronic counterpart in 2001. The digital products consisted of files compatible with geographic information system (GIS) software as well as interactive maps for online viewing—the digital equivalents of the maps in the printed volumes (Long 1993–2000). This project was successor to the experimental U.S. Historical County Boundary Data File project (1976–82), which had produced both printed atlases and a historical cartographic data file (Long 1984).

Enthusiasm for historical applications of GIS spread in the 1990s, when funding agencies strongly supported digital infrastructure, particularly national historical geographic information systems (NHGIS) that combined compilations of historical administrative boundaries with related data. The first was Great Britain's Historical Geographic Information System (HGIS), directed between 1994 and 1999 by geographer Humphrey Southall at Queen Mary College, University of London. The boundary component encompassed different administrative units in England and Wales: parishes (1870s–1974), local government districts (1911–74), and registration districts and Poor Law unions (1840–1911). In 2000 the project moved to the University of Portsmouth, where substantial topical content was added and the boundaries were converted from line segments to topologically structured polygons. In 2000 Southall organized a conference on historical European boundaries that drew representatives of projects in Belgium, Germany, the Netherlands, Portugal, Russia, and Sweden, among others (Gregory and Healey 2007; McMaster et al. 2005).

The U.S. National Historical GIS commenced in 2001 at the Minnesota Population Center at the University of Minnesota under the direction of John S. Adams. The goal was a comprehensive data set for every federal census of population consisting of boundary files—institutional counties alone for 1790–1900 and census counties and tracts for 1910–2000—and statistics. The main boundary sources for pre-1910 censuses were Thorndale and Dollarhide's *Map Guide* (1987) and the *Atlas of Historical County Boundaries*.

The China Historical GIS/Zhongguo lishi dili xinxi xitong 中国历史地理信息系统 started in 2001, directed by historians Peter Kees Bol of Harvard University and Ge Jianxiong 葛剑雄 of Fudan University. The focus was populated places through the period 222 B.C. to A.D. 1911 and included three levels of historical administrative units: provinces, prefectures, and counties. While boundaries of all three units are the core of the project, they sometimes had to be represented as points, an ironic turn in boundary mapping.

JOHN H. LONG

SEE ALSO: Administrative Cartography; Boundary Disputes; Boundary Surveying; Cartobibliography; Historians and Cartography

BIBLIOGRAPHY:

Gregory, Ian N., and Richard G. Healey. 2007. "Historical GIS: Structuring, Mapping and Analysing Geographies of the Past." *Progress in Human Geography* 31:638–53.

Long, John H. 1995. "Atlas of Historical County Boundaries." *Journal of American History* 81:1859–63.

———, ed. 1984. *Historical Atlas and Chronology of County Boundaries, 1788–1980*. 5 vols. Boston: G. K. Hall.

———, ed. 1993–2000. *Atlas of Historical County Boundaries*. 19 vols. New York: Simon & Schuster and Charles Scribner's Sons.

McMaster, Robert B., et al. 2005. "Reports on National Historical GIS Projects." *Historical Geography* 33:134–64.

Rabenhorst, Thomas D., ed. 1984. *Historical U.S. County Outline Map Collection, 1840–1980*. Baltimore: Department of Geography, University of Maryland Baltimore County.

Thorndale, William, and William Dollarhide. 1987. *Map Guide to the U.S. Federal Censuses, 1790–1920*. Baltimore: Genealogical Publishing.

National Atlas. National atlases are atlases dedicated to a specific country, with a complete and detailed representation of all socioeconomic, physical, and cultural aspects in such a way that these can be compared. Konstantin Alekseyevich Salishchev defines them as "basic multi-subject geographic atlases of single countries, containing a summary representation of contemporary scientific knowledge of the country in the fields of physical, economic and political geography" (Salishchev 1960, 3; 1972, intro.) National atlases gradually developed at the end of the nineteenth century, when such a multitude of statistical data and geoscientific observations had become available that the only way to represent them in a legible way was cartographic visualization. Although the *Administrativ-Statistischer Atlas vom Preussischen Staate (1827/8)*, the *Khozyaystvenno-statisticheskiy atlas Yevropeyskoy Rossii* (1851), the *Statistical Atlas of the United States* (1874), and *The Royal Scottish Geographical Society's Atlas of Scotland* (1895) have been cited as early examples, the first atlas that fits the above definition is the *Atlas öfver Finland* (1899; also published in French) published by the Finnish geographical society, Suomen maantieteellinen seura, in Helsinki. Finland at that time was a province of Russia, and this makes another point: the production of national atlases can be seen as a manifestation of separate identity. The early national atlases, including the *Atlas of Canada* (1906), viewed through early twenty-first-century eyes, emphasized physical aspects, presented inventories of the infrastructures (the road network, telephone net, or lighthouses), and visualized trade and transportation. Population statistics were presented as well.

A national atlas is a signpost that shows the extent of (also the gaps in) knowledge about the national territory. Apart from a scientific repository, a national atlas forms a starting point for further research and can play roles in social, economic, and natural resource development. These atlases help in planning (in its early inventory stages) and decision making. They serve as information sources for politicians, legislators, administrators, research, education, and reference in general. User investigations into national atlases have been scant; examples are those by Richard Groot (1979) and Bruce Wright (1999). In addition to their primary functions, national atlases serve as an organizational framework that brings together the geospatial experts that produced the diverse maps and made them comparable. In order to maximize this benefit, government support is needed: to provide free data sets, help collect data, and for financing.

After World War I newly independent countries like Finland, Poland, and Czechoslovakia produced national atlases to enhance their independence and to publicize themselves as a national unit. The production of a national atlas necessitates the mobilization of the scientific community within a nation and state support in making available statistical and scientific data. For example, in the Netherlands, the total input in research time by senior researchers on behalf of the collection and analysis of geospatial data for the second edition was estimated at 15–20 person years (Bakker 1990, 39). National atlas projects were initiated in the past by geographical societies (in Denmark, Finland, France, Sweden), academies of science (in Czechoslovakia, the Netherlands, the United States), and specific governmental departments (in Russia, the Soviet Union, Italy, Canada). In India in 1954 the National Atlas Organization (now the National Atlas and Thematic Mapping Organization [NATMO], a government institution) was established in Calcutta to produce a national atlas in order to make the most efficient use of national resources, to realize a useful subdivision of the country, and to characterize the regional particularities. In Italy it was the Touring Club Italiano, a commercial company, that served as the national atlas bureau and most ably compiled and visualized all the scientific data.

The contents of national atlases published before World War II were rather uneven—some emphasized physical aspects, while others presented a more even portrayal of physical and socioeconomic themes. This made it difficult to compare national atlases and contributed to the efforts of the International Geographical Union (IGU) Commission on National Atlases, chaired by Salishchev (1956–72) and Edgar Lehmann (1972–76), to develop a research program to specify the optimal way of representating specific map topics, leading to a national atlas model with fixed contents, map scales, and data reference periods. Salishchev had already standardized the regional atlases of the Soviet Union. For national atlases under his chairmanship a list of contents that had to be included was compiled; maps of specific characteristics of countries (such as volcanism in Iceland and Italy or polder drainage in the Netherlands) were allowed as extensions in this model. The program was a grandiose attempt to effectuate a national atlas of the world by combining the maps from all individual national atlases. This goal was reflected in the commission publications' *Atlas nationaux* and *Regional Atlases* (Salishchev 1960; 1964). The ideal was never reached as there were neither penalties nor inducements to follow these elaborated standards, but in the aftermath of the commission's existence national atlases flourished as never before (figs. 65 and 66). Until 1960 only twelve countries had published national atlases, while between 1960 and 1978 an additional forty-two countries published them (Bakker, Elzakker, and Ormeling 1987).

After 1976 the IGU commission was continued jointly with the International Cartographic Association (ICA) (1976–84) as the Joint IGU-ICA Working Group on Environmental Atlases, chaired by F. Vázquez Maure (1976–82) and David P. Bickmore (1982–84). It was generally assumed that all countries that had produced a national atlas would see it as their next task to produce an atlas of the conditions of their national environment. With the rapid switch to electronic technology near the end of the twentieth century, the focus of the Joint IGU-ICA Working Group changed from atlases to databases, and the need was felt again for a joint forum to gauge national atlas production. In 1986 during the Auto Carto conference in London, the ICA Working Group on National Atlases was established and accepted as a full commission the next year at the ICA conference in Morelia.

The twentieth century can be called the age of national atlases, with the period 1950–80 as its apogee. Some exceptional national atlases were published, such as the *Atlas der Schweiz = Atlas de la Suisse = Atlas della Svizzera* (1961–78, ed. Eduard Imhof), which stood out because of its graphical quality and elegance, and the *Atlas över Sverige = National Atlas of Sweden* (1953–71, chief ed. Magnus Lundqvist), because of its innovative character. Part of its preparation was computer aided, and it pioneered applied maps: e.g., not just climate maps but maps of humidity and precipitation during the growing season. In the United States work started on a national atlas in 1952 when the American Geographical Society produced a prototype of some 400 pages. The National Academy of Sciences continued the project from 1954 onward and set layout specifications according to which individual federal agencies would produce loose-leaf sheets. From these beginnings in 1962 the U.S. Geological Survey (USGS) started to produce the final map sheets resulting in *The National Atlas of the United States of America* (1970, ed. Arch C. Gerlach).

In the 1980s and 1990s, the standards proposed by Salishchev no longer satisfied the requirements of atlas cartography due to the use of new technology. National atlases were not regarded as statements of national achievements and aspirations or as national business cards, but became increasingly regarded as tools for problem solving of issues like unemployment, pollution, extramarital births, abortion, decaying services in the countryside, or aging (fig. 67). Only crime and mental health, both privileged subjects in the development of nineteenth-century thematic mapping, were omitted. Other topics were selected for visualization on maps according to the new view that national atlases were instruments for the elaboration of socioeconomic policies and intended to help all national citizens gain equal access to the nation's resources. This view emphasized aspects relevant to the nation's inhabitants and not geoscientific topics. The *Atlas van Nederland* and the *Nationalatlas Bundesrepublik Deutschland* are examples of this human-centered trend, which also had an impact on the organizational structure of national atlas endeavors.

FIG. 65. PUBLICATION OF NATIONAL ATLASES BEFORE 1960. After Bakker, Van Elzakker, and Ormeling 1987, 84 (fig. 1).

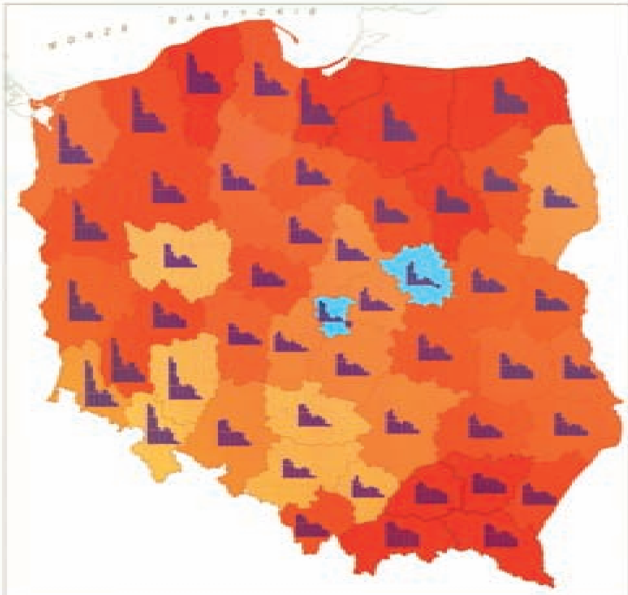
FIG. 66. NATIONAL ATLASES PUBLISHED 1960–78. After Bakker, Van Elzakker, and Ormeling 1987, 84 (fig. 2).

(*Facing page*)

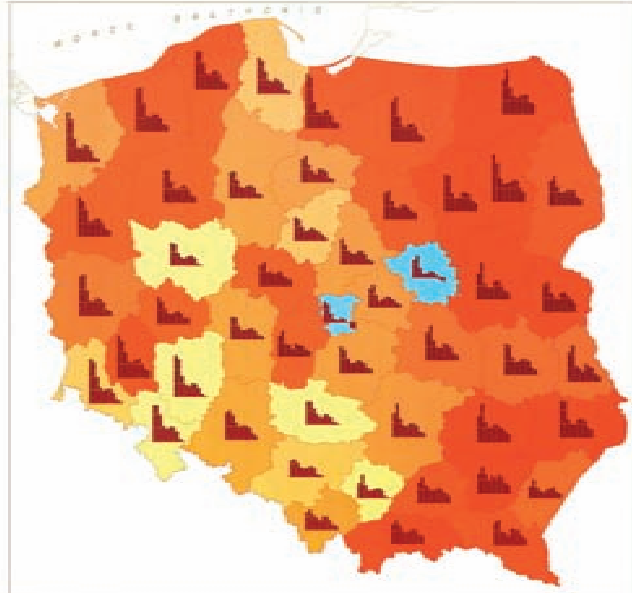
FIG. 67. PAGE FROM A POLISH NATIONAL ATLAS. This map, *Przyrost naturalny i reprodukcja ludności*, shows the natural increase and reproduction of the population based on 1992 data. Size of the original: 48.5 × 63.3 cm. From *Atlas Rzeczypospolitej Polskiej*, ed. Michał Najgrakowski (Warsaw: Główny Geodeta Kraju, 1993), sheet 64–4.

