# B

***Bagrow, Leo.*** Born in 1881 in Siberia, Leo Bagrow (Lev Semenovich Bagrov) spent most of his professional career in Berlin and Stockholm, where he founded and edited the prestigious journal *Imago Mundi*, wrote over seventy scholarly publications on the history of cartography, and discovered and collected many rare maps. Bagrow attended preparatory school in Siberia before graduating from the Archaeological Institute in St. Petersburg. Entering the Russian Imperial Navy, he was trained as a navigator. Subsequent service as an officer in the Hydrographic Department took him to the four corners of Russia.

In November 1918, Bagrow and his wife Olga emigrated to Berlin. In 1935 he published the first volume of *Imago Mundi: Yearbook of Old Cartography*. However, political developments in Germany forced Bagrow to transfer *Imago Mundi* to London, where two more volumes were issued before the war began. In 1945, Swedish authorities flew Bagrow and his wife to Stockholm, where, with financial support, publication of *Imago Mundi* was revived. During the remainder of his life, ten more volumes (4–13) were edited and produced. He also published four volumes of *Anecdota cartographica*, a series of facsimile reproductions of early maps.

*Imago Mundi* included illustrated scholarly articles, shorter notices, and reviews. Bagrow's editorial and promotional flair, together with his extensive correspondence with fellow scholars and collectors from many countries, gave the journal its Eurocentric, if not international, focus on the history of cartography (Harley 1986) It has remained the only periodical devoted exclusively to this subject and must be regarded as one of the more important formative influences in the development of that discipline. Its antiquarian and bibliographic bias has made it an indispensable reference work.

Bagrow's first scholarly publication, on maps of the Caspian Sea, was published in 1912. His seventy-first, on a Dutch globe in Moscow, was published in 1956. Twenty-nine of these works were on specific Russian topics, his abiding lifelong interest. Four more works were published posthumously, including *A History of the Cartography of Russia Up to 1600* and *A History of Russian Cartography Up to 1800*.

Bagrow traveled widely throughout his lifetime. When living in Europe he was agent for various commercial and financial firms. During his leisure time, he was able to discover, report, and sometimes purchase many rare Russian maps for his private collections. His abrupt departures from St. Petersburg and later from Berlin meant that he lost many of these treasures. To his discredit, some of his Russian items were acquired illegally. Despite this, his work and contributions were known and studied in the Soviet Union. But because he never returned there, some of his later work may have suffered from unfamiliarity with archival collections and contemporary Soviet research.

His last trip, an unfortunate visit to Ethiopia in the rainy season, led to his death in 1957 at seventy-six. Shortly before, he circulated a description of his map collection to several potential buyers or agents. Contrary to common belief, Harvard University bought only ten items (Jackson 1956, 1–4). The other sixty-one, some of great rarity and importance, can no longer be accounted for.

HENRY W. CASTNER

SEE ALSO: Histories of Cartography; *Imago Mundi*

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***Bertin, Jacques.*** Jacques Bertin was born in Maisons-Laffitte, France, in 1918. After secondary studies, he entered l'École de cartographie, established by Emmanuel de Martonne in 1934 at l'Université de Paris. Because de Martonne's program sought to combine technical training and geographical education, Bertin studied not only cartographic drawing and mathematical geography but also general geography.

After graduating with a degree in cartography, Bertin worked in publishing. Following World War II he joined the Centre national de la recherche scientifique, participating in research on Parisian social space as part of a team headed by the sociologist Paul Henry Chombart de Lauwe. The resulting publication, *Paris et l'agglomération parisienne*, appeared in 1952. Contributing a chapter on graphic research, Bertin presented his first theoretical thoughts on cartographic language. Among other things he outlined the idea of visual variables and their properties. He thought the cartographer should strive to display data as a bold and visually unified image that would contrast effectively with the less conspicuous base map (Bertin 1952). Although Bertin discussed methods of mapping both univariate and bivariate data, his comments and map illustrations reflected his preference for graphically simpler univariate maps (fig. 78). That view broke with French geographical tradition, which regarded regional synthesis as the height of cartographic art.

In 1954, prompted by historians Lucien Febvre and Charles Morazé, Bertin joined section VI of l'École pratique des hautes études, a center for social sciences research founded after the war with Rockefeller Foundation support. There he created and directed le Laboratoire de cartographie, which in 1974 became the Laboratoire de graphique. During that period he developed his ideas on graphic semiology (the study of signs and symbols). The laboratory prepared maps and diagrams on request for a wide range of researchers. Confronted with diverse demands in regard to data and types of illustrations, Bertin and his colleagues gradually worked out general principles to guide graphic representation.

They published their conceptual framework in *Sémiologie graphique* in 1967. The treatise, a landmark in cartographic thought, set forth a single language, *la graphique* (the graphic system), for all forms of graphic expression. Bertin began with the principles of informa-

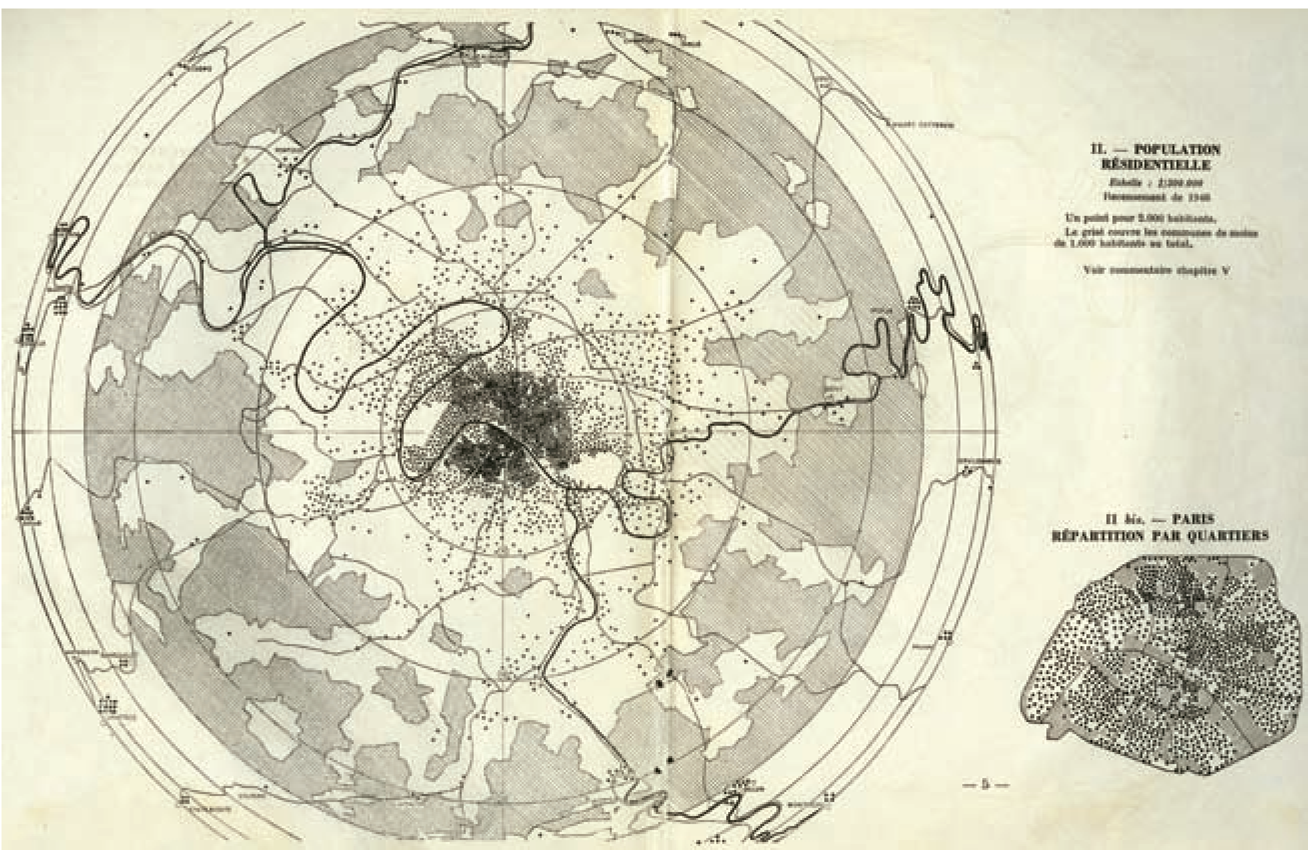


FIG. 78. *POPULATION RÉSIDENTIELLE*, 1946. This map showing residential population in a proletarian sector of Paris by means of graduated circles is a typical univariate map illustration designed according to Bertin's graphic grammar.
Size of the original: ca. 21.9 × 34.4 cm. From Paul Henry Chombart de Lauwe et al., *L'espace social dans une grande cité*, vol. 1 of *Paris et l'agglomération parisienne* (Paris: Presses Universitaires de France, 1952), 4–5. Copyright © Presses Universitaires de France. Permission courtesy of Presses Universitaires de France, Paris.