64.4 PRZYROST NATURALNY I REPRODUKCJA LUDNOŚCI

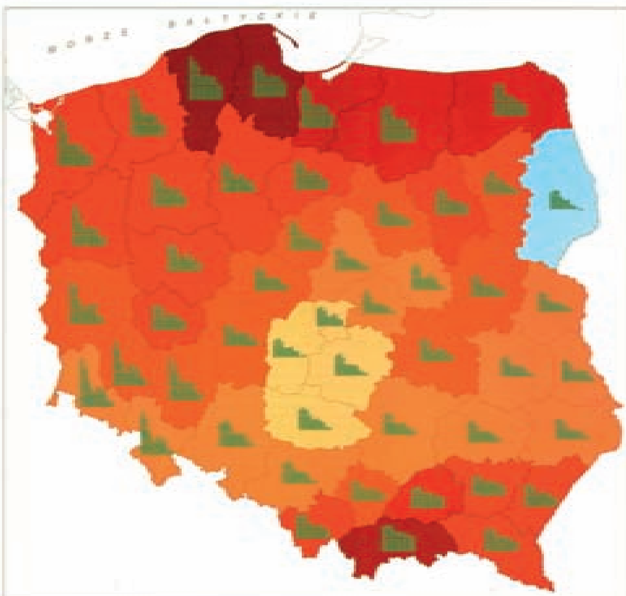
1. PRZYROST NATURALNY
OGÓŁEM
NATURAL INCREASE
TOTAL
Adam Jelonek



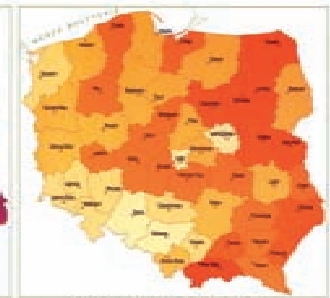
2. PRZYROST NATURALNY
MIASTA
NATURAL INCREASE
URBAN AREAS
Adam Jelonek



3. PRZYROST NATURALNY
WIEŚ
NATURAL INCREASE
RURAL AREAS
Adam Jelonek



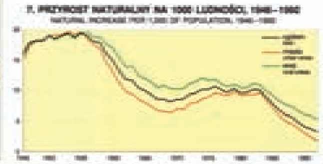
4. PŁODNOŚĆ KOBIET 1992
GENERAL FERTILITY RATE, 1992
Adam Jelonek



5. REPRODUKCJA LUDNOŚCI BRUTTO, 1992
GROSS REPRODUCTION RATE, 1992
Adam Jelonek

6. DYNAMIKA DEMOGRAFICZNA 1992
DEMOGRAPHIC DYNAMIC, 1992
Adam Jelonek

7. PRZYROST NATURALNY NA 1000 LUDNOŚCI, 1946–1992
NATURAL INCREASE PER 1,000 OF POPULATION, 1946–1992



POLSKA AKADEMIA NAUK • INSTYTUT GEOGRAFII I PRZESTRZENNEGO ZAGOSPODAROWANIA
© GŁÓWNY GEODETA KRAJU
POLSKIE PRZEDSIĘBIORSTWO WYDAWNICTW KARTOGRAFICZNYCH im. E. Romera, S.A.

These national atlases were about the population and included only a selection of geoscientific aspects deemed relevant for humans. This resulted in phasing out the national academies of sciences as sponsors. The new focus went hand in hand with a new target audience. Increasingly in the 1980s and 1990s, the atlases were created for well-educated laymen interested in their environment instead of the scientific community. This meant that the texts had to be rewritten to reach people who had completed a secondary education and be presented in a more acceptable physical format. The very heavy previous volumes were exchanged for smaller bindings that could be handled by one person alone. It became possible to publish an atlas in a number of separate topical volumes (e.g., *Atlas över Sverige* [20], *Atlas Nacional de España* [over 40], *Nationalatlas Bundesrepublik Deutschland* [12], *Atlas de France* [14]), so one who was interested only in a specific topic did not need to buy the entire atlas.

By the end of the century the enormous increase in geospatial data brought further change in the national atlas concept and led to the national atlas information system, in which the national atlas (on paper or on screen) is only the visual portal to the database. The portal can display time series and different aggregation levels; provide the opportunity to change scales, class boundaries, and symbols; and visualize combinations of data sets. These modern digital national atlases are available on CD-ROM or DVD (like the *Atlas der Schweiz*) or can be accessed on the Internet (like the *Atlas of Canada*).

The emergence of different platforms for national atlases also revealed that the various versions—paper, digital on CD-ROM or DVD, and Internet-based—serve different functions. The paper atlas with its superior graphics and selection of interesting map images appeals to a more casual audience with wide interests. This audience would follow up on specific topics by looking at the CD or DVD with its almost inexhaustible number of maps and statistical data combinations; regular updates would be available through the national atlas website.

Websites for national atlases were pioneered by National Resources Canada. Using the National Atlas Information System, the web version of the Canadian national atlas was made publicly accessible. It provided maps about the environment of Canada, its people and society, economy, history, climate change, freshwater, and health, reference maps, topographic maps, and also maps produced for previous editions of the national atlas, thereby creating a historical archive. As an example of the topical scope, the section on the environment was subdivided into climate, ecology, forests, geology, hydrology, land, natural hazards, protected areas, and sea ice; the land section contained maps on land cover, permafrost, plant hardiness zones, relief, world heritage sites, surface materials, physiographic regions, shield physiographic regions, and various types of borderland regions. The functionality was impressive, and by the end of the twentieth century there were extensive zoom possibilities, comments on the maps, map size options, adjustable map legends, and clickable maps. Additionally, order facilities for paper maps, map games to attract young map users, and classroom use options were available.

Other major national atlas endeavors around the turn to the twenty-first century have been a five-volume printed set for China, and one for Russia, which started in 1995 and is planned for distribution in ten volumes; both are also published or planned as CDs or DVDs. For China, the national atlas consists of a general geographic volume (1996), volumes on agriculture (1990) and economics (1993), a physical atlas (1999), and a national historical atlas (2001). In a national geospatial data infrastructure, national atlases can be embedded and be one of the tools made available to all schools, as was the case in Canada with the Canadian Geospatial Data Infrastructure. At the end of the twentieth century the ICA Commission on National and Regional Atlases—with important meetings in London (1985), Stockholm and Kiruna (1989), Beijing (1990), Madrid (1992), Prague and The Hague (1996), Reykjavik (1998), and Beijing (2001)—was the center for new developments.

In 1997, work began on an innovative national atlas of the United States. The new edition produced by the USGS included both electronic and paper map products and exploited information presentation, access, and delivery technologies that did not exist in 1970. The new national atlas was intended to provide a comprehensive, map-like view into the enormous wealth of data collected by the U.S. government. It offered authoritative scientific, social, and historical information; easy-to-use online interactive maps; and tools to display, manipulate, and query its data so that users could produce their own analyses. Above all, this national atlas was intended as a showcase for the geospatial data collected by federal agencies. Changed funding priorities influenced its success. The new U.S. National Atlas can be viewed online. The spin-off of this and similar national atlases cannot be overestimated: there have been derived editions and editions for schools, and the contents were used to update school and reference atlases.

FERJAN ORMELING

SEE ALSO: *Atlas of Canada*; Atlas of Finland; *Bol'shoy sovetskiy atlas mira*; Decolonization and Independence; *National Atlas of the United States of America, The*; Nation-State Formation and Cartography; Salishchev, Konstantin Alekseyevich

BIBLIOGRAPHY:
Bakker, Nico J. 1990. "De productie van 1000 kaarten in 6 jaar." In *Verslag van de themadag georganiseerd ter gelegenheid van het gereedkomen van de tweede editie van de Atlas van Nederland*, ed. Ferjan Ormeling and M. L. Straus, 33–40. Utrecht: Geografisch Instituut der Rijksuniversiteit.
Bakker, Nico J., C. P. J. M. van Elzakker, and Ferjan Ormeling. 1987. "National Atlases and Development." *ITC Journal* 1987-1:83–92.
Benedict, E. 1989. "From the Real Object to the Object of Cognition—On the Conception of a New Generation of National Atlases." Papers Presented to the Fourteenth International Cartographic Conference, Budapest. Unpublished.
Chatterjee, S. P. 1964. "National and Regional Atlases." Report submitted to the Commission on National Atlases, International Geographical Union, for its meeting to be held in London in July 1964. Unpublished.
Groot, Richard. 1979. "Canada's National Atlas Program in the Computer Era." In *The Purpose and Use of National and Regional Atlases*, ed. Barbara J. Gutsell, Monograph 23, *Cartographica*, 41–52. Toronto: Toronto University Press.
Huber, Stefan, Patrik Jeller, and Marianne Ruegsegger. 2005. "Thinking Modular: Towards a Pluggable Atlas User Interface." In *Proceedings of the 22nd International Cartographic Conference*, A Coruña, Spain. Online publication.
Huber, Stefan, and Christoph Schmid. 2003. "2nd Atlas of Switzerland: Interactive Concepts, Functionality and Techniques." In *Proceedings of the 21st International Cartographic Conference*, Durban, South Africa, 1398–1405. Online publication.
Imhof, Eduard. 1966. "Der 'Atlas der Schweiz.'" *International Yearbook of Cartography* 6:122–39.
National Advisory Committee for the National Atlas of Canada. 1988. *The National Atlas Information System: A Report to the Minister of State (Forestry and Mines)*. Ottawa.
Ormeling, Ferjan. 1991. "The Atlas of the Netherlands, Second Edition." *Tijdschrift voor Economische en Sociale Geografie* 82: 58–62.
Robinson, Arthur H. 1971. "The National Atlas of the United States of America." *Surveying and Mapping* 31:330–38.
Salishchev, Konstantin Alekseyevich, ed. 1960. *Atlas nationaux: Histoire, analyse, voies de perfectionnement et d'unification*. Moscow: Édition de l'Académie des Sciences de l'URSS. Also published in Russian. In English, *National Atlases: Their History, Analysis, and Ways to Improvement and Standardization*. Monograph 4, *Cartographica*. Toronto: University of Toronto Press, 1972.
———, comp. 1964. *Regional Atlases: Tendencies of Development, Subject Matters of the Maps on Natural Conditions and Resources*. Moscow: Science.
Sieber, René, Christoph Schmid, and Samuel Wiesmann. 2005. "Smart Legend—Smart Atlas!" In *Proceedings of the 22nd International Cartographic Conference*, A Coruña, Spain. Online publication.
Smidt, M. de. 1986. "The Human Scope of Geography—Towards a New National Atlas of the Netherlands." *Cartographic Journal* 23:70–72.
Trainor, Timothy F., ed. 1995. "Electronic Atlases: National and Regional Applications." *Cartographic Perspectives* 20.
Wright, Bruce. 1999. "The National Atlas of the United States of America." In *Proceedings of the Seminar on Electronic Atlases and National Atlas Information Systems in the Information Age*, ed. Agust Gylfason et al., 35–40. Reykjavik: International Cartographic Association.

Regional Atlas. Regional atlases have had a distinct evolution beginning in the early twentieth century. This atlas genre prevailed throughout the twentieth century as concurrent advances in statistical mapping created a new lexicon for regional analysis. The development of regional atlases is also influenced by developments in regional methodologies in Europe and the United States, prevailing despite midcentury fluctuations in popularity experienced by the academic discipline of regional geography. (See table 3 for a selected list of regional atlases.)

In 1964, Russian geographer Konstantin Alekseyevich Salishchev compiled the first stand-alone history of the regional atlas. Salishchev borrowed heavily from the terminologies of regional geography to codify the regional atlas. His methodology was based on the "interrelated phenomena" and "observed peculiarities" derived from a small collection of atlases that shared basic characteristics and thematic organization (Salishchev 1964). Mapping regional complexes became an integrated system of cartographic analysis, and later regional atlases were formally classified according to their "complex" or "semi-complex" characteristics (Stams 1980, 12). German-born Werner Stams built upon Salishchev's classification and compiled an international inventory of national and regional atlases commissioned by the relatively short-lived joint International Geographical Union–International Cartographic Association (IGU-ICA) Commission on Environmental Atlases (1976–84). By 1985 the regional atlas had emerged from its obscurity in academic circles to share the spotlight with national atlases with the formation of ICA's Commission on National and Regional Atlases.

1900–1945: Birth of Thematic Cartography and Expanding Regional Topics

The *Atlas Aziatskoy Rossii* (1914) was one of the first regional atlases to address a regional problem on a massive scale. The intent was to facilitate the colonization of Siberia, Central Asia, and the Russian Far East in order to alleviate the land crisis in European Russia. Though it was produced primarily for propaganda purposes, it included topics such as climate, habitable lands, agricultural development, livelihood (fig. 68), and other conditions of the environment of Asiatic Russia (Fremlin and Sebert 1972, 5).

Specialization became key in this period, and academics from many disciplines contributed knowledge and expertise to a diverse lineup of products. Numerous regional atlases from the Soviet Union became the prototypes from which Salishchev later developed his atlas classification in 1964. In the Soviet Union, such notables as Vladimir Il'ich Lenin and economic geographer Nikolay N. Baranskiy inspired the thematic or cognitive cartography and complex mapping that fueled an exten-

Table 3. Regional atlases

Atlas	Author/Editor/Publisher	Year
Atlas Aziatskoy Rossii	Edited by G. V. Glinka. St. Petersburg: Izdaniye Pereselencheskago Upravleniya, Glavnago Upravleniya Zemleustroistva i Zemledeliya.	1914
Rhein-Mainischer Atlas für Wirtschaft, Verwaltung und Unterricht	Edited by Walter Behrmann and Otto Maull. Frankfurt am Main: H. L. Brönner.	1929
Atlas Moskovskoy oblasti	Moskovskaya oblastnaya planovaya komissiya, Nauchno issledovatel'skii institut ekonomiki. Moscow: Izdaniye Mosoblispolkoma.	1933
Atlas Niedersachsen: Natur und Bevölkerung, Siedlungs-, Wirtschafts-, und verkehrsverhaltnisse eines deutschen Kultur- und Lebensraumes	By Kurt Brüning. Oldenburg: Gerhard Stalling.	1934
Saar-Atlas	Edited by Hermann Overbeck and Georg Wilhelm Sante. Gotha: Justus Perthes.	1934
Atlas géographique et historique du Congo belge et des territoires sous mandat du Ruanda-Urundi	By René de Rouck. Brussels: Éditions R. de Rouck.	1938
Linguistic Atlas of New England	Edited by Hans Kurath. Providence: Brown University for the American Council of Learned Societies.	1939
Thüringen-Atlas der Reichsarbeitsgemeinschaft für Raumforschung	Edited by Johannes Müller. Gotha: Justus Perthes.	1939
Atlas of Climatic Types in the United States, 1900–1939	C. W. Thornthwaite. Washington, D.C.: Government Printing Office.	1941
Burgenland (1921–1938): Ein Deutsches Grenzland im Südosten	Edited by Fritz Bodo. Vienna: Österreichischer Landesverlag.	1941
Atlas de la mutualité agricole en Afrique du Nord	Alger: Caisse Central de Réassurance des Mutuelles Agricoles de l'Afrique du Nord.	1947
Atlas général du Congo et du Ruanda-Urundi	Brussels: Institut royal colonial belge.	1948–63
A Statistical Atlas of the Madras Province	Madras: Government Press.	1949
Atlas pastoral pour la Mauritanie et le Senégal	By F. Bonnet-Dupeyron. Paris: O.R.S.T.O.M.	1950–51
Macmillan's Atlas for South-East Asia	Edited by R. E. Parry. London: Macmillan.	1953
The U.S.S.R. and Eastern Europe	Economist Intelligence Unit and the Cartographic Department of the Clarendon Press. [London]: Oxford University Press.	1956
The Oxford Australia Atlas	Cartographic Department of the Oxford University Press. Melbourne: Oxford University Press.	1957
Coloured States Atlas of India	By B. S. Kaushal. Delhi: Indian Book Depot.	1958
The Oxford School Atlas for India, Pakistan, Burma & Ceylon	By John (Ian) Bartholomew. London: Oxford University Press.	1958 (20th ed.)
Statistical Atlas Rajasthan	Directorate of Economics & Statistics, Rajasthan, Jaipur. Jaipur: The Directorate.	1959
Atlas of the Arab World and the Middle East	Introduction by C. F. Beckingham. London: Macmillan.	1960
National Geographic Atlas of the Fifty United States	Washington, D.C.: National Geographic Society.	1960
Regional Income Atlas of Madhya Pradesh	Directorate of Economics and Statistics, Madhya Pradesh, Bhopal. Bhopal, N.p.	1960
Urban Atlas: 20 American Cities	By Joseph Passonneau and Richard Saul Wurman. Cambridge: M.I.T. Press.	1966

Atlas	Author/Editor/Publisher	Year
Economic Atlas of Ontario	Edited by W. G. Dean. Toronto: Published for the Government of Ontario by the University of Toronto Press.	1969
Issues in the Middle East: Atlas	Washington, D.C.: Central Intelligence Agency.	1973
USSR Agriculture Atlas	Washington, D.C.: Central Intelligence Agency.	1974
Urban Atlas: Tract Data for Standard Metropolitan Statistical Areas	U.S. Department of Commerce, Social and Economic Statistics Administration, Bureau of the Census, U.S. Department of Labor, Manpower Administration. Washington, D.C.: The Bureau.	1974–75
People in Durham—A Census Atlas	Edited by John C. Dewdney and David Rhind. Durham: Census Research Unit, Department of Geography, University of Durham.	1975
Atlas of Oregon	Edited by William G. Loy. Eugene: University of Oregon.	1976
A Comparative Atlas of America's Great Cities: Twenty Metropolitan Regions	By John S. Adams and Ronald F. Abler. Minneapolis: Association of American Geographers and the University of Minnesota Press.	1976
Atlas of Winnipeg	Compiled and edited by Thomas Weir. Toronto: University of Toronto Press.	1978
Polar Regions: Atlas	National Foreign Assessment Center. Washington, D.C.: Central Intelligence Agency.	1978
Atlas of California	Michael W. Donley et al. Culver City: Pacific Book Center.	1979
Atlas Ost- und Südosteuropa: Aktuelle Karten zu Ökologie, Bevölkerung und Wirtschaft = Atlas of Eastern and Southeastern Europe: Up-to-date Ecological, Demographic and Economic Maps	Edited by Peter Jordan. Vienna: Österreichisches Ost- und Südosteuropa-Institut.	1989 (initiated)
The Electronic Atlas of Arkansas [computer file]	Edited by Richard M. Smith. Fayetteville: University of Arkansas Press.	1989
Atlas of Central Europe	Digital facsimile of the 1945 atlas by András Rónai. Digital facsimile technique developed by László Zentai. Online publication.	1993
Atlas of the New West: Portrait of a Changing Region	Edited by William E. Riebsame. New York: W. W. Norton.	1997
Atlas Śląska Dolnego i Opolskiego	Uniwersytet Wrocławski, Polska Akademia Nauk—Oddział we Wrocławiu. Wrocław: Uniwersytet Wrocławski, Pracownia Atlasu Dolnego Śląska.	1997
Atlas du Québec et de ses régions	Online publication.	1999

sive portfolio of regional and national products in the 1920s and 1930s (Salishchev 1988, 182). In his support of Baranskiy's methodologies, Lenin set the stage for an unprecedented regionalization of the Soviet Union in the 1920s based on a diverse body of information regarding natural resources, physical conditions, population, and types of economy in each of twenty-one regions (Martin 2005, 260). The complex *Atlas Moskovskoy oblasti* (1933) is a noteworthy example of the use of this methodology (Salishchev 1988, 181).

Germany followed the Russian model of regional atlas production in its lineup of regional studies such as the *Rhein-Mainischer Atlas* (1929), the *Atlas Niedersachsen* (1934), the *Saar-Atlas* (1934), and the *Thüringen-Atlas* (1939). Maps in these atlases filled the need to confirm and reconstruct German territories following World War I and delineated the geology, climate, history, relief, plant and animal distribution, building forms and plans, settlement types, anthropology, religion, health and disease, education, and population of these regions. The prized Burgenland region, awarded to Austria at the end of World War I, was the inspiration for Austrian Fritz

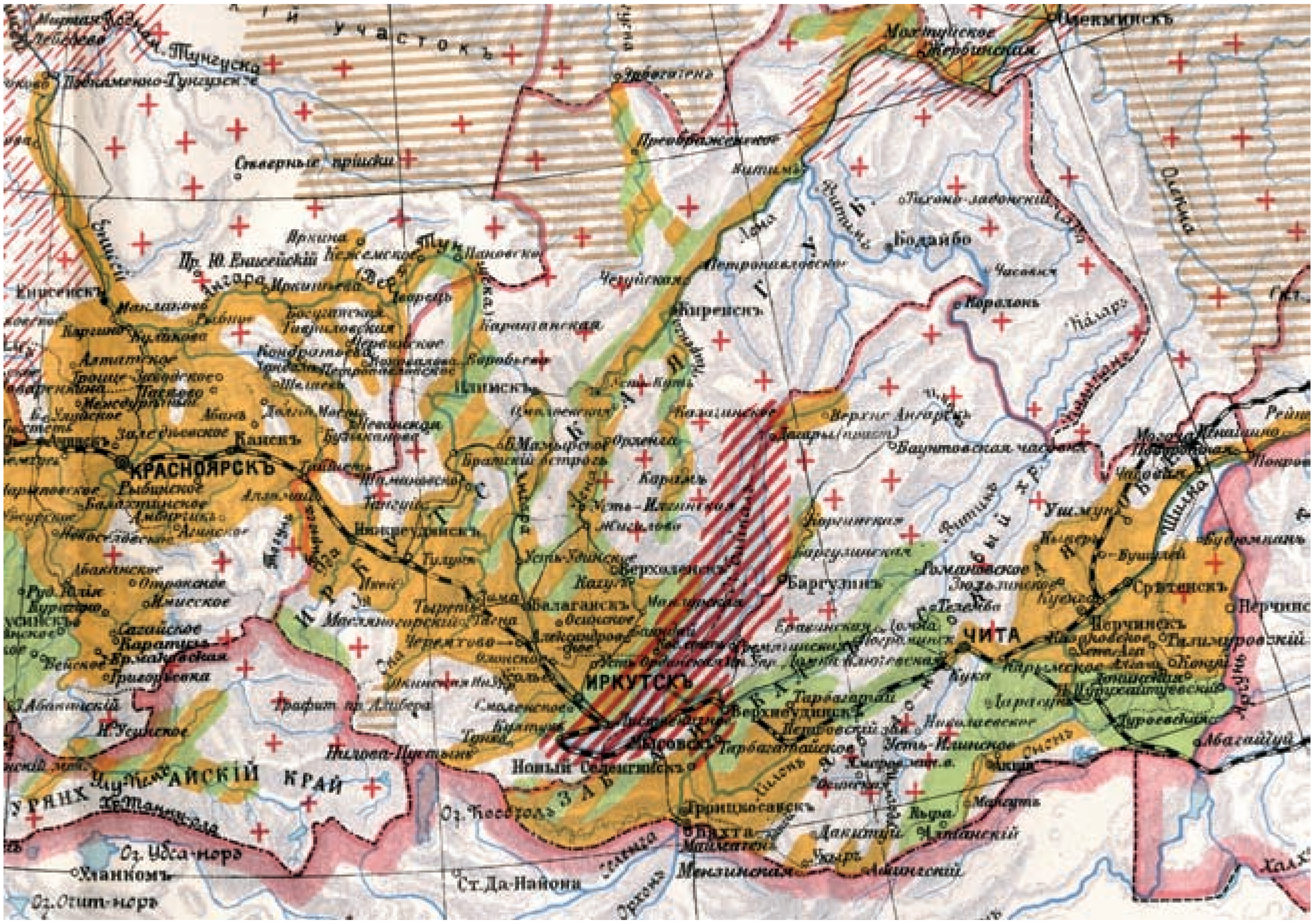


FIG. 68. DETAIL FROM A MAP OF OCCUPATIONS IN ASIATIC RUSSIA, 1914. This area around Irkutsk on the *Karta promyslov" Aziatskoy Rossii* shows agricultural areas (orange), cattle breeding (green), deer breeding (brown horizontal lines), hunting (red crosses), and fishing (narrow and wider red diagonal lines).
Size of the entire original: 49.3 × 68.9 cm; size of detail: 12.1 × 17.3 cm. From *Atlas Aziatskoy Rossii*, 1914, pl. 47.

Bodo's *Burgenland* atlas—the idea for the atlas originating as early as 1933, just prior to the annexation of Austria by Germany in 1938 (Ristow 1951, 482).

In 1939, Hans Kurath's *Linguistic Atlas of New England* became an example of a comprehensive and scholarly regional atlas that is thematic, rather than general, in scope (Monmonier 1981, 201). C. W. Thornthwaite's *Atlas of Climatic Types in the United States* (1941) differed from Kurath's atlas, but was far-reaching in importance for regional biogeography, climatology, and environmental atlases to come.

The *Atlas of Central Europe* (Rónai 1945) was initiated in Budapest in 1926 during an extremely volatile period in the history of Central Europe and the Carpathian Basin. It summarized the state of affairs in the historical territory of Hungary and its twelve neighboring countries with over 134 detailed maps of the geographical, demographic, and economic condition of this region compiled from official statistical data and other sources (facsimile edition, 1989; available online, 1993).

1946–60 Post–World War II Atlas Boom

Both national and regional atlases experienced a postwar atlas boom fed by the grassroots efforts of national superpowers awakened by global conflict. New regional atlases from England, France, Belgium, Germany, India, Canada, and the United States focused on international regions, territories, states, and provinces of particular significance to their political infrastructure (Núñez de las Cuevas 1993).

Though Rand McNally's *Goode's* atlases had become the standard school atlas for high school and college geography curriculums in the United States since 1923, postwar consumer demand for regional atlases was at its peak. Publishers like Macmillan, Oxford University Press, and National Geographic produced atlases of multinational territories and regional hotspots around the world that were carefully crafted for a new audience of users suddenly thrust into an age of political transition. Macmillan's atlases covered such areas as Southeast Asia (1953) and the Arab world and Middle East (1960). Oxford published atlases of the U.S.S.R. and Eastern Europe (1956), Australia (1957), and India, Pakistan, Burma, and Ceylon (1958). The *National Geographic Atlas of the Fifty United States* (1960) was a welcome addition and forerunner to a new generation of state and regional atlases to follow in the 1970s (Stams 1980, 41, 121, 123–24, 143, 167).

Some regional atlases were also inventories of well-established imperialism in Africa and Asia. The French atlases of African regions—*Atlas de la mutualité agricole en Afrique du Nord* (1947) and *Atlas pastoral pour la Mauritanie et le Senégal* (1950–51)—focused on the singular theme of French agricultural interests in North Africa (Tunisia, Morocco, Algeria) and West Africa (Mauritania, Senegal) prior to the Algerian War (1954–62) and subsequent transitions to independence (Stams 1980, 151). The Institut royal colonial belge produced a complex regional atlas devoted to European colonial interests in Central Africa that was years in the making—*Atlas général du Congo et du Ruanda-Urundi* (1948–63) (Ristow 1951, 483). This atlas and René de Rouck's earlier *Atlas géographique et historique du Congo belge et des territoires sous mandat du Ruanda-Urundi* (1938) are lasting records of Belgium's political presence and economic influence in these temporary regional strongholds (Stams 1980, 155; Ristow 1951, 483).

Though the British Survey of India had practiced modern European cartographic traditions for nearly two centuries, India's independence from Britain in 1947 sparked a prolific period of regional atlas production based in the newly formed governments and states in India. *A Statistical Atlas of the Madras Province* (1949), *Regional Income Atlas of Madhya Pradesh* (1960), *Statistical Atlas Rajasthan* (1959), and *Coloured States Atlas of India* (1958) are exceptional examples of contemporary Indian advances in thematic cartography combined with traditional European regional methodologies (Stams 1980, 124, 234–35).