tion analysis, a prerequisite for representation. He held that the appropriate measurement scale for the data, *qualitatif* (nominal-qualitative), *ordonné* (ordinal), or *quantitatif* (ratio), was key, as was the multiplicity of data elements. He proceeded to describe how the visual variables could vary the visual effect of graphic marks. He discussed eight variables: shape, orientation, texture, color, value, size, and position on the plane surface (*x,y* coordinate position). For each variable Bertin explained how the inherent visual properties of *selectivité* (selection or difference), *associativité* (association or similarity), *ordre* (order), and *quantité* (quantity or proportionality) affected perception (fig. 79). For example, the property of *selectivité* enables a viewer to quickly perceive families of red symbols or green symbols. Bertin next laid out a graphic grammar, that is, a set of rules about construction and readability of graphic images aimed at achieving effective communication. In the second major section of the book, he demonstrated the application of the graphic grammar, organizing his examples according to the types of information represented.

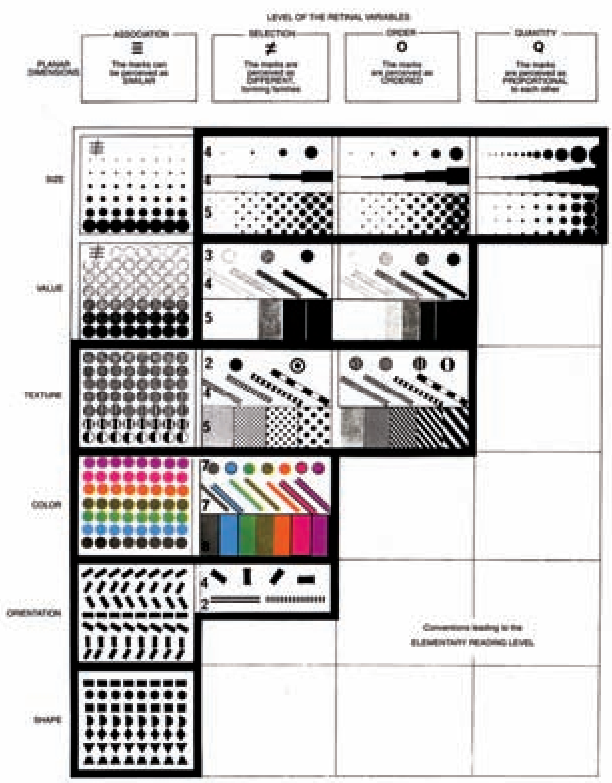


FIG. 79. JACQUES BERTIN'S TABLE OF PROPERTIES OF VISUAL VARIABLES. This graphic summary illustrates the visual variables and types of symbols associated with the visual properties of association, selection, order, and quantity.
Size of the original: 22.9 × 18 cm. From Jacques Bertin, *Semiology of Graphics: Diagrams, Networks, Maps*, trans. William J. Berg (Madison: University of Wisconsin Press, 1983), 96. © 1983 by the Board of Regents of the University of Wisconsin System. Reprinted by permission of the University of Wisconsin Press.

Bertin used graphic images as tools not only for presenting data but also for processing data. In his laboratory Bertin perfected various graphic tools for processing complex data: classing and its permutations, reorderable matrices and image files. His text described how, through manual operations of matrix permutation and reordering, it was possible to identify categories of objects and spaces with similar characteristics. Bertin considered his discovery of the mobility of the image, also known as seriation, a decisive moment in the evolution of his conceptual thinking. He developed his methods of visual processing in *La graphique et le traitement graphique de l'information* (1977).

Bertin produced a solid body of work as a cartographer: he innovated map projection methods during the 1950s, illustrated numerous books and textbooks, and produced wall maps and several historical atlases. During the 1960s he was also the first in France to experiment with automated cartography. Even so, those efforts pale in comparison to his contribution to theory. His 1967 and 1977 books were translated into several languages. Bertin also transmitted his ideas to French and foreign students through classes that he taught in Paris. His ideas about graphic design made an impression on several generations of cartographers and permeated most introductory cartography textbooks. Even though his methods of visual processing, more difficult to use than mathematical data analysis, have rarely been applied, statisticians also recognize Bertin's contribution to visual data analysis as groundbreaking. Bertin died in Paris 3 May 2010.

GILLES PALSKY

SEE ALSO: Academic Paradigms in Cartography: Europe; Art and Cartography; Perception and Cognition of Maps: Perception and Map Design

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***Bibliographies of Maps.*** See Cartobibliography

***Biogeography and Cartography.*** The twentieth century inherited a rich tradition of using maps to document and understand our planet's biota. The depiction of life-forms on maps had already been used for purposes as diverse as the depiction of different climatic zones on early Greek and Islamic maps, the demonstration of the richness of the creation on *mappaemundi*, and the theorizing of distinct latitudinal and altitudinal vegetation communities based on the work of pioneering field geographers, such as Alexander von Humboldt (Wood and Fels 2008). Work in the twentieth century in the area of biogeographical cartography built on this earlier tradition in at least three areas: the acquisition of biological and geological data; the ways in which data are depicted on maps; and the ways in which these resulting maps can be used to uncover and explore biogeographical patterns and processes.

It often takes a conscious effort to remember how little was known of the geographical, ecological, and biological features of the surface of the earth in 1900, especially given the appearance of apparently assured knowledge on the many detailed, yet very small-scale, maps produced by various scientists and geographical societies at the beginning of the century. A good example of this supposed assurance is the large map that was published separately to illustrate E. Bretschneider's (1898) extremely detailed history and inventory of all the European botanical discoveries in China to 1900. The impression created by this four-sheet general map of China (fig. 80), which depicts a large mass of geographical data, as well as the routes and collecting locations of the scores of botanists whose work he documents, is one of detailed knowledge; something that it is easy for early twenty-first-century scholars, with access to such real-time resources as Google and satellite imagery, to take for granted.

Yet the other six much larger-scale supplemental maps that Bretschneider included in the second edition of his 1898 supplement show a much more tentative grasp, not only of botanical knowledge, but of the basic geographical features of the area under consideration. The large-scale map depicting French priest Jean Marie Delavay's collecting sites in northwestern Yunnan, for instance, actually had to have been drawn by Delavay himself once Bretschneider's letter containing that request had found him in his remote mission, as detailed cartographic information of the area was not available in Europe.

The need of many early twentieth-century field scientists to be both specialized in their own area of interest and simultaneously good geographers and cartographers becomes even more evident looking at the careers of the self-taught George Forrest (fig. 81) and his friend and colleague Heinrich Handel-Mazzetti, an Austrian botanist trapped in northwestern Yunnan during World War I. Handel-Mazzetti's additional training as a cartographer enabled him to improve dramatically on then available maps of the area provided at both 1 inch to 4 miles and 1:1,000,000 by the Survey of India (fig. 82). Indeed, Handel-Mazzetti's maps remained some of the most accurate and detailed maps of large portions of this region of the world until the Allied Command in World War II commissioned yet another field botanist-cum-geographer, Joseph Francis Charles Rock, to synthesize all existing topographical data to produce the maps that were used for the Burma Road and to fly safely over the Hump. This model of the cross-trained biologist-geographer is commonly replicated all around the world well into the late 1950s and 1960s and indicates the centrality of the first task in biogeographical cartography in the twentieth century: the detailed and accurate collection of both biological and geographical data.