1961–80 Digital Transformation

Cartography readily incorporated the new quantitative methodologies of the 1960s and 1970s, and the regional atlas maintained its unique role as a specialized research tool. A new classification of subnational and urban atlases had joined the ranks of specialized atlases during this period (Dean 1970, 52). These new trends were most visible in the state and provincial atlases for at least twelve states in the United States and three provinces in Canada (Monmonier 1981, 201–2). The *Economic Atlas of Ontario* (1969) is perhaps the most exemplary regional atlas during this period. William G. Loy's *Atlas of Oregon* (1976) and Michael W. Donley and colleagues' *Atlas of California* (1979) are among the better state atlas prototypes to employ the interpretive and comprehensive approach and to feature data from a multitude of academics, scientists, and official government sources (Monmonier 1981, 202–3).

Urban design visionary and information architect Richard Saul Wurman and fellow architect Joseph Passonneau were keenly aware of geographical integration in atlases when they published the *Urban Atlas* (1966)—their first cartographic summary of urban phenomena and growth in the United States. Within the next decade, several census-driven urban atlas projects were launched in Canada, the United States, and the United Kingdom (Monmonier 1981, 203–4). The 1971 British Census was the source for John C. Dewdney and David Rhind's *People in Durham* (1975), the first atlas of its kind to test the limits of computer-assisted cartography for such a small, highly detailed area. The U.S. Census Bureau's *Urban Atlas* (1974–75) series was more ambitious in its cartographic interpretation of 1970 census data for the sixty-five largest Standard Metropolitan Statistical Areas in the United States. United States and Canadian urban geographers soon adopted these specialized atlas prototypes for John S. Adams and Ronald F. Abler's *Comparative Atlas of America's Great Cities* (1976) and Thomas Weir's *Atlas of Winnipeg* (1978).

At a time when regional atlases were desperately needed to map the volatile areas of the world, the government-document thematic atlases like those produced by the U.S. Central Intelligence Agency (CIA) deserve special mention. CIA atlases such as *Issues in the Middle East* (1973), *USSR Agriculture* (1974), and *Polar Regions* (1978) provided the incentives for commercial firms like Rand McNally and National Geographic to publish regional atlases with information from the public domain combined with their own trusted networks of regional specialists (Monmonier 1981, 208).

1981–2000 Regional Atlas Redefined

The eclectic pluralism evident in regional sciences also translated to the regional atlases produced during the 1980s and 1990s (Martin 2005, 424). New subject matter addressing water issues, migrations, new lifestyles, and nuclear testing sites (fig. 69) were reflected in the *Atlas of the New West* (1997). The Polish *Atlas Śląska Dolnego i Opolskiego* (1997) had a strong focus on the environment and detailed the historical, demographic, and socioeconomic structure of Silesia, a dynamic crossroads and economic heartland of Central Europe (Jordan 2004,

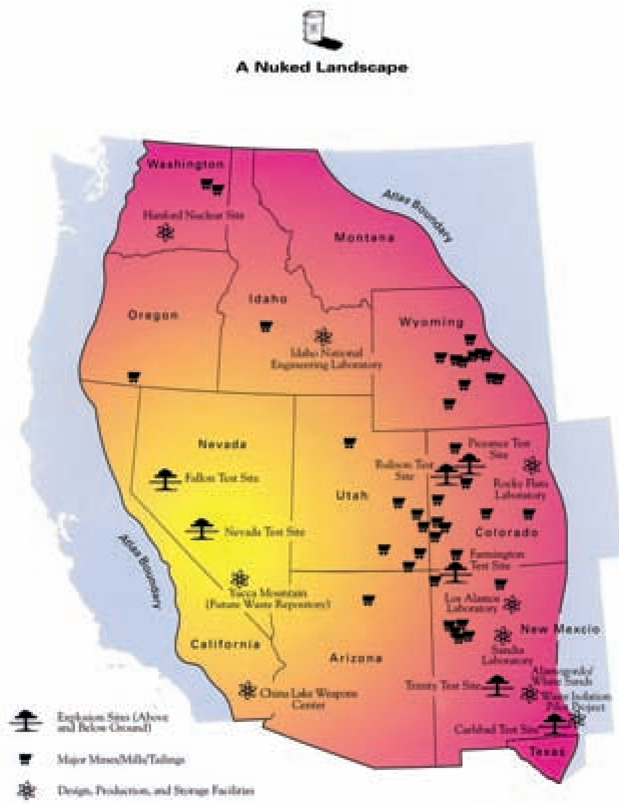


FIG. 69. *A NUKED LANDSCAPE*, 1997.
Size of the original: 24.1 × 18.6 cm. From *Atlas of the New West*, 1997, 134. Permission courtesy of the Center of the American West, Boulder.

160–61). Multiple Chinese regional atlas titles during this period used words and phrases like "environmental quality research," "ecology," "industry," "agricultural regionalism," and "climate disaster" and reflected this infusion of new atlas themes for provinces, watersheds, and urban areas in China (Trainor and Liao 2003).

One of the first regional electronic atlases, *The Electronic Atlas of Arkansas* (1989), initiated the transition from passive to active viewing in a format where a set of static maps were accessed from a detailed menu. Web atlases were envisioned and conceptualized as a dynamic product or set of maps that could be generated from a variety of geospatial data from multiple sources. In this new framework products like the *Atlas du Québec et de ses régions* (1999) crossed over the conventional standards to become a multipurpose atlas, an amalgamation of national atlas, school atlas, and regional atlas (Kraak 2001). The *Atlas Ost- und Südosteuropa*, initiated in 1989, set a precedent for regional atlases to develop a web version either during or immediately following the release of the print version (Resch and Jordan 2001).

The regional atlas has realized transformative traits throughout the twentieth century. Its conventional qualities of uniqueness and eclectic subject matter for a limited audience have evolved through time to reflect new developments in geographical thinking and regional methodologies. The regional atlas of the twenty-first century has integrated a wider breadth of topics and has a shorter shelf life than its predecessors. Gone are the decades-long research projects and expensive atlas budgets. The regional atlas has earned its rightful place as a unique atlas genre in the twentieth century and beyond.

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SEE ALSO: Geographical Mapping; Thematic Mapping

BIBLIOGRAPHY:
Dean, W. G. 1970. "The Structure of Regional Atlases/An Essay on Communications." *Canadian Cartographer* 7:48–60.
Fremlin, Gerald, and L. M. Sebert, eds. 1972. *National Atlases: Their History, Analysis, and Ways to Improvement and Standardization*. Monograph 4, *Cartographica*. Toronto: B. V. Gutsell, Department of Geography, York University.
Jordan, Peter. 2004. "National and Regional Atlases as an Expression of National/Regional Identities: New Examples from Post-Communist Europe." *Cartographic Journal* 41:150–66.
Kraak, M. J. 2001. "Web Maps and Atlases." In *Web Cartography: Developments and Prospects*, ed. M. J. Kraak and Allan Brown, 135–40. London: Taylor & Francis.
Martin, Geoffrey J. 2005. *All Possible Worlds: A History of Geographical Ideas*. 4th ed. New York: Oxford University Press.
Monmonier, Mark. 1981. "Trends in Atlas Development." In *Maps in Modern Geography: Geographical Perspectives on the New Cartography*, ed. Leonard Guelke, Monograph 27, *Cartographica* 18, no. 2:187–213.
Núñez de las Cuevas, Rodolfo. 1993. "Atlas Regional: Lenguaje cartográfico y nuevas orientaciones." *Serie Geográfica* 3:9–14.
Resch, Christian, and Peter Jordan. 2001. "Characteristics in Data Management within a Scientific Multinational Internet Atlas." In *Mapping the 21st Century: Proceedings 2 of the 20th International Cartographic Conference*, 884–93. Beijing: [The Society].
Ristow, Walter W. 1951. "Some Recent Regional Atlases: A Review." *Geographical Review* 41:479–84.
Rónai, András. 1945. *Atlas of Central Europe*. Budapest: Institute of Political Sciences. Digital facsimile, Budapest: Society of St. Steven Püski Publishing House, 1989. Online publication 1993.
Salishchev, Konstantin Alekseyevich. 1988. "Problems and Achievements of Soviet Thematic Cartography." *Mapping Sciences and Remote Sensing* 25:179–87.
———, comp. 1964. *Regional Atlases: Tendencies of Development, Subject Matters of the Maps on Natural Conditions and Resources*. Moscow: Science.
Stams, Werner. 1980. *National and Regional Atlases: A Bibliographic Survey (Up to and Including 1978)*. Enschede: International Cartographic Association.
Trainor, Timothy F., and Ke Liao. 2003. "List of Atlases on Exhibition at the Seminar of ICA National and Regional Atlases Commission." *Proceedings: Seminar for ICA Commission on National and Regional Atlases, 2001 Beijing*, ed. Ke Liao and Timothy F. Trainor, 83–88. Beijing: China Meteorological Press.

School Atlas. School atlases were used throughout the twentieth century at all levels of education. For the most part they were adapted to the intellectual and educational level of pupils (from kindergarten to university). They were produced to support geography education and were used by schoolchildren both to learn to read, interpret, and analyze maps and to become aware of the environment. In order to reach these objectives the design of school atlases used didactic principles that conveyed the necessary geospatial information in a methodical way.

School atlases are more generalized and selective than reference atlases, and are able to concentrate on individual topics. The contents of school atlases can be regulated by the geography curriculum set by a country's educational authorities. Governed by them and by the restrictions on size and production imposed by publishers, atlas authors have to find their individual approaches to render what they regard as essential.

As an example, the general objectives of the geography curriculum for secondary schools in the Netherlands in the 1990s were to (1) provide the children with a spatial frame of reference, (2) provide an understanding of the existence of various physical environments that can be used differently by mankind, (3) provide for an awareness that one should not pass this planet to the next generation in a worse condition, (4) teach students to manipulate simple statistical files, and (5) enable students to link the perception of the risk of a natural disaster (such as floods) to the actual risks. Appropriate school atlases had to support these objectives set by the nation.

In the United Kingdom, the Education Acts of 1870 and 1902 stimulated the teaching of geography in secondary schools, and similar acts were passed in other parts of the Western world (Prussia, the Netherlands) from about 1870 onward. In the United States geography was an independent school subject until the end of World War I; afterward it became part of a social sciences curriculum and resurfaced as a separate subject during World War II. This boosted the production of school atlases.

By the end of the nineteenth century the Sydow-Wagner school atlases published by Justus Perthes in Gotha, Germany, and the Kozenn and Slanar atlases produced by Ed. Hölzel in Vienna were regarded as models and copied throughout the world. The important position of German and Austrian school cartography was highlighted by the existence of the journal *Kartographische und Schulgeographische Zeitschrift* (1912–22) published by Freytag & Berndt in Vienna, which specialized in products for the teaching of geography.

Around 1900 these Central European school atlases were characterized by an emphasis on the physical aspects of geography: relief and morphology, temperature, rainfall and climate in general, and vegetation, inspired by some deterministic philosophies that claimed that a society's economic level (shown with a population density map) would be determined by their physical circumstances. To illustrate current political issues, ethnographic or language maps were incorporated for unstable areas such as the Balkans.

Initially school atlases were designed to help students learn the required topography by rote, but as the century progressed, increasingly the focus was on concepts of geospatial relationships and links. As the hypsometrical knowledge of the earth increased, so did the hypsographic portrayal of the world in school atlases. By the turn of the century the subdivision into layered zones with lowlands (green), hills (yellow), and mountainous areas (brown) based on Karl Peucker's theses of color psychology (see fig. 680) was one school atlas convention.

In addition to physical maps, separate political maps were incorporated; in Anglo-Saxon areas these maps would have pride of place and would generally be rather overcrowded with place-names. Among the strengths of the above-mentioned German-language school atlases was their methodological, systematic approach: a logical sequence of maps, systems of map scales, references (with ticks) to locations outside the map on the same geographical latitude, small representations of the home country in the map margin (for purposes of comparison), attempts at equal area projections, and symbols and colors that had the same meaning throughout the atlas. In retrospect it all seems logical, but when one takes a closer look at many of the school atlases produced in the first half of the twentieth century, many of these aspects were lacking. The unfortunate practice of "island cartography"—with the focus on a specific country on each atlas page with the surrounding areas blank thereby almost obliterating the crucial spatial relationships with neighboring areas that the atlases were supposed to teach—also had a long life.

Between the world wars, school atlases increased their number of topical maps, showing economic themes (mostly with figurative symbols) and sociocultural themes (usually religion and languages). American school atlases reduced their coverage of the home country from 80 percent to 50 percent from the turn of the century until World War II. It was during World War II that the tendency to better portray relationships between continents began. It was only after World War II that more economic maps were incorporated, and even this went in phases: qualitative maps first and quantitative economic maps later, with a gradual shift of emphasis from the general political and physical maps to topical maps including more demographic and environmental themes, and from morphological maps to functional town plans. These shifts in the contents of school atlases mirrored the shifts in the geography curriculum.

Physical or political overview maps at the end of the century formed a small minority, and the large majority of school atlases consisted of topical maps. The older the age group the atlas was intended for, the more topical maps were included. In some editions, like the Alexander Atlas from Klett Verlag (Stuttgart), land cover maps with added symbols for manufacturing and tertiary occupations replaced physical base maps.

In the United States in 1923 J. Paul Goode prepared *Goode's School Atlas* for Rand McNally. This atlas prided itself on using equivalent projections, opposing the previously omnipresent use of the Mercator, and using physical and economic maps instead of the hitherto prevalent political ones. *Goode's School Atlas* also simplified the contents of the maps, which had far fewer place-names than its competitors and consequently much better legibility. In one sense this atlas came on the market too late, as geography teachers in the United States had become used to imports or sibling editions of German school atlases. Rand McNally protested in vain against these imports (Schulten 2001, 197–98).

Most school atlases (some leading ones are listed in table 4) followed a similar structure. The atlases either started with the world and then zoomed in on the home country or would do the reverse (centripetal/centrifugal approaches). Within this general structure they could be confrontational, in the sense that for every depicted region physical and economic (land use) maps would appear opposite one another, or remote sensing imagery would appear opposite economic maps. For the home country there would be a more extensive section with maps on a larger scale, and the scales of other world areas would generally diminish with the distance from the home country. Topical maps on the home country would also be put in a relevant causality-linked sequence.