The advent of the Great Depression in the decade before World War II slowed the production of biogeographical maps, as departments and universities struggled for funding, but some field exploration and mapping continued, usually concerning economic species such as rubber trees. World War II brought new technologies to cartography and the acquisition of field data, and it contributed to the accelerated creation of high-quality and standardized base maps, especially in parts of the world that saw actual combat.

With the end of World War II, and as increasingly accurate field data became more available for larger parts of the world's surface, the second great task of biogeographical cartography gained importance: the accurate cartographic depiction of this mass of data in ways that allowed biogeographers and other scientists to see, understand, and theorize biogeographical relationships. In addition, a rebounding and expanding global economy began to create pressure both to conserve parts of the natural world and to be able to better predict the impacts of industrial development.

In the English-speaking world, one of the first meetings to discuss these cartographic challenges and provide some guidelines to biogeographical cartographers was convened by the Royal Geographical Society on 6 March 1950 in London. The resulting monograph from this session (Royal Geographical Society 1954) reveals the many technical cartographic questions that concerned the participants, revolving around appropriate projections, the production of an agreed-upon series of base maps, and the many possible uses of various quantitative symbols. Some of the impacts of the results of this meeting can be seen in the cartographic products within the British Empire, for instance in the biogeographical plates of the *Atlas of Uganda* (Parker, Downer, and Cole 1962).

Immediately after World War II, in 1947, French bot-


FIG. 80. E. BRETSCHNEIDER, *MAP OF CHINA AND THE SURROUNDING REGIONS: COMPILED FROM THE LATEST INFORMATION*, 1900. Published St. Petersburg: A. Illiin, 2d rev. ed. Small-scale maps in the early twentieth century often conveyed a message that the area depicted was well known.

Size of the original: 62 × 71 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

anists and cartographers worked with the French government to establish the Service de la carte phytogéographique as a part of the larger Centre national de la recherche scientifique (CNRS). The service was, in turn, divided into two sections, the Service de la carte de la végétation de la France au 200,000 echelle, based in Toulouse and headed by Henri Gaussen and Paul Rey, and the Service de la carte des groupements végétaux de la France au 20,000 echelle, based in Montpellier and headed by L. Emberger and J. Braun-Blanquet. Individuals from both services were also involved with the Institut Français de Pondichéry, based in India, and with United Nations Educational, Scientific and Cultural Organization (UNESCO).

One of the first major publications of this group of French biocartographers was the short monograph *Service de la carte phytogéographique* (CNRS 1955), which provides a detailed overview of the larger biocartographical project and, most importantly, specific details and examples of the cartographically sophisticated methods being used to produce these maps. Based on a desire to illustrate the work of phytosociologists such as

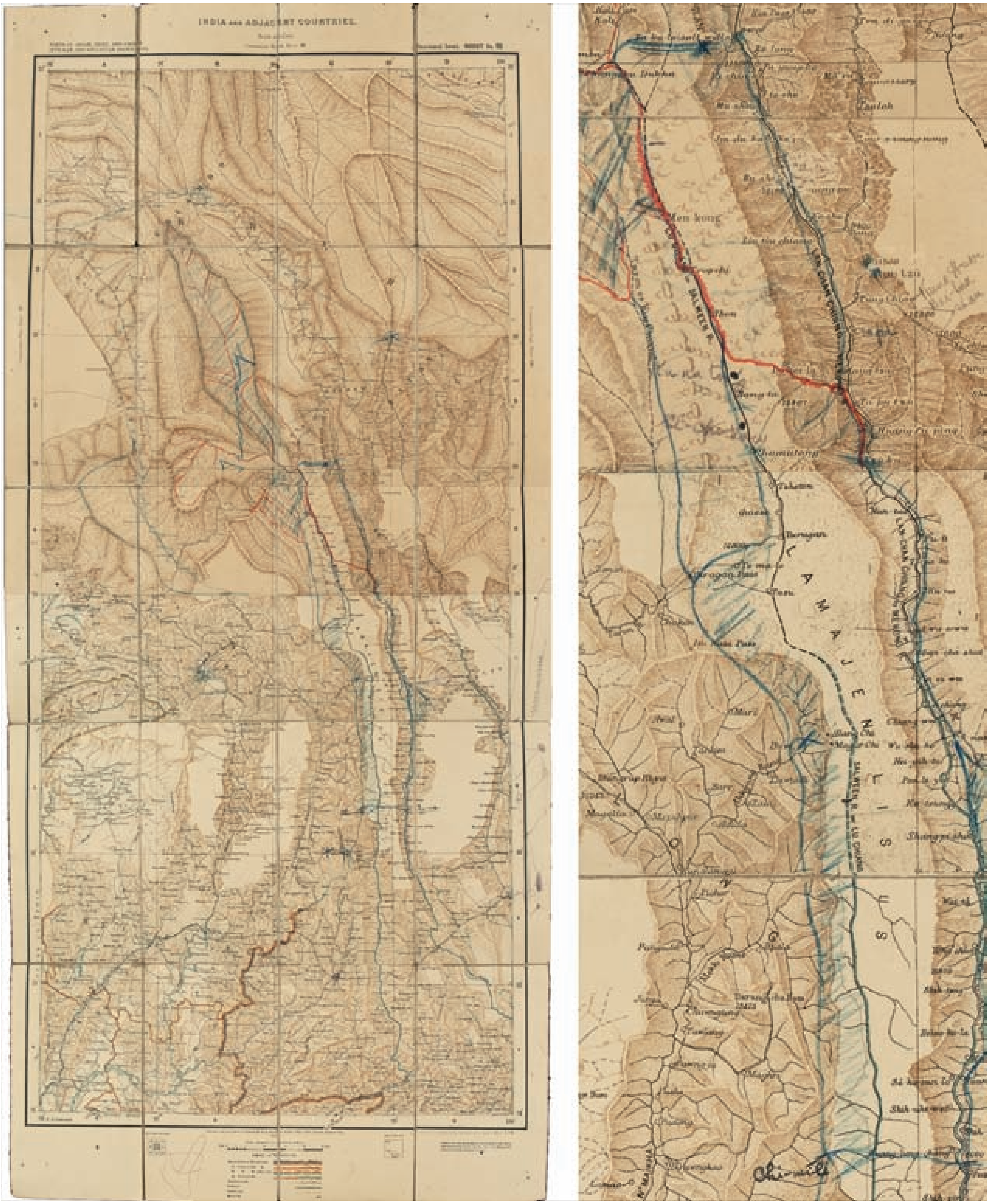


FIG. 81. SURVEY OF INDIA, *INDIA AND ADJACENT COUNTRIES* (PROVISIONAL ISSUE), 1:1,000,000, 1914. Published Calcutta: Government of India. This copy of sheet 91 (left) was used by George Forrest, a plant collector active in northwestern Yunnan from 1905 until his death in 1932. Forrest also quietly gathered cartographic data on the area for the Government of India, an activity many field scientists engaged in around the world. Forrest's routes are shown in colored pencil (detail, right).
Size of the original (left): ca. 101 × 47.8 cm; size of detail (right): 31.7 × 10.8 cm. Image courtesy of the Royal Botanic Garden Edinburgh.

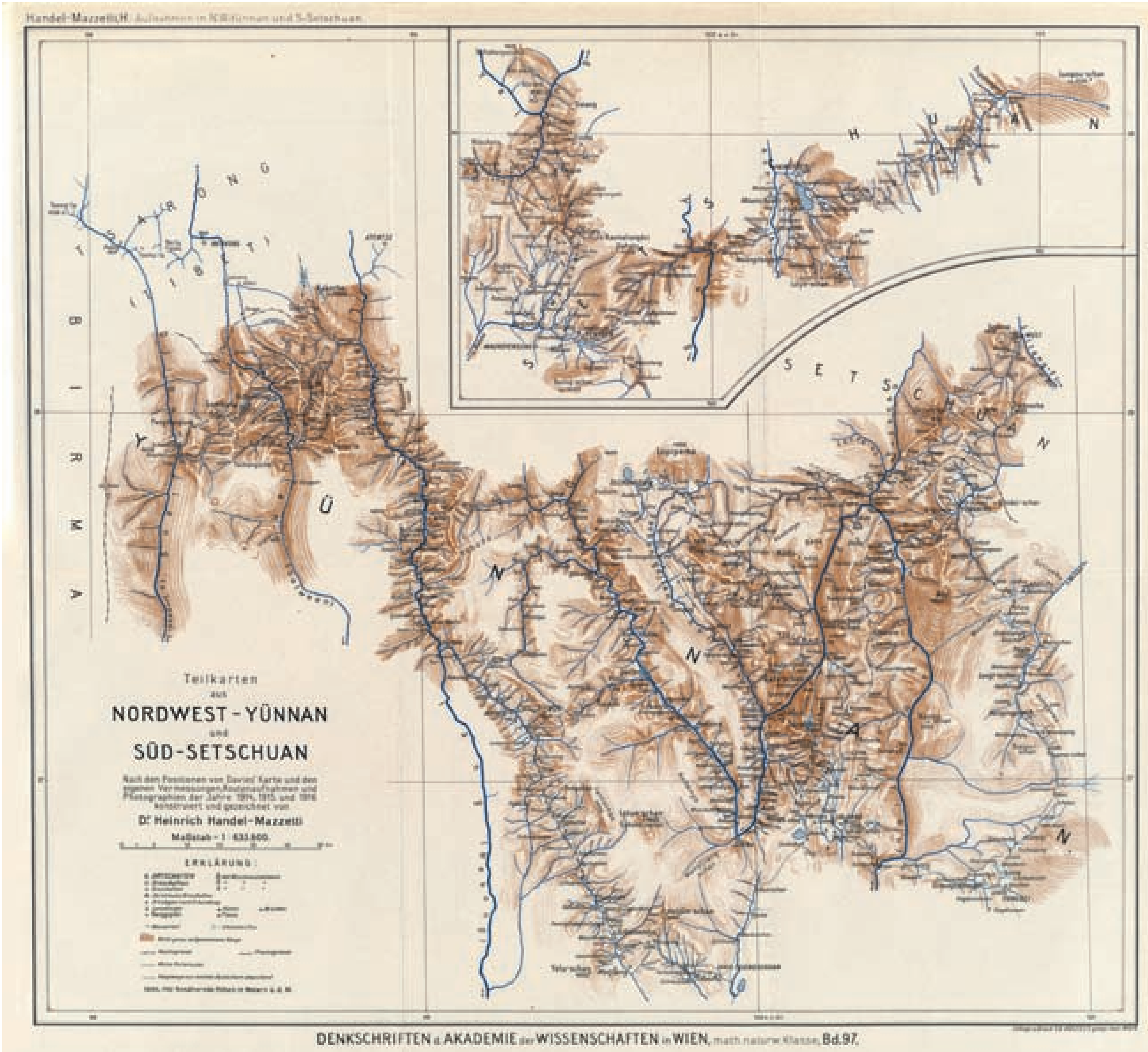


FIG. 82. HEINRICH HANDEL-MAZZETTI, *TEILKARTEN AUS NORDWEST-YÜNNAN UND SÜD-SETSCHUAN*, 1:633,600, 1919. Published Vienna: Ed. Holzel's Geogr. Inst. Size of the original: 48 × 53 cm. From Heinrich Handel-Mazzetti, "Neue Aufnahmen in NW-Yünnan und S-Setschuan," *Denkschriften: Akademie der Wissenschaften in Wien, Mathematisch-Naturwissenschaftliche Klasse* 97 (1921): 257–68, map following 268.

Braun-Blanquet, these cartographic methods were far in advance of anything being done in the English-speaking world (Fosberg 1961; Küchler 1967). This leadership in the field was reflected in the decision by UNESCO to ask the Institut Français de Pondichéry to host the international colloquium Méthodes de la cartographie de la végétation in Toulouse in 1960 (CNRS 1961), in order to launch the new international initiative headed by Gaussen to create a detailed series of maps of the entire world's vegetation, the *Carte internationale du tapis végétal*.

The participants in the 1960 Toulouse symposium included virtually every significant plant biogeographer-cartographer then active in the world—Pierre Mackay Dansereau, F. Raymond Fosberg, A. W. Küchler, V. B. Sochava, and Reinhold Tüxen among others (CNRS 1961). For the first time, researchers from around the world were meeting in one place, seeing each other's work, and comparing notes. UNESCO had begun planning for a series of maps covering global distribution of species in the early 1950s, and the 1960 symposium in Toulouse added tremendous momentum to the project, leading to further significant international meetings in Montpellier, for instance in 1962 on the methodology of plant ecophysiology hosted by F. E. Eckardt (Eckardt 1965), and to the development and publication of *International Classification and Mapping of Vegetation* (UNESCO 1973). Finally, this first meeting in Montpellier served to motivate biogeographers in North America to focus more attention and resources on the challenges of mapping biological populations, a field that they had relatively ignored (Fosberg 1961).

It should be noted that French biogeographical cartography was based strongly on fieldwork, which provided the necessary information for accurate symbolization, and on training in the techniques of cartography, in order to have the tools to make and understand the complex maps necessary to illustrate complex landscapes. A now classic example of the product of this French method is the 1:200,000 sheet for Perpignan produced under Gaussen as part of the series of maps of the vegetation of France (fig. 83).

Developments in the fields of electronics, computers, aviation, and space-borne sensors in the last quarter of the twentieth century, especially in North America, dramatically shifted the focus of biogeography toward the use of remote sensing and statistical modeling. In addition, an increasing desire to be able to accurately model and predict changes to the distribution of flora and fauna that occur as a result of human activity became more vital as industrial economies spread across the globe. This new more technological and quantitative focus led to much richer understandings of the ecology and biogeographical characteristics of a whole range of species and biotic assemblies (Alexander and Millington 2000).

At the same time, this new technological focus raised cartographic challenges that became increasingly serious by the end of the century. For instance, cartographers grappled with how to map multidimensional and multitemporal spaces in new marine protected areas in the Arctic. Cartographic challenges include the depiction of volumetric currents containing biological life-forms passing through the spatially static volumetric "protected" space that includes seasonally present ice.

These new cartographic tasks were and continue to be made more challenging by a severe reduction of training in biogeographical fieldwork and basic cartographic principles, especially in North America. The reliance in the new biogeographical sciences on the use of computers, remote sensing, and other forms of technology created the need for training in these new tools. The use of geographic information system (GIS) software, for instance, required courses on the software and on computer languages. In addition, many biogeography, ecology, and biology educational programs incorporated courses on quantitative and laboratory methods. Many universities made room for these new courses by removing traditional courses in field methods and cartography. The absence of cartographic training meant that many of the people who most needed to know how to interpret cartographic information lacked the skill to understand the weakness of the maps they used. Finally, the lack of cartographic training removed the tools that could be used by biogeographers to defend the idea that maps can be more or less accurate reflections of pieces of the world against the more extreme relativist attacks of cartographic critics in the humanities and social sciences. The result of all this by the beginning of the twenty-first century has been an increased intellectual understanding of biogeographical systems but a serious reduction in the quality and innovative cartography that is necessary to visually convey and visually understand the results of the new science.

The twentieth century saw the birth and development of accurate, innovative, and aesthetically pleasing maps in the field of biocartography. These maps were usually constructed using detailed field studies and advanced cartographic techniques. The end of the century saw the introduction of computerized cartography and remote sensing, which brought new challenges and possibilities to the need to portray and study the distribution of plant and animal life on the earth.