School atlases tended to be produced in special editions for different age groups (called *Stufenatlanten* in German), and where the curriculum placed great emphasis on the more immediate environment of the children, atlases would be published in regional editions. There were special Russian school atlases, for instance, for the fourth through ninth grades of primary school, in addition to secondary school atlases. Their content would be curriculum based, e.g., fifth grade, introduction to maps and Russia; sixth and seventh grades, the world and the continents; eighth grade, physical geography; and ninth grade, economic and social geography of the world (figs. 70 and 71).

One issue for school atlas editors has remained: the question of whether to label geographical features on a map with conventional names (exonyms) or with local official names (endonyms). As exonyms are adapted to the receiver language they would be easier to pronounce and would lack potential diacritic marks. If endonyms were used, school atlases had to try to show at least how foreign names might be pronounced. The *Goode's World Atlas* was a good example of an atlas with a register of geographical names with the pronunciation of all names indicated.

In addition to answering the requirements of the school curriculum, school atlases must be kept up to date. This requires continuous input and revision. Even keeping a single atlas up to date requires that documentation work be shared for consistency among several atlases. The production of a new edition of a school atlas requires a major capital outlay (this means that even for a small country like the Netherlands, a new edition

TABLE 4. Main twentieth-century school atlases in selected countries

Country	Title (exact titles often varied over time)	Publisher
Austria	*Österreichischer Mittelschulatlas: Kozenn-Atlas*	Ed. Hölzel
Canada	*l'InterAtlas*	Centre Éducatif et Culturel
Germany	*Diercke Weltatlas*	Westermann
Italy	*Atlante geografico metodico*	De Agostini
Japan	different titles for upper and lower secondary school atlases	Teikoku Shoin
Netherlands	*De Grote Bosatlas*	Wolters-Noordhoff
Switzerland	*Schweizerischer Mittelschulatlas*	Orell Füssli and Kantonaler Lehrmittelverlag
United Kingdom	*The University Atlas*	Philip
	Oxford Student Atlas	Oxford
	Collins-Longman Student Atlas	HarperCollins
United States	*Goode's School Atlas*	Rand McNally

FIG. 70. EXAMPLES OF GRADE-RELATED SOVIET SCHOOL ATLASES. Fifth grade is on the left; eighth grade on the right. From *Geograficheskiy atlas dlya pyatogo klassa* (Moscow: GUGK, 1980) and *Geograficheskiy atlas dlya 8-go klassa* (Moscow: GUGK, 1976). Image courtesy of Ferjan Ormeling.

can only be produced once every seven to ten years). These financial considerations force the production of school atlases to be internationalized. This is done by the phenomenon of sibling editions. For example, in the 1960s the Austrian Kozenn-Slanar atlas produced by Ed. Hölzel in Vienna was produced in separate sibling editions for France, Israel, the Netherlands, Belgium, the United Kingdom (Faber atlas), the European Union, Turkey, and the United States (Prentice Hall). Wolters-Noordhoff from the Netherlands produced separate editions of its school atlases for Belgium, France, Denmark, Norway, Sweden, Canada, and Zaire. British school atlas producers likewise served many of Britain's former colonies.

FERJAN ORMELING

SEE ALSO: Education and Cartography: Teaching with Maps

BIBLIOGRAPHY:

Badziag, Astrid, and Petra Mohs, with Wolfgang Meinecke. 1982. *Schulatlanten in Deutschland und benachbarten Ländern vom 18. Jahrhundert bis 1950: Ein bibliographisches Verzeichnis*. Ed. Lothar Zögner. Munich: K. G. Saur.

Carswell, R. J. B., Gary J. A. de Leeuw, and Nigel M. Waters, eds. 1987. *Atlases for Schools: Design Principles and Curriculum Perspectives*. Monograph 36, *Cartographica* 24, no. 1.

Freitag, Ulrich. 1992. "Conception, Compilation and Construction of a Study Atlas of Thailand (1984)." In *Kartographische Konzeptionen = Cartographic Conceptions*, by Ulrich Freitag, 221–40. Berlin: Freie Universität, Technische Universität, Technische Fachhochschule.

Jefferson, Mark Sylvester William. 1925. "An American School Atlas." Review of *Goode's School Atlas, Physical, Political, and Economic, for American Schools and Colleges*, by J. Paul Goode. *Geographical Review* 15:168–69.

Kanakubo, Toshitomo, and Kei Kanazawa, eds. 1997. *Proceedings of the Seminar on Cognitive Maps, Children and Education in Cartography*. Gifu, Japan, 1996. Tokyo: ICA.

Mayer, Ferdinand, ed. 1992. *Schulkartographie: Wiener Symposium 1990*. Vienna: Institut für Geographie der Universität Wien, Ordinariat für Geographie und Kartographie.

Ormeling, Ferjan. 1997. "Functionality of Electronic School Atlases." In *Proceedings of the Seminars on Electronic Atlases II*, ed. Barend Köbben, Ferjan Ormeling, and Timothy F. Trainor, 33–39. Enschede: International Cartographic Association.

———. 2005. *Biografie van de Bosatlas, 1877-Heden*. Groningen: Wolters-Noordhoff.

Ormeling, Ferjan, Klaas Villanueva, and Tjeerd Tichelaar, eds. 1998. *Atlas Production for Southeast Asia*. Vol. 2 of *Proceedings of the International Workshop/Seminar "Modern Cartography for Navi-*

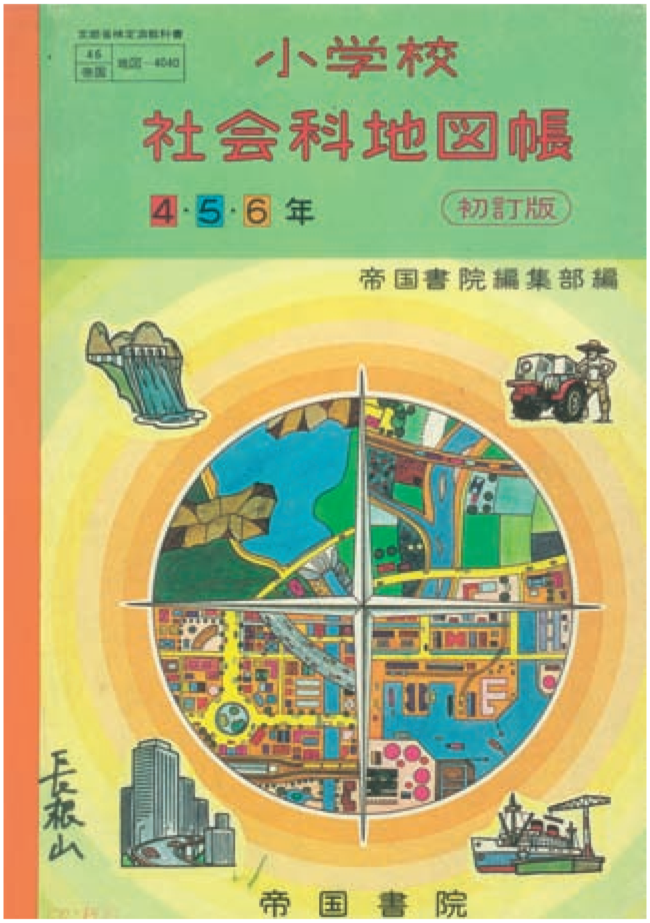


FIG. 71. JAPANESE SOCIAL STUDIES SCHOOL ATLAS. Cover of a primary school atlas for fourth through sixth grades.
From *Shōgakkō shakaika chizuchō: 4, 5, 6-nen* 小学校社会科地図帳: 4, 5, 6年 (Elementary social studies atlas: grades 4, 5, 6), 1st rev. ed. (Tokyo: Teikoku-Shoin, 1975). Image courtesy of Teikoku-Shoin Co., Ltd., Tokyo.

gating the Information Highway." Groningen: International Cartographic Association.

Reyes Nuñez, José Jesús, ed. 2000. *Conference on Teaching Maps for Children: Theories, Experiences and Perspectives Beginning the 3rd Millennium*. Budapest: Eötvös Loránd University, Department of Geography.

Sandford, Herbert A. 1987. "The State of Canadian Children's Atlases from a European Perspective." In *Atlases for Schools: Design Principles and Curriculum Perspectives*, ed. R. J. B. Carswell, Gary J. A. de Leeuw, and Nigel M. Waters, Monograph 36, *Cartographica* 24, no. 1:1–15.

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

Wise, M. J. 1986. "The Scott Keltie Report 1885 and the Teaching of Geography in Great Britain." *Geographical Journal* 152:367–82.

Subscription Atlas. Atlas publishing financed through public subscription prior to publication dates from the seventeenth century. The subscription trade in cartographic materials reached the height of its popularity in the latter half of the nineteenth century in North America through the sale of commercially produced county landownership maps, atlases, and plat books (Conzen 1997). In the twentieth century, county subscription atlases were issued primarily in the United States. Bates Harrington (1890) provided a critical contemporary overview of the development and business practices of the county subscription map and atlas trade, including the canvassing of potential subscribers, field surveying and collecting of cadastral data, map compilation, and printing.

County atlas publishing in the twentieth century was centered in the north central United States, with a focus on atlases of counties with numerous farms and high agricultural production. Presentation differed somewhat by publisher, but a typical subscription atlas included lithographically printed maps of each township, frequently at a scale of two inches to one mile (1:31,680), featuring the names of property owners and containing a variety of cultural details, including roads, railroads, schools, cemeteries, and administrative boundaries (fig. 72). Towns and cities within the county were mapped separately, and these maps often represented the earliest printed cartographic record of those communities. Completing the atlas was a listing of subscribers, advertising, photographic illustrations, and a variety of historical and farm-oriented text.

Geo. A. Ogle & Co. of Chicago dominated the county subscription atlas trade in the late nineteenth and early twentieth centuries. Selling its "standard atlases" for $15.00, Ogle issued over 650 county atlases between 1890 and 1923. The subscription marketing model, viable through the 1920s, was supplanted by less expensive county atlases, reduced in size and simplified in cartographic content. Marketed by a variety of means, these more modest atlases were published through the twentieth century. The Rockford Map Company (Rockford, Illinois) issued over 4,000 atlases covering some 600 counties from 1944 to the end of the century. Although there is no comprehensive bibliography of county landownership atlases, Clara Egli Le Gear's *United States Atlases* (1950–53) remains the most extensive printed record of county atlas publishing in the United States.

The commercially produced county landownership atlas catered to farmers, county officials, and merchants interested in detailed and accurate local geographic information. The county atlas confirmed the ownership of real property and the farmer's place within the local economy and society. For modern researchers county landownership atlases are sources for studying genealogy; investigating population distribution, ethnic pat-

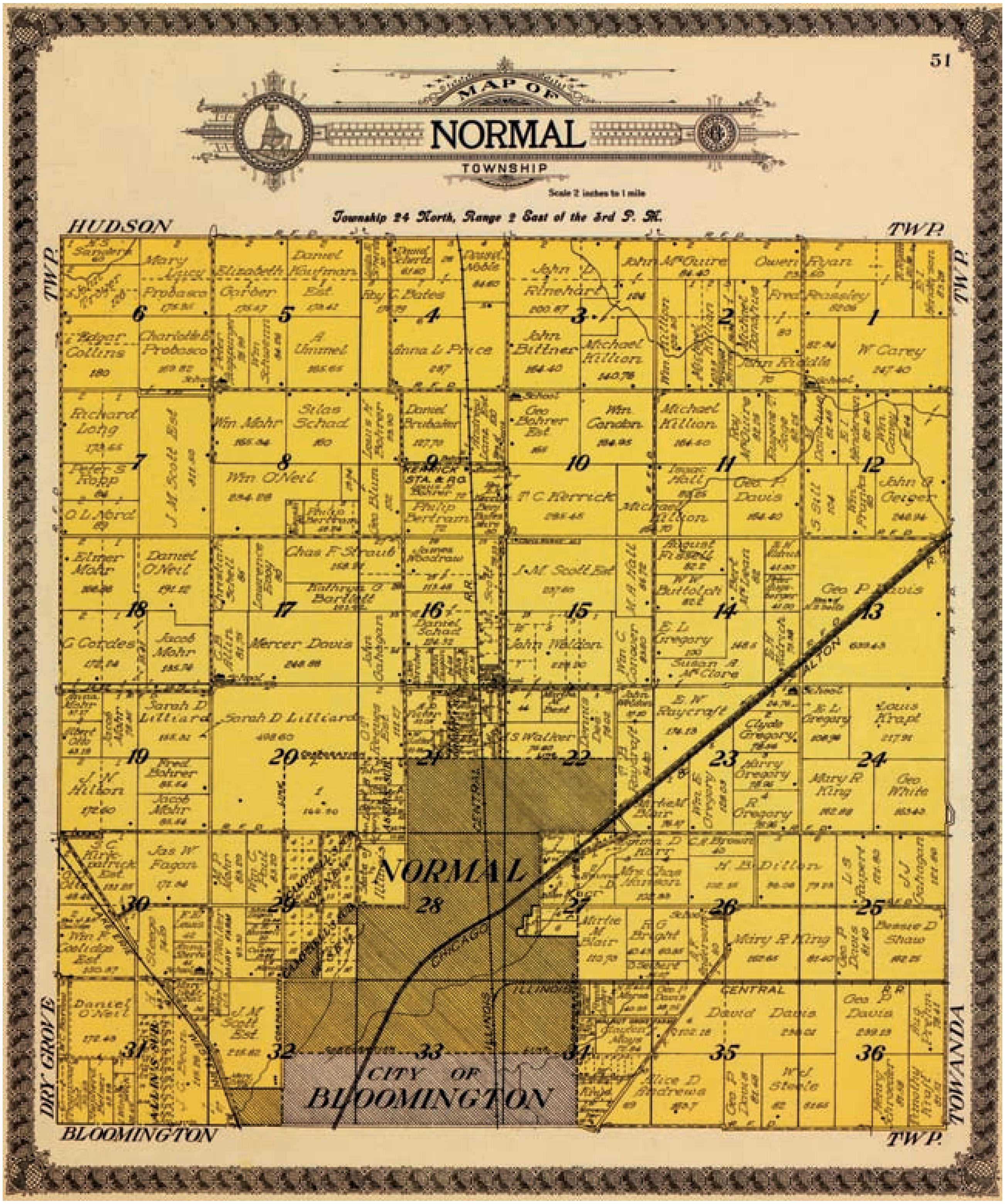


FIG. 72. GEO. A. OGLE & CO., "MAP OF NORMAL TOWNSHIP." Ogle's 1914 atlas of McLean County, Illinois, with thirty township maps, provides detailed cadastral and landownership information and documents aspects of the cultural and physical geography of the county. More than 1,000 residents purchased subscriptions. Scale, 1:31,680. Size of the original: ca. 41.4 × 34.3 cm. From *Standard Atlas of McLean County Illinois Including a Plat Book of the Villages, Cities and Townships of the County* (Chicago: Geo. A. Ogle, 1914), pl. 51. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C.

terns, and ownership by gender; and documenting the economic, cultural, and physical landscape of agrarian society (Conzen 1990).