WILLIAM WILSON

SEE ALSO: Climate Map; Environmental Protection; Forestry and Cartography; Remote Sensing: Earth Observation and the Emergence of Remote Sensing; Scientific Discovery and Cartography; Soils Map

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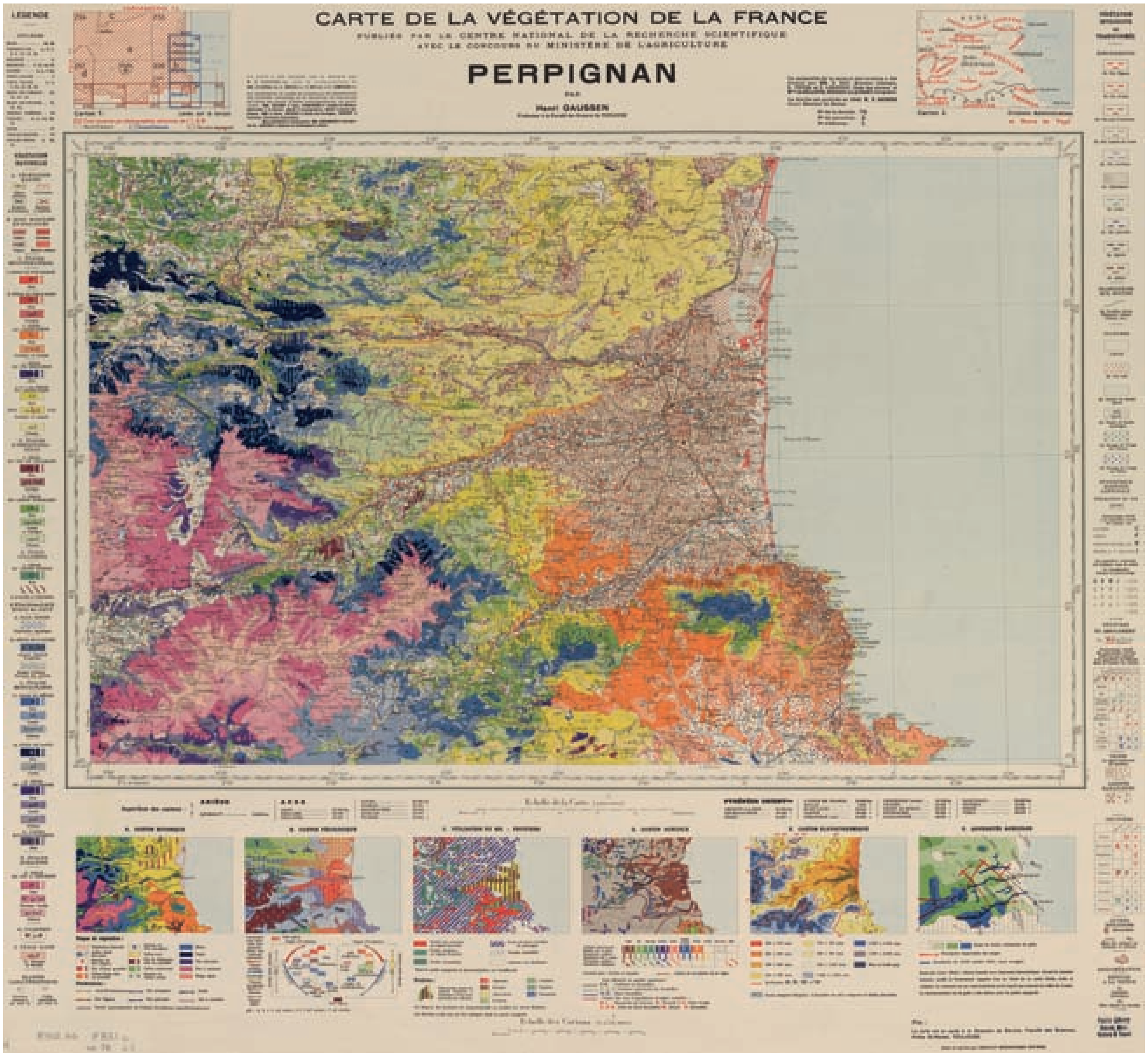


FIG. 83. HENRI GAUSSEN, *PERPIGNAN* SHEET OF THE *CARTE DE LA VÉGÉTATION DE LA FRANCE*, 1:200,000, 1948. Published Toulouse: Centre National de la Recherche Scientifique. This map is widely considered one of the best examples of refined biogeographical cartography, especially when compared to standard outputs from a GIS today. (Map is shown here without left and right marginal text.)

Size of the original: 68.6 × 74.6 cm. Image courtesy of the Stephen S. Clark Library, University of Michigan, Ann Arbor. Permission courtesy of the Cartothèque, Institut géographique national.

Parker, D., E. R. Downer, and G. E. D. Cole, eds. 1962. *Atlas of Uganda*. [Kampala, Uganda]: Department of Lands and Surveys.

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Wood, Denis, and John Fels. 2008. *The Natures of Maps: Cartographic Constructions of the Natural World*. Chicago: University of Chicago Press.

***Bivariate Map.*** One of the elementary methods for furthering geographic understanding is to compare different characteristics for the same units of observation in order to study the relationship between the character-

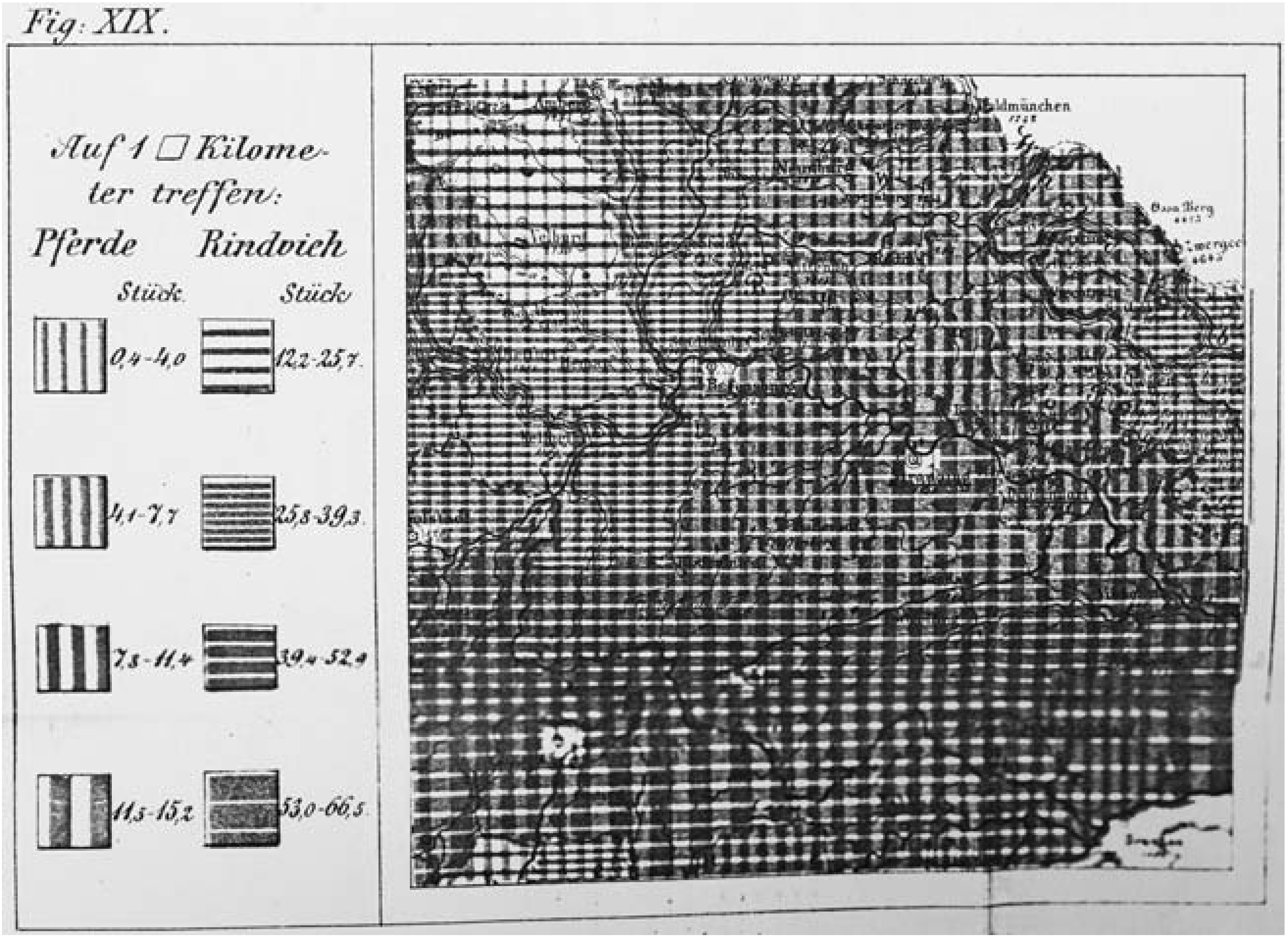


FIG. 84. THE FIRST KNOWN PUBLISHED BIVARIATE MAP. Size of the original: 21.7 × 31.1 cm. From Mayr 1874, fig. XIX. © The British Library Board, Document Supply X9/7708.

istics. For geographic places, the relationship between average income of the population and average longevity might be informative, for example. In this case, the focus is on the relationship between income and longevity as seen in the geographic pattern of similarities and differences that might lead to further investigation of possible causal relationships.

In a geographic study, comparing maps of individual factors or variables is a natural first step. Is there a way to compare more than one variable on a single map? Georg von Mayr answered this affirmatively in 1874 through practical experiments with choropleth maps. He recommended at most the simultaneous presentation of two variables, with parallel horizontal bars in one color selected for one variable and parallel vertical bars of another color used for the second variable. He also assumed that only a few bar widths (perhaps four) representing different classes would be constructed for each variable.

Mayr's choropleth map (fig. 84) used this parallel bar width symbolism to portray the correlation between the density of horses (vertical bars) and cattle (horizontal bars) as reported in the cattle census of 1873 published by the Bavarian statistical bureau. This late nineteenth-century example is perhaps the first published instance of a bivariate or "cross" map. In this kind of map, the values for two variables are classified separately and symbolized such that at any place on the map both values can be read. The intent of the map is to show the spatial pattern of both positive and negative associations between the variables. The simplest type of classification for two numerically scaled variables would be into low and high classes for each variable, giving the map four classes: low-low, low-high, high-low, and high-high. Two of the classes indicate positive association and two negative.

Starting in the middle of the twentieth century, and perhaps earlier, a number of atlases published bivariate maps using ideas similar to Mayr's (for example, atlases of Eastern and Central Europe, Finland, and Brazil).

Some of these maps showed more than two variables. A typical example is a map of agriculture regions in *Suomen kartasto = Atlas of Finland = Atlas över Finland 1960*. The percentage of land in cultivation for each region is symbolized in a spectrum of hues. Then two additional variables are displayed with contrasting line density symbols. Cattle density is shown with horizontal line densities, and forest area per farm with vertical line densities. Indeed, nominally scaled data in geology, soils, and other fields have been presented on single maps with different symbols for different aspects of the subject for many years.

Bivariate maps became more widely used with the advent of computer technology. The U.S. Census Bureau published what may have been the first bivariate maps created with computers in the 1970s (Meyer, Broome, and Schweitzer 1975). The bureau used color shading with contrasting hue ranges for a small number of numerical classes for each variable and a square or rectangular legend showing the combinations of classes as mixed hues (fig. 85). These maps fostered an extensive literature criticizing, studying, and enhancing the technique. A number of publications in the statistical literature offered judgments on the effectiveness of the technique, experimental studies of perceptual issues, or suggestions for design improvements.

Cartographers also joined in the debate. Starting in the 1980s a number of journal articles by Judy M. Olson (1981) and others explored user perceptions of both color and other types of bivariate symbolism in increasing degrees of sophistication. Rather than dismissing the bivariate technique as the first round of critics in statistics had done, cartographers have carefully explored and elucidated the types of symbolism that could be effectively used in these maps.

Cartography books also began to address the issues of using the bivariate mapping technique. Jacques Bertin (1981) was perhaps the first, demonstrating the construction of what he called a "synthesis" type of superimposition map proceeding from the ordering of values in a data matrix, to grouping, and then to choice of symbolism. One example map displays one variable in gray tone shading and the other in point and line pattern symbolism (Bertin 1981, 167).

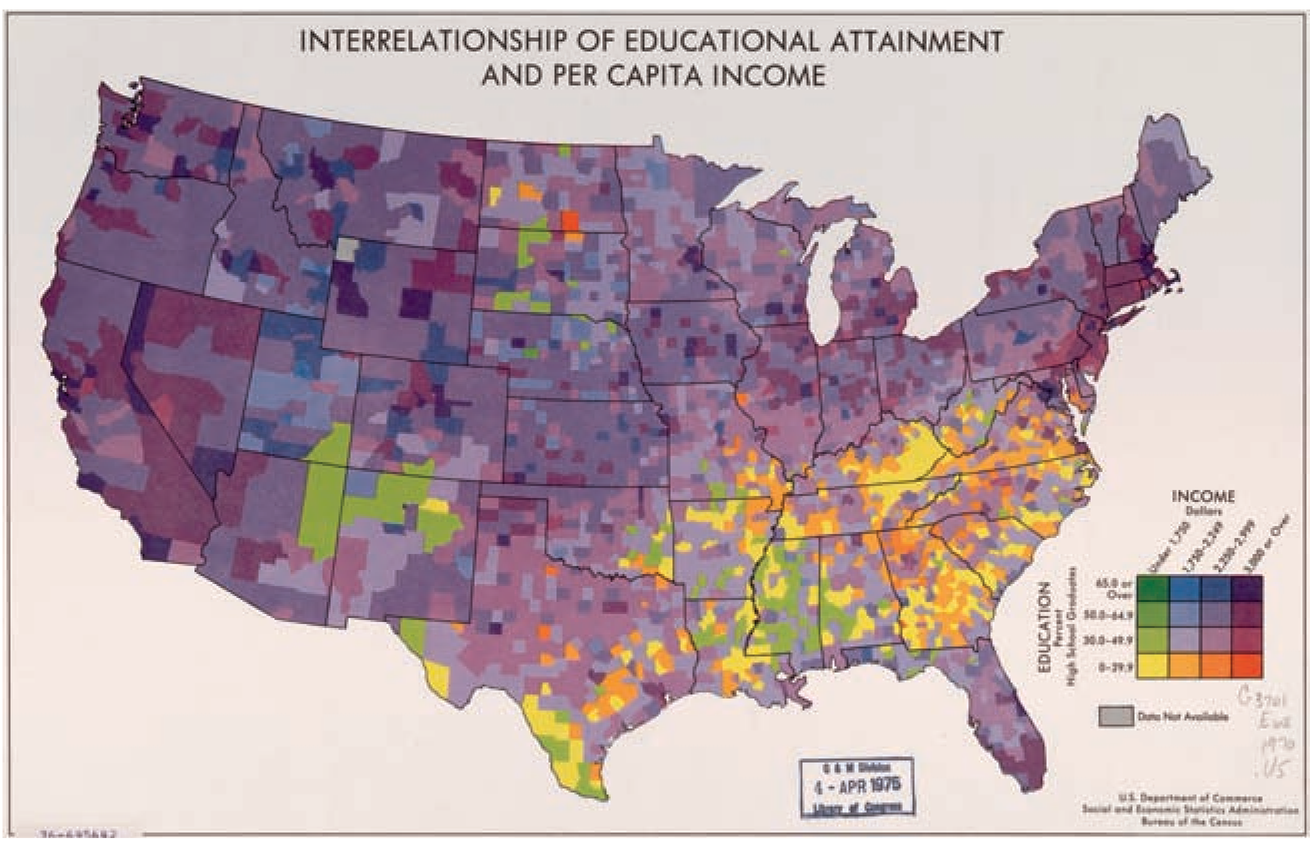


FIG. 85. BIVARIATE MAP SHOWING EDUCATION AND INCOME. *Interrelationship of Educational Attainment and Per Capita Income* (Washington, D.C.: U.S. Census Bureau, 1970). These maps produced by computer initiated a large body of research and design on bivariate maps in the last quarter of the twentieth century.
Size of the original: 25 × 38 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C.