Related cartographic formats, including urban real estate atlases, panoramic views, and world atlases, were issued in the early twentieth century using subscription practices. Variations on the advance-sale model, such as loose-leaf and updating services, installment sales, and blanket order plans, were also used to market cartographic materials. Examples of the subscription and colportage sale of German *Handatlanten* in the twentieth century have also been compiled and described (Espenhorst 2003–8).

JAMES A. FLATNESS

SEE ALSO: Cadastral Map

BIBLIOGRAPHY:

Conzen, Michael P. 1990. "North American County Maps and Atlases." In *From Sea Charts to Satellite Images: Interpreting North American History through Maps*, ed. David Buisseret, 186–211. Chicago: University of Chicago Press.

———. 1997. "The All-American County Atlas: Styles of Commercial Landownership Mapping and American Culture." In *Images of the World: The Atlas through History*, ed. John A. Wolter and Ronald E. Grim. 331–65. Washington, D.C.: Library of Congress.

Espenhorst, Jürgen. 2003–8. *Petermann's Planet: A Guide to German Handatlases and Their Siblings Throughout the World, 1800–1950*. 2 vols. Ed. and trans. George R. Crossman. Schwerte, Germany: Pangaea Verlag.

[Harrington, Bates]. 1890. *How 'Tis Done: A Thorough Ventilation of the Numerous Schemes Conducted by Wandering Canvassers, Together with the Various Advertising Dodges for the Swindling of the Public*. Syracuse: W. I. Pattison.

Le Gear, Clara Egli, comp. 1950–53. *United States Atlases: A List of National, State, County, City, and Regional Atlases in the Library of Congress* (vol. 1). *United States Atlases: A Catalog of National, State, County, City, and Regional Atlases in the Library of Congress and Cooperating Libraries* (vol. 2). Washington, D.C.: Library of Congress.

Thematic Atlas. Thematic atlases emerged relatively late in the history of cartography. Although there are antecedents, such as the *Civitates orbis terrarum* of Georg Braun and Frans Hogenberg (1572), these earlier works differ from the modern thematic atlas, which is typically based on data from an official census and consists largely of single-purpose maps in book format (Creutzburg 1953). National and state censuses became common in the nineteenth century and are reflected in the cartography of that period. In the twentieth century, a number of world map projections were devised for use in thematic cartography. Prominent examples include J. Paul Goode's homolosine equal-area projection and the Robinson projection, designed by Arthur H. Robinson as a "correct-looking" compromise between area-conserving and shape-conserving world maps.

The thematic atlas is distinct from the general atlas, which consists primarily of maps delineating relief (terrain/landforms), hydrography (rivers/lakes/seas), settlement (cities/towns/villages), transportation features (roads/railroads/airports), and, in some cases, the juxtaposition of these and other features to show geographic relationships. General atlases typically have many more place-names on their maps, which are also indexed in a special, alphabetized listing in a gazetteer section at the back of the atlas. Although general atlases sometimes have thematic maps throughout the volume or gathered together as a special signature, most of the maps in a thematic atlas are special-purpose maps, not general maps (Alexander 1971; Podell 1994). This preponderance of special-purpose maps reflects the thematic atlas's customary focus on a specific theme, such as population or climate.

Several symbolization techniques have dominated the design of thematic atlases (fig. 73). Dot maps use countable symbols, typically uniform in size, to show variations in density. For maps emphasizing magnitude rather than density, variable-size circles or squares, typically, portray counts for cities and other point locations, and occasionally for areal units, such as countries, states, or provinces. Choropleth maps and dasymetric maps employ area symbols, different colors, or shading (typically gray tones ranging from light to dark) to represent categories of data values ordered from low density to high density. Choropleth maps apply their area symbols to data collection units, which are assumed (often incorrectly) to be homogeneous, whereas the area symbols on dasymetric maps emphasize homogeneity and discontinuities rather than administrative boundaries. Other symbols used in thematic atlases include lines of uniform or variable width, directional arrows, and sectored circles, also called pie charts.

Approximately a quarter of all atlases published since 1950 are thematic. Of these, the most common subjects, in descending order, are history, transportation, economics, and population. In addition, many national atlases are essentially thematic. Examples include *The National Atlas of the United States of America* (1970), in which approximately fifty general reference maps are outnumbered about five to one by maps on special subjects. Inspired by the centennial of the *Statistical Atlas of the United States*, which was based on the 1870 national census, the American national atlas was never revised or updated as a single, bound collection of maps. Even so, the U.S. Geological Survey continued to publish the National Atlas Series of thematic maps standardized in sheet size, projection, and scale, and similar in overall appearance. By contrast, the national atlas of Finland has been revised on a regular basis since its initial publication. Although first published in 1899, it became the model for later, thematic atlases.

In addition to these largely thematic national atlases,

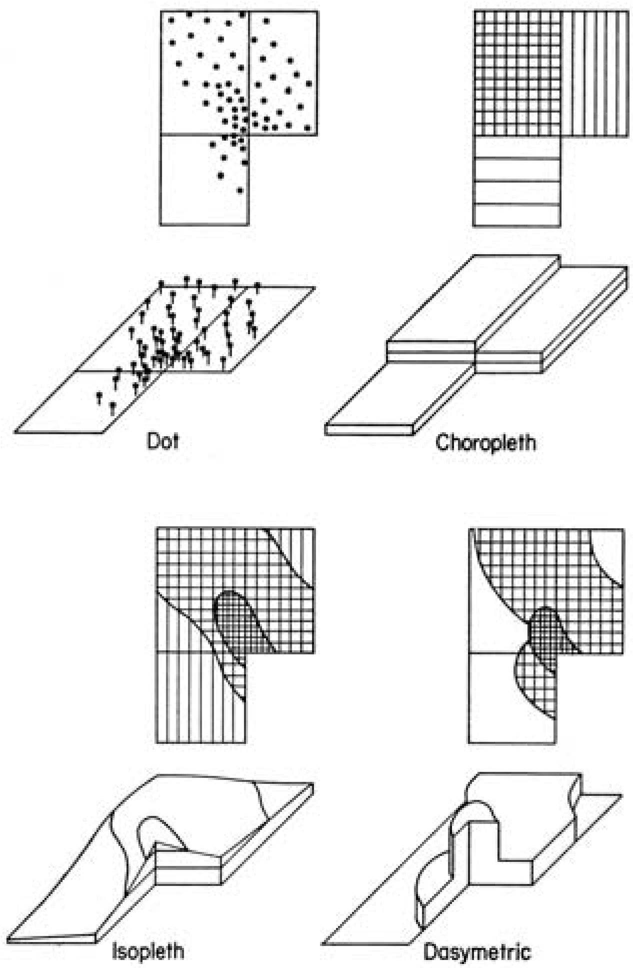


FIG. 73. QUANTITATIVE METHODS USED IN TWENTIETH-CENTURY SMALL-SCALE THEMATIC ATLAS MAPPING. Shown in two- and simulated three-dimensional form. The same distribution, human population, is shown in each example.
Size of the original: 17.7 × 11.4 cm. From Norman J. W. Thrower, "Relationship and Discordancy in Cartography," *Internationales Jahrbuch für Kartographie* 6 (1966): 13–24, esp. 21 (fig. 4). Permission courtesy of Orell Füssli Verlag, Zurich.

many thematic atlases have been published by governments, commercial firms, and other nongovernment organizations. These belong mostly to one of two genres: thematic atlases covering many subjects and single-topic thematic atlases. The latter are by far the more common.

Although purists might reject the idea of a global thematic atlas with many different topics, this genre is exemplified by Norman J. W. Thrower's *Man's Domain*, which released the first of three editions in 1968. The atlas contains over two hundred thematic maps and insets, about one third of which illustrate world patterns of key aspects of physical, political, economic, and cultural geography. Most of the maps are world, continental, or subcontinental in scope. Some of the special-purpose maps treating individual continents (or occasionally an individual country) are accompanied by diagrams, including more than one hundred climatic graphs. Themes covered include religion, race, language, vegetation, fuel, agriculture, minerals, and energy. Shaded relief maps contain comparatively few place-names, and several maps with relief shading give the ocean floors special attention. Only six pages are devoted to the index, which is usually more prominent in general atlases than in thematic atlases. *Man's Domain* employs all of the principal symbolization methods and uses color throughout. An introductory section that discusses map projections includes graticules for a selection of representative projections.

Three single-subject thematic atlases are discussed below—one cultural, one historical, and one physical. These are representative of the numerous single-subject thematic atlases published in the twentieth century and included in the inventories of atlases by Gerard L. Alexander (1971) and Diane K. Podell (1994).

The Atlas of the Arab World (Boustani and Fargues 1991) discusses twenty-one countries in the contemporary Arab world using a thematic, rather than a country-by-country, approach. Its over 150 color maps cover population, health, education, the economy, and regional unity, and the back matter includes an index. With a focus on issues relating to all Arab countries, the atlas treats common problems of the several nation-states mapped (fig. 74). A unifying theme of the atlas is religion, an important influence on the modern Arab state's relations with the West.

Focused on one of the Arabs' key rivals, *A Historical Atlas of the Jewish People* (Barnavi 1992) is an English translation of *Juifs, une Histoire universelle*. Unlike *The Atlas of the Arab World*, it deals chronologically with the life and traditions of the Jewish people over thousands of years and throughout the world (fig. 75). Complementing the approximately 175 color maps are lavishly illustrated double-page spreads, which include time lines as well as illustrations and text. Its theme is the continuity of Jewish culture, transcending time and place.

By contrast, *The Water Atlas* has as much text as maps, which are mainly choropleth maps based on country units (Clarke and King 2004). Within the broad theme of water, the atlas maps and discusses many aspects of this topic, including shortages and demands, irrigation, industrial uses, pollution, and power generation. Other themes include sanitation, wetlands, groundwater, floods, and droughts. Insets that supplement the global maps include various statistical devices such as sectored circles (pie charts) as well as photographs. Un-

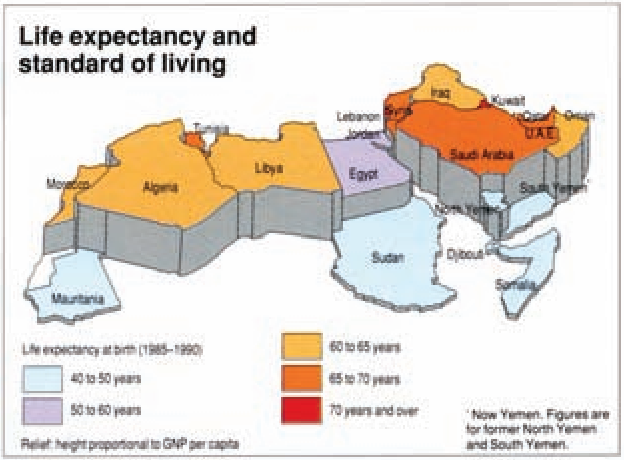


FIG. 74. *LIFE EXPECTANCY AND STANDARD OF LIVING* IN THE ARAB WORLD. The map illustrates the close link between life expectancy and poverty.
Size of the original: 7 × 9.5 cm. From Boustani and Fargues 1991, 52.

fortunately, the choropleth approach, used for the maps with the country or nation as the statistical unit, often masks important internal, regional differences. Color is used throughout the book, which also has pictures and diagrams.

Twentieth-century thematic atlases collectively cover many topics, including astronomy, the Bible, Communism, the Crusades, endangered species, human anatomy, maritime history, Middle-earth, natural wonders, past worlds, outlaws, rain forests, stamps, wine, women, and zones of conflict. The roster of thematic atlases is expected to increase in the future as "knowledge grow[s] from more to more," as Alfred, Lord Tennyson, reminds us ("In memoriam," l. 25).

Near the end of the twentieth century thematic atlases took advantage of electronic publishing, which provided convenient, low-cost distribution on CD-ROMs and the Internet. In 1992 the National Geographic Society published a multimedia *Picture Atlas of the World*, which included hundreds of maps depicting the oceans, continents, and nations, only some of which can be described as thematic. New media in use at the close of the century included animated maps, which are more emphatically thematic in character. As in the case of cartography

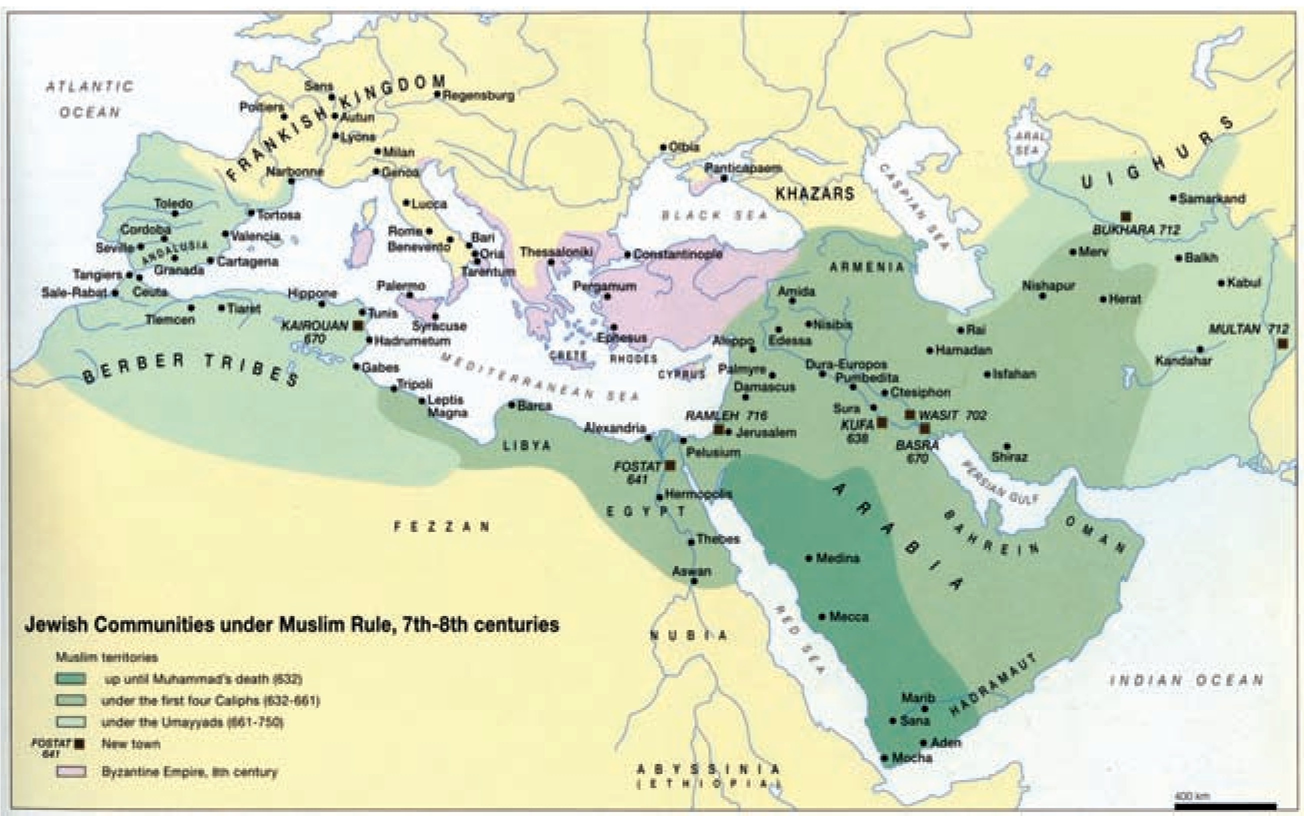


FIG. 75. *JEWISH COMMUNITIES UNDER MUSLIM RULE, 7th–8th CENTURIES.* Size of the original: 13 × 21 cm. From Barnavi 1992, 81.

generally, modern techniques, including animation, have significantly transformed the thematic atlas, which is no longer just a bound collection of printed maps.

NORMAN J. W. THROWER

SEE ALSO: Demographic Map; Statistical Map; Thematic Mapping; Wayfinding and Travel Maps: Road Atlas

BIBLIOGRAPHY:

Alexander, Gerard L. 1971. *Guide to Atlases: World, Regional, National, Thematic, An International Listing of Atlases Published since 1950*. Metuchen: Scarecrow Press.

Barnavi, Elie, ed. 1992. *A Historical Atlas of the Jewish People: From the Time of the Patriarchs to the Present*. English edition ed. Miriam Eliav-Feldon. New York: Knopf.

Boustani, Rafic, and Philippe Fargues. 1991. *The Atlas of the Arab World: Geopolitics and Society*. Trans. Darla Rudy. New York: Facts on File.

Clarke, Robin T., and Jannet King. 2004. *The Water Atlas*. New York: New Press.

Creutzburg, Nikolaus. 1953. "Zum Problem der thematischen Karten in Atlaswerken." *Kartographische Nachrichten* [3], no. 3/4:11–12.

Podell, Diane K. 1994. *Thematic Atlases for Public, Academic, and High School Libraries*. Metuchen: Scarecrow Press.

Robinson, Arthur H. 1982. *Early Thematic Mapping in the History of Cartography*. Chicago: University of Chicago Press.

Thrower, Norman J. W., ed. 1968. *Man's Domain: A Thematic Atlas of the World*. New York: McGraw-Hill.

U.S. Geological Survey. 1970. *The National Atlas of the United States of America*. Ed. Arch C. Gerlach. Washington, D.C.: [Department of the Interior].

World Atlas. The growing popularity of the world atlas in the twentieth century was fueled by increasing political interdependence, the proliferation of geographic education, and new cartographic printing technologies that continually lowered the cost of production. In fact, the world atlas became one of the most reliable sellers for twentieth-century commercial map companies.

As a genre, world atlases are unique for their claim to comprehensiveness, and this attempt to draw a normative picture of the world makes them rich documents for historians. By the twentieth century, the structure of world atlases ranged widely, but nearly all included a series of maps—sometimes on vastly different scales—as well as other graphic devices and narrative commentary on the world's economy, populations, and geography. Thus the atlases appear as reference works, even while the content depended upon the availability of information and the demands of the market. Among the century's most significant titles were *Goode's School Atlas* (United States, Rand McNally & Company), Adolf Stieler's *Hand-Atlas* (Germany, Justus Perthes), and the *Times* atlas of the world (United Kingdom, John Bartholomew & Son).

Stieler's *Hand-Atlas* was distinct for its emphasis on relief and a variety of cartographic projections, both of which suggest a sophisticated understanding of geography. Yet there has also been a strong strain of geographical parochialism in European world atlases. For instance, the number of non-European regional maps in Austrian atlases rose from about 20 percent in the 1870s to 30 percent by World War I, corresponding to a decrease in the number of Austro-Hungarian and European maps.

Britain's most illustrious series has been the *Times* atlas of the world, first published in 1895 with over half of its 117 pages of maps devoted to Europe. In 1914 publication of the *Times* atlas moved to John Bartholomew & Son in Edinburgh, which began a collaboration that would continue throughout the century. After World War I the atlas was substantially revamped in order to reflect the political changes brought by the war and renamed *The Times Survey Atlas of the World*. Published in 1922, it still contained well over one hundred maps but now devoted only one-third to Europe. With the midcentury edition of 1955–59, maps of Europe declined even further as the colonial era drew to a close.

This declining cartographic parochialism extends to the world atlases published in the United States as well. In the 1880s and early 1890s, from 75 to 80 percent of the atlas maps were devoted to coverage of the nation, but after 1898 this number shrank to about 50 percent (Schulten 2001, 29). Still, as late as World War I, Rand McNally's *Imperial Atlas of the World* opened with a map of America's territorial expansion westward and abroad. In fact, it was this world atlas—one of Rand McNally's bestsellers—that redesigned the United States by extending its borders beyond the continent to Cuba, the Philippines, Puerto Rico, Alaska, and Hawaii.

The longest running and most authoritative world atlas published in the United States was created by Rand McNally's chief cartographer, J. Paul Goode, in 1923. *Goode's School Atlas* grew out of his dissatisfaction with the company's popular atlases in the early twentieth century. His own version sold particularly well in schools (where it is still widely used) and in the military, institutions in need of geographic and cartographic material not available in other popular atlases. Goode's work stressed physical geography over politics and even omitted political boundaries on most maps in an effort to depict physical continuity over "artificial" political borders. Goode's atlas was also the first American atlas to insist on uniformity of scale and to present a range of cartographic projections in order to expose readers to the fundamental cartographic concepts.

A second milestone in the United States came with Rand McNally's *Cosmopolitan World Atlas* (1949). This atlas represented a departure for the company. By normalizing scale, reincorporating physical geography, and adopting projections that reflected a more interdependent and mobile world, the *Cosmopolitan World*

Atlas implicitly admitted the new cartographic styles and spatial concepts that circulated so extensively during the World War II.

One of the most innovative recent world atlases has been Michael Kidron and Ronald Segal's *The State of the World Atlas*, published in 1981. Here, rather than make any pretense of comprehensiveness, the authors highlighted specific concerns such as poverty and inequality, the arms race, and environmental dangers. This reference work was unapologetically selective and interpretive, partly in reaction to the prevailing encyclopedic style of world atlases that dominated for much of the century.

SUSAN SCHULTEN

SEE ALSO: Esselte Kartor AB (Sweden); Freytag-Berndt und Artaria KG (Austria); Geographical Mapping; Goode, J(ohn) Paul; Hallwag Kümmerly+Frey AG (Switzerland); Hammond Map Company (U.S.); John Bartholomew & Son (U.K.); Justus Perthes (Germany); Rand, McNally & Company (U.S.); Projections: World Map Projections; *Times* Atlas of the World

BIBLIOGRAPHY:

Barclay, Sheena. 2004. "Publishing the World: Perspectives on *The Times Atlas*." *Scottish Geographical Journal* 120:19–31.

Kain, R. J. P., and Catherine Delano-Smith. 2003. "Geography Displayed: Maps and Mapping." In *A Century of British Geography*, ed. R. J. Johnston and Michael Williams, 371–428. Oxford: Oxford University Press.

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

Wolter, John A., and Ronald E. Grim, eds. 1997. *Images of the World: The Atlas through History*. New York: McGraw-Hill.

Atlas Mira. See *Bol'shoy sovetskiy atlas mira*

Atlas of Canada. The Canadian government produced a national atlas as early as 1906, and four printed editions have appeared since then, followed in the last decade of the twentieth century by the creation of a dynamic digital atlas accessible on the Internet. This ongoing electronic manifestation, the sixth edition, represents the successful culmination of a century of effort.

The first edition of the *Atlas of Canada* was published in 1906 by the Department of the Interior, and its content reflected national concerns such as immigration, demography, resources, and communications. In 1915 the same department published a second revised edition. The design of these editions was broadly similar and employed the basic scale of 1:12,000,000.

In 1957 a third edition, published separately in English and French (as were all later editions), increased the basic scale of the maps to 1:10,000,000 and covered a comprehensive range of subject matter illustrative of Canada's development. Designed as a loose-leaf volume of 110 sheets, the *Atlas of Canada* (*Atlas du Canada*) was produced by the Department of Mines and Technical Surveys (Nicholson and Sebert 1981, 165–70).

The content and design of the fourth edition were influenced more by the cultural significance of a national atlas rather than its purely informational value. Convenience and portability were achieved by adopting the basic scale of 1:15,000,000. Its 127 sheets treated many themes. Maps were available first in special loose folios from 1970 to 1974 and in boxed form in 1973. A bound and revised edition, now titled *The National Atlas of Canada* (*L'Atlas national du Canada*), was copublished in 1974 by Energy, Mines and Resources Canada, Information Canada, and the commercial publisher Macmillan of Canada.

The fifth edition, also titled *The National Atlas of Canada*, was undertaken in an uncertain environment of organizational change, fiscal restraint, and rapid computerization. The recommendations of various advisory bodies led to reorientation of the project toward the eventual creation of a digital national atlas information system. A perceived diversity of user needs influenced the return to a separate-sheet format and the adoption of a larger scale. The fifth edition was published as a series of maps between 1978 and 1994 and also as a boxed set of 92 maps at 1:7,500,000 (Falconer, Wonders, and Taylor 1999, 270–80).

By 1994 the atlas had an initial exploratory presence on the Internet. In the following five years Natural Resources Canada undertook a painstaking evaluation of technological requirements, user needs for mapped information, and the potential for close cooperation with Canadian governmental, educational, and other organizations.

The sixth edition was launched in 1999, at an International Cartographic Association (ICA) meeting in Ottawa, and the original title, *Atlas of Canada*, was restored in 2002. The sixth edition reemerged in 2006 as an Internet-based system focused on the needs of educational users and the general public. This new version combines an array of online services encompassing over 600 interactive thematic map layers and over 1,450 maps, including scanned maps from all previous editions, with ongoing publication of new digital and paper maps dealing with subjects of national concern, as well as nationwide coverage of topographic maps and toponymic information (Kramers 2007; Palko 1999).

GEORGE FALCONER

SEE ALSO: Atlas: National Atlas

BIBLIOGRAPHY:

Falconer, George, Lillian J. Wonders, and Iain C. Taylor. 1999. "Canadian Atlases: National, Provincial, Educational, and Thematic." In *Mapping a Northern Land: The Survey of Canada, 1947–1994*, ed. Gerald McGrath and L. M. Sebert, 270–303. Montreal: McGill-Queen's University Press.

Kramers, R. Eric. 2007. "The Atlas of Canada—User Centred Development." In *Multimedia Cartography*, 2d ed., ed. William Cartwright, Michael P. Peterson, and Georg F. Gartner, 139–60. Berlin: Springer.

Nicholson, N. L., and L. M. Sebert. 1981. *The Maps of Canada: A Guide to Official Canadian Maps, Charts, Atlases and Gazetteers*. Folkestone: Dawson; Hamden: Archon Books.

Palko, Stefan. 1999. "Partnerships and the Evolution of The National Atlas of Canada." In *Touch the Past, Visualize the Future: Proceedings, 19th International Cartographic Conference and 11th General Assembly of ICA*, ed. C. Peter Keller, CD-ROM. Ottawa: Organizing Committee for Ottawa ICA.