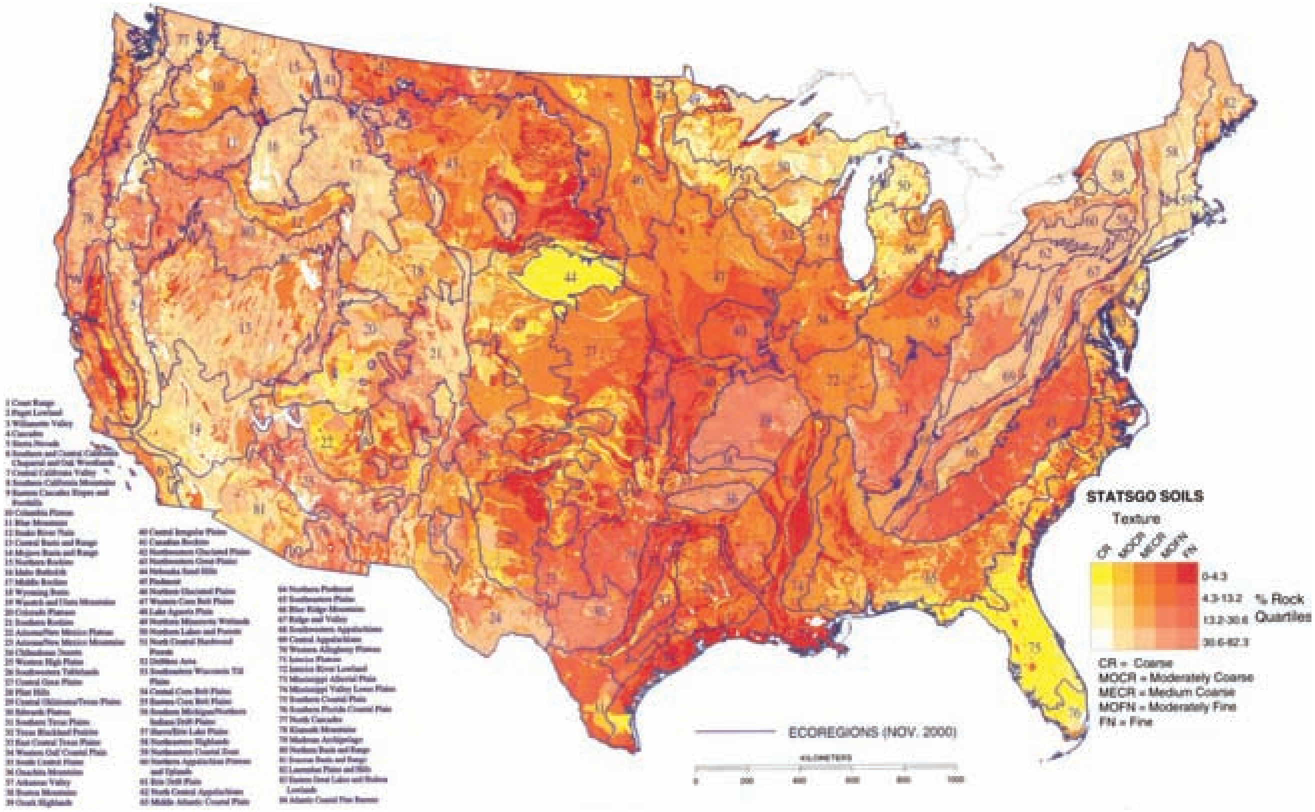


FIG. 86. BIVARIATE MAP SHOWING SOILS AND ECOREGIONS IN THE UNITED STATES.

From Shirazi et al. 2003, fig. 1. Permission courtesy of the *Journal of Environmental Quality*, Madison.

Has the bivariate technique influenced cartography beyond academic investigation of the technique itself? There is some evidence that maps using the technique are being presented in venues other than the cartographic and statistical. For example, two properties of soils are mapped in a cross map (fig. 86). Soil texture classed in five categories from coarse to fine is displayed in a hue ramp from yellow to dark red, and quartiles of percentage of rock are displayed in four levels of saturation. This map differs from the cross map in figure 85 because a 4 × 5 classification does not have unambiguous most positive and most negative correlation axes. That is, there is not a straight diagonal sequence from the lowest class in both variables to the highest class in both variables as there is in a square (e.g., 2 × 2, 3 × 3) classification. In addition, the map portrays possible correlation between the bivariate soils classes mapped by soils map units with a much coarser resolution delineation of ecological regions depicted by dark lines superimposed on the choropleth map of soils data.

Several techniques closely related to the bivariate cross map have been developed. As early as 1966 a map of three variables whose summation is a constant (for example, percentages of three land use types that add to 100 percent) was presented (Board and Wilson 1966). This version of the technique uses a triangular legend with three directions of parallel lines, one for each of the variables. Similar maps were subsequently produced using color mixing taking advantage of the trivariate nature of color perception.

At the turn of the twenty-first century a sophisticated technique was developed for portraying the relationship between a response variable and two "conditioning" variables (Carr, White, and MacEachren 2005). In this type of map, each conditioning variable is divided into three classes for display in a 3 × 3 grid of maps where each map has only those observations for one of the nine combinations of classes. One of the variable's classes divides the maps horizontally and the other vertically. Thus the spatial patterns of association are shown by map position in the 3 × 3 grid. In addition, a dependent variable is displayed in color choropleth shading for each of the observations.

With an initial proposal and example developed in the late nineteenth century, the bivariate mapping technique has seen a steady increase in use throughout the twentieth century, accelerated in the 1970s and 1980s by the application of computers. In fact, one of the leading map software vendors in the twenty-first century offers the bivariate cross map as a standard technique. While research has demonstrated that selection of symbolism for this technique is crucial for effective communication, it is likely that the new century will see more of these maps produced.

DENIS WHITE

SEE ALSO: Analytical Cartography; Choropleth Map; Color and Cartography; Exploratory Data Analysis; Statistical Map; U.S. Census Bureau

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***Board on Geographic Names (U.S.).*** By the 1880s, it had become increasingly apparent that maps and charts of the United States often contained misspelled or incorrectly located geographic names. In 1890, President Benjamin Harrison created the U.S. Board on Geographic Names (BGN) to examine such problems, develop appropriate nomenclature, and assure that names were accurately located on cartographic products. In 1892, the first BGN report outlined these directives, defined the BGN's principles and policies, identified procedures that federal agencies should use to establish accurate names, and listed the BGN's decisions on names during its first year. The report also identified the first ten BGN members, who were officials of federal mapping and charting agencies, which had a vested interest in the correct use of standardized names for geographic features and populated places. These agencies were the U.S. Coast and Geodetic Survey (two members), the Engineer Corps, the U.S. Geological Survey (two members), the Hydrographic Office, the Light-House Board, the Smithsonian Institution, the Department of State, and the Post-Office Department (U.S. Board on Geographic Names 1892).

Over the years, the United States increased its involvement in both domestic and foreign affairs, and federal departments (including new agencies) expanded their responsibilities and size. As a result, federal agencies required more cartographic products and became involved with the BGN. By the turn of the twentieth-first century, the BGN had a total of twenty-nine members representing the Departments of Agriculture, Commerce, Defense, Interior, and State; the Government Printing Office; the Central Intelligence Agency; the Library of Congress; the Postal Service; and the Federal Emergency Management Agency (FEMA). Decision making was divided between two committees, the Domestic Names Committee (DNC) and the Foreign Names Committee (FNC). Some agencies had representatives on both committees. Members of the FNC represented the Departments of Commerce, Defense, and State as well as the Central Intelligence Agency and the Library of Congress. The DNC had representatives from the Departments of Agriculture, Commerce, and Interior as well as the Government Printing Office, FEMA, and the Library of Congress. Advisory committees also are formed to work on names of areas beyond any national sovereignty. As relevant, they collaborate with other organizations. Following historical precedent, the secretary of the Department of the Interior is the legal director of the BGN but plays no active role in managing BGN activities.

In 2006 the Department of the Interior was represented by six persons from various offices, and the Department of Defense had four representatives, including two from the National Geospatial-Intelligence Agency (NGA), created in 2003 as the successor to several other associations responsible for cartographic and other products intended to meet military and intelligence requirements. Headquartered in Maryland near Washington, D.C., the NGA has supported the FNC with a staff of about twelve linguists, geographers, and cartographers who researched accurate spellings of names for maps of foreign lands and maritime areas. During World War II, the staff had about thirty-five experts. Since that era, contracts have also been made with outside groups to meet demands.