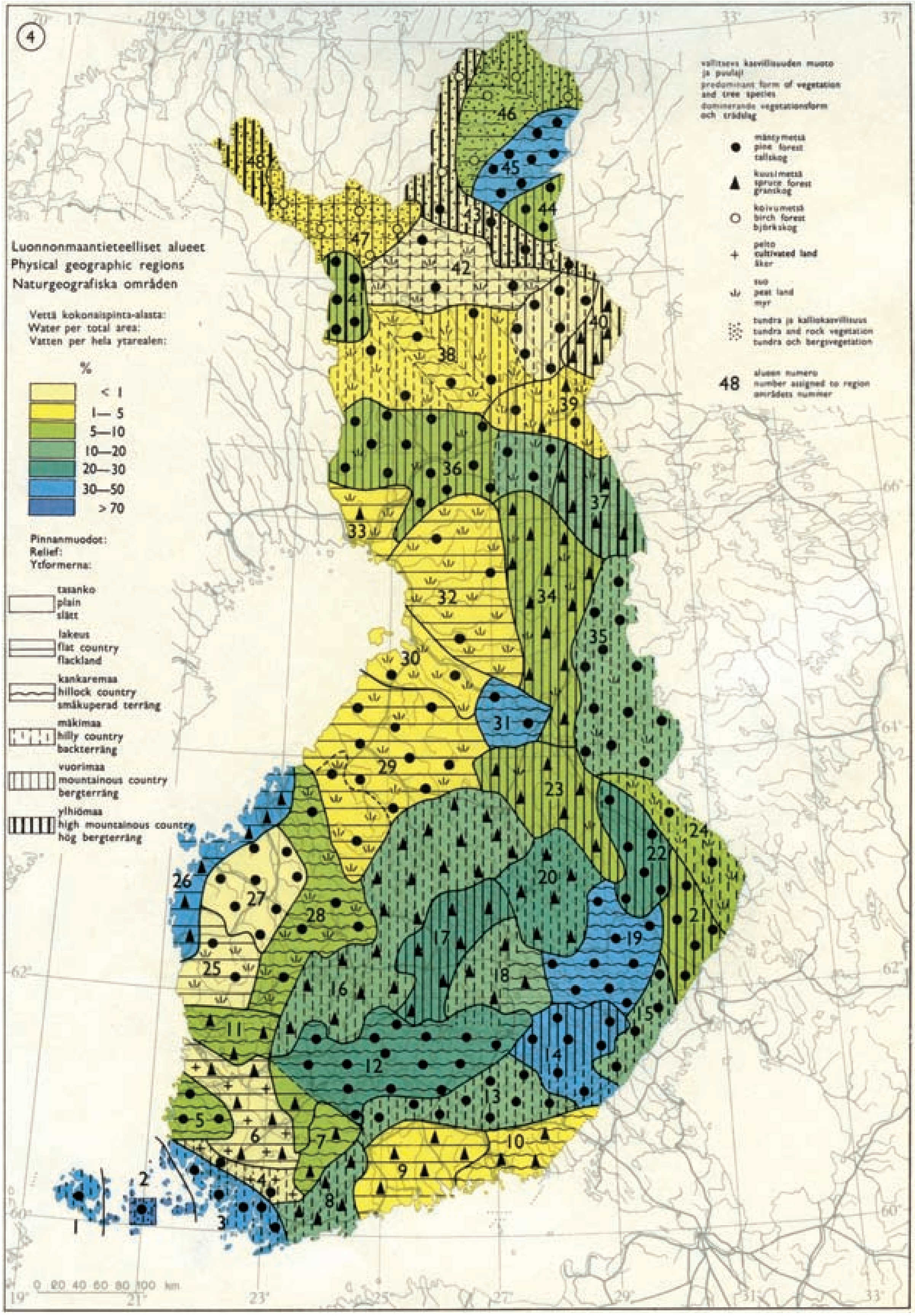
Atlas of Finland. The Atlas of Finland, the world's first national atlas, appeared in six editions from 1899 to 2002 (table 5). They give a unique perspective on the cartographic images of Finland's geography, showing how atlas production improved and the focus of geographical knowledge shifted over time.

The first four editions were published by the geographical society of Finland, Suomen maantieteellinen seura (1899, 1910, 1925, and 1960). The first two editions appeared in French (in addition to Finnish and Swedish), when Finland was part of the Russian Empire, thus underscoring the nationalistic role of academic contributions. Nationalism was still more evident in the third edition (1925–29) published in English (in addition to Finnish and Swedish) after Finland's independence in 1917. The first three editions covered infrastructure and population distribution more than socioeconomic conditions and physical geography. The fourth edition was more academic and well-rounded geographically, portraying themes from physical and cultural geography on thematic maps, often with multivariate superimposed symbols (fig. 76).

The fifth edition was published jointly by the Suomen maantieteellinen seura and the Maanmittaushallitus, the national land survey of Finland. Stig Jaatinen chaired the Scientific Editorial Committee (appointed by the Government Council) supervising the editorial staff at the Maanmittaushallitus. Specialists from various fields participated in the conception and design of the maps and wrote explanatory texts. They made extensive use of statistics. The twenty-five atlas volumes covering forty-four different subjects appeared from 1977 to

TABLE 5. Editions of the Atlas of Finland

Ed.	Year of Publ.	Title of atlas volume (languages of map legends)	Notes on separate text volumes	Comments
1st	1899	*Atlas öfver Finland* (Swedish and Finnish) *Atlas de Finlande* (French)	Text volume issued separately in three languages: French, trans. Jean Poirot (Fennia 17 [1899]); Finnish; and Swedish	Atlas volume (maps and introductory material) published in two versions
2d	1911	*Atlas öfver Finland 1910* (French, Swedish, Finnish) *Atlas de Finlande 1910* (French, Swedish, Finnish)	Text volumes issued separately in three languages: French, trans. Jean Poirot (*Fennia* 30, nos. 1 and 2 [1910-11]); Finnish; and Swedish	Atlas volume published in one version; introductory material in different languages, but identical maps in the two versions
3d	1925–29	*Suomen kartasto=Atlas of Finland=Atlas över Finland 1925* (Finnish, English, and Swedish)	Text volume issued separately in three languages: English (*Fennia* 48 [1929]); Finnish; and Swedish	
4th	1960	*Suomen kartasto=Atlas of Finland=Atlas över Finland 1960* (Finnish, English, and Swedish)	*Atlas of Finland 1960 Explanatory Notes* (1962), in English	
5th	1977-94	*Suomen kartasto* (Finnish, English, and Swedish)	Text volume issued separately in two languages: Swedish and English	Issued in folio format; 25 vols.
	1994	*Suomen kartasto 350* (Finnish, English, and Swedish)	*Finland's Landscapes, and Urban and Rural Milieus*	Ed. Pentti Alalammi; 234 pp.
6th	1999	*Suomen kartasto 1999: 100-vuotisjuhlakartasto* (Finnish)		Ed. John Westerholm and Pauliina Raento
	2002	*Finland—Nature, Society, and Regions* (English); *Fennia* 180, nos. 1 and 2 (2002) with a CD-ROM		Ed. John Westerholm and Pauliina Raento


4
Luonnonmaantieteelliset alueet
Physical geographic regions
Naturgeografiska områden
Vettä kokonaispinta-alasta:
Water per total area:
Vatten per hela ytarealen:
%
< 1
1—5
5—10
10—20
20—30
30—50
> 70
Pinnanmuodot:
Relief:
Ytformerna:
tasanko
plain
slätt
lakeus
flat country
flackland
kankaremaa
hillock country
småkuperad terräng
mäkimaa
hilly country
backterräng
vuorimaa
mountainous country
bergterräng
ylhiömaa
high mountainous country
hög bergterräng
vallitseva kasvillisuuden muoto ja puulaji
predominant form of vegetation and tree species
dominerande vegetationsform och trädslag
mäntymetsä
pine forest
tallskog
kuusimetsä
spruce forest
granskog
koivumetsä
birch forest
björkskog
pelto
cultivated land
åker
suo
peat land
myr
tundra ja kalliokasvillisuus
tundra and rock vegetation
tundra och bergsvegetation
48
alueen numero
number assigned to region
områdets nummer
0 20 40 60 80 100 km

1994 in folio format that enabled a single-page portrayal of Finland at a scale of 1:1,000,000. The map and diagram legends were in Finnish, Swedish, and English, while the texts were available separately in Swedish and English. The fifth edition was concluded with an associated book (Alalammi 1994), best described as a love-letter from Finnish geographers to the landscape of Finland. It appeared in Finnish, Swedish, and English versions.

The sixth edition of the atlas was published in Finnish to commemorate the centenary of the first edition. The goals were to introduce the achievements and trends of academic geography to the public and also to trace Finland's evolution over time as part of complex networks of interaction, ranging from local environments to global contexts. An updated, expanded English-language edition appeared with a CD-ROM in 2002 (Raento and Westerholm). More than a translation, the English-language edition also updated and expanded selected themes.

A comparison of the six editions of the Atlas of Finland reveals much about the growth of scholarship, thematic information, and cartographic presentation during the twentieth century. Internationally it had few, if any, counterparts in the tradition of national atlas production. For its own country, the Atlas of Finland was a national symbol and an essential part of the national culture, both scientific and popular. A scientific approach had been evident from the beginning. Each edition was founded on solid scientific research, was organized systematically, and made use of cartographic methods that supported the scholarly aims of the atlas for each subject covered. The selection of topics included in each edition of the Atlas of Finland was not only a statement of what its authors deemed important and interesting but also a reflection of its time.

BENGT RYSTEDT

SEE ALSO: Atlas: National Atlas

BIBLIOGRAPHY:

Alalammi, Pentti, ed. 1994. *Finland's Landscapes, and Urban and Rural Milieus*. Helsinki: National Land Survey of Finland and Geographical Society of Finland.

Raento, Pauliina, and John Westerholm, eds. 2002. *Finland—Nature, Society, and Regions*. *Fennia* 180, no. 1–2. Helsinki: Geographical Society of Finland.

Automobile Association (U.K.). The AA, as it is universally known, was founded in 1905 in response to complaints about police speed traps. It soon expanded its activities to include road signing and the provision of customized itineraries for motorists and by the early 1920s was supplying maps to motorists (Keir and Morgan 1955). Edinburgh map publisher John Bartholomew produced the vast majority of AA maps (Nicholson 1983). A few of these were produced in-house, notably the 1:760,320 maps of main roads of the British Isles (1925–30) and the town plans for successive editions of *The AA Road Book of England and Wales*. From 1925 onward, the *Road Book* included set itineraries along main roads and was apparently produced exclusively for the AA. Even so, most AA maps were adaptations or repackagings of standard Bartholomew products. This arrangement was complementary insofar as the AA revised road information for Bartholomew's 1:253,440 (four miles to the inch) maps of Great Britain from the inception of this series in 1929 into the 1950s.

In the late 1960s the cartographic publisher Geographia produced a 1:200,000 map series for Great Britain in conjunction with the AA, and the series continued as a coproduction into the 1980s. At the same time the AA developed its own cartographic unit; a notable early production was the *AA Motorists' Atlas of Great Britain* at 1:316,800 (1977). This atlas followed the usual pattern of road mapping of Britain: a variety of formats offered at various times. A later companion volume was the *AA Directory of Town Plans of Britain* (1985). AA mapping also appeared in various guidebooks by other publishers.

By 1990 digital methods were well established, exemplified by the *AA Road Atlas of the British Isles*, which replaced the 1:316,800 maps introduced in 1977 with 1:200,000 material (fig. 77) and added a selection of the earlier town plans as well as a long, lavishly illustrated, introductory essay, "The Tourist's British Isles." The elegance and sophistication of these publications reflected several factors, both technical and social: the continuing growth in motoring (the AA had about 250,000 members in 1925 and about 9,000,000 in 2000; the growth in the number of motor vehicles in Britain was roughly proportionate); increasing leisure and mass affluence;

(*Facing page*)

FIG. 76. PHYSICAL GEOGRAPHIC REGIONS, IN THE FOURTH EDITION OF THE ATLAS OF FINLAND, 1960. This multivariate map of physical geographic regions at 1:3,000,000 combines transparent point symbol patterns for vegetation and trees with transparent line patterns for types of relief, both superimposed on graduated area colors for percent of water per total area.

Size of the original: 20.2 × 13.9 cm. From *Suomen kartasto = Atlas of Finland = Atlas över Finland, 1960* (Helsinki: Otava, 1960), pl. 38 (map 4). Permission courtesy of the Suomen maantieteellinen seura, Helsinki.

FIG. 77. DETAIL OF SOUTHEASTERN ENGLAND INCLUDING CANTERBURY FROM AN AA ROAD ATLAS, 1:200,000, 1990. This was produced by digital methods, but the style is generally similar to the analog-based *AA Motorists' Atlas of Great Britain* of 1977. The rural road system looks fairly complete, and numerous tourist attractions are shown, but there is no indication of groundforms.

Size of the entire original: 29.5 × 20.6 cm; size of detail: ca. 14.1 × 19.4 cm. From *AA Road Atlas of the British Isles* (Basingstoke: Automobile Association, 1990), 29. Contains Ordnance Survey data © Crown Copyright and database right 1990. Permission courtesy of AA Media, U.K.

the increasing facility, thanks to four-color printing and techniques such as scribing, for producing colorful, attractive, and legible mapping; and intense competition from other publishers of comparable mapping and guidebooks. At the same time, the AA reflected its origins in systematically mapping the locations of police speed cameras, which was the leading attribute advertised on the cover of the *Close-Up Britain Road Atlas*, published at 1:100,000 in 2006. The inclusion of details such as hill shading, small areas of woodland, and some rural roads off limits to motorists reflected trends apparent elsewhere in cartography, notably the technical opportunities afforded by large quantities of digital data (in this instance from the Ordnance Survey) and an effort to capture market share by creating the impression (often superficial) of serving a wide range of interests, including cycling.

RICHARD OLIVER

SEE ALSO: John Bartholomew & Son (U.K.); Road Mapping: Europe; Travel, Tourism, and Place Marketing

BIBLIOGRAPHY:

Keir, David, and Bryan Morgan, eds. 1955. *Golden Milestone: 50 Years of the AA*. London: Automobile Association.

Nicholson, T. R. 1983. *Wheels on the Road: Maps of Britain for the Cyclist and Motorist, 1870–1940*. Norwich: Geo Books.