From its inception, the BGN has been administered by individuals with outstanding records in cartography and related fields. Perhaps the most significant of these was Meredith F. Burrill. As executive secretary of the BGN from 1943 until his retirement in 1973, Burrill also participated in numerous national and international meetings, collaborated closely with BGN staff and agency representatives, and wrote many papers (Detro and Walker 2004). Under his guidance, the United States was a principal founder of a United Nations (UN) program on names standardization. Burrill and his international colleagues understood that cartographic products with incorrect or disputed names affected the reliability of maps for a great variety of uses. In 1967, Burrill headed the first UN conference on geographic names attended by representatives of UN member nations and various international organizations. At that initial session as well as at UN conferences held every five years thereafter, BGN members and staff played key roles. The UN Group of Experts on Geographical Names (UNGEGN), a related organization formed to implement UN initiatives on names standardization, has met approximately every two years, often at sessions coinciding with UN conferences.

Several BGN officials made noteworthy contributions. Richard R. Randall of the NGA, who served as the executive secretary of both the BGN and the FNC from 1973 to 1993 and was the principal U.S. delegate to the UN, worked to assure that UN programs would address practical as well as academic issues. Furthermore, in 1987, with the support of the Cartography Commission of the Pan American Institute of Geography and History (PAIGH)/Instituto Panamericano de Geografía e Historia (IPGH) and the NGA, Randall initiated and taught a series of annual courses on names standardization in Latin American countries. Donald J. Orth, a long-time U.S. Geological Survey (USGS) employee, was executive secretary of the DNC for several years and authored numerous works, including a bibliography of BGN actions (Orth 1990). Roger Payne of the USGS, who was executive secretary of both the BGN and the DNC from 1993 to 2006, was influential in introducing automated procedures for processing names. Since 2006 he continued to work with the PAIGH names courses. At that same year, Lou Yost (USGS) was appointed executive secretary of BGN and DNC. Members of BGN and DNC meet regularly with committee staff to review papers regarding names questions and to disseminate approved names to appropriate agencies.

Place-names outside the United States have continuously required BGN attention. For example, with the collapse of the Soviet Union in 1991, virtually all place-names in Ukraine were changed back to earlier traditional names (Randall 2001, 56). The FNC worked overtime to incorporate such changes to support the revision of cartographic products. Although Germany and Austria tolerated FNC endorsement of "Munich" (rather than "München") and "Vienna" (rather than "Wien") as spellings acceptable for use by federal agencies, some foreign governments resented American resistance to the renaming of a city or a country. Perhaps the most controversial decision to reject a new name followed the takeover of Burma by a military junta in 1988. In 1989 the new government changed the county's long-form name from "Union of Burma" to "Union of Myanmar," and the corresponding short-form name from "Burma" to "Myanmar." Although the UN readily accepted the regime's renaming of the country, and also the changed spelling of its capital to "Yangon," U.S. government reports and official correspondence continued to use "Burma" and "Rangoon."

The BGN has also worked with comparable organizations in other countries. An early association was made with the Canadian Permanent Committee on Geographical Names, founded in 1897. A major collaborator has been the United Kingdom's Permanent Committee on Geographical Names (PCGN), founded in 1919. The PCGN's interest in standardized names for maps and charts was similar to those of the United States during World War II and especially during the Cold War. Collaboration between the PCGN and the BGN has also helped their countries meet NATO (North Atlantic Treaty Organization) requirements for standardized names on cartographic products.

On the domestic front, the DNC has dealt over the years with numerous controversies, including the restoration of the *h* in Pittsburgh in 1911, the blanket renaming of features with names containing *Nigger* (replaced by *Negro* in 1963) and *Jap* (replaced by *Japanese* in 1974), the renaming of Cape Canaveral (which had been Cape Kennedy between 1963 and 1973), and various unsuccessful attempts to restore Mount McKinley's Native American name, Denali (Monmonier 2006). In the late 1990s names containing *Squaw* had become particularly troublesome: not all names experts agreed that the term was pejorative, and the lack of a simple, widely accepted substitute precluded blanket renaming. As with names containing *Negro*, names with *Squaw* had to be replaced individually by a name that satisfied BGN rules for new and replacement names.

At the subfederal level, state names committees have collaborated with the DNC in vetting proposals to name or rename geographic features within their jurisdictions. To encourage state names boards to comment on pending federal decisions, DNC officials participated in an annual forum that began in 1977 as the Intermountain States Geographic Names Conference. As its membership grew wider, the group renamed itself the Western States Geographic Names Conference in 1979, the Western States Geographic Names Council in 1982, and the Council of Geographic Names Authorities in the United States in 1998. With mixed results, the DNC has worked with tribal officials to resolve issues involving names with a Native American origin and names of geographic features on tribal lands.

Despite the appearance of continuity, the BGN was virtually nonexistent on several occasions, most notably a ten-year period starting in 1934, when the BGN was reduced to a separate entity under a committee of the Department of the Interior. Little work was done until 1944, by which time the onslaught of World War II prompted several agencies to request the creation of a larger staff to provide satisfactory names data for military maps and charts of foreign areas. The resulting group of some sixty-five persons produced upward of 3,000,000 geographic names, mostly for maps of China, Japan, and Korea, whose names required conversion to Roman alphabet versions. But shortly after the war, support for such efforts declined. Hearings at the U.S. House of Representatives in 1946 and 1947 revealed that various elected representatives opposed continued support for these activities. Some objected, saying that the Department of the Interior budget should not fund BGN support for the War Department and other agencies outside the Interior Department. Despite dissenting voices, Congress voted in 1947 to establish a structure for BGN that has lasted beyond the end of the century (Stephens 1968, 60–86).

Although its decisions are binding only on federal agencies, BGN's work continues to be widely influential among state and local governments as well as with private mapmakers, who used federal maps and BGN publications and databases as source material. Its centennial celebration in 1990, which drew names experts from several countries to Washington, D.C., as well as participants from numerous federal and state agencies, commercial firms, and academic bodies, underscored the BGN's role in assuring that twentieth-century American cartographic products contained accurately spelled and correctly located geographic names. In a world where it is increasingly challenging to standardize geographic names, the work of BGN in the twenty-first century remains an essential element of communications in the United States.

RICHARD R. RANDALL

SEE ALSO: Gannett, Henry; Geographic Names: (1) Social and Political Significance of Toponyms, (2) Applied Toponymy; Indigenous Peoples and Western Cartography; Permanent Committee on Geographical Names (U.K.); United Nations; U.S. Geological Survey

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**Bol'shoy sovetskiy atlas mira.** The great Soviet world atlas, *Bol'shoy sovetskiy atlas mira*, was published in Moscow in 1937–40. Often called the *Atlas mira*, it is here referred to as the *BSAM* in order to avoid confusion with other twentieth-century atlases titled *Atlas mira*. Planning, research, and supervision of compilation took place at a specially created scientific publishing institute, the Nauchno-izdatel'skiy institut. Between 1931 and 1933 the Vsesoyuznyi kartograficheskyi trest of the Glavnoye geodezicheskoye upravleniye had assembled the base information. Leading academic Soviet geographers and cartographers, including Nikolay N. Baranskiy, Aleksandr A. Borzov, and Konstantin Alekseyevich Salishchev, were recruited in 1933. The institute also trained its own cartographers (mainly draftsmen). The first outcome was a book of scientific and methodological essays, *Voprosy geografii i kartografii* (1935). The authors critically analyzed Soviet and foreign map sources and reported research findings regarding map content, generalization, and design (Motylev 1935). The initial plan for the *BSAM* was three volumes: (1) general maps of the world, (2) maps of the Union of Soviet Socialist Republics (USSR), and (3) maps of other countries of the world.

The first volume appeared in 1937 on the twentieth anniversary of the October Revolution. Both its world and USSR sections included physical-geographical, socioeconomic, political, and historical maps. The first section also included hemispheric, polar, and oceanic maps. Socioeconomic and political maps showed population density, nations, national groups, peoples and tribes, industry, agriculture, communications routes, resources, export markets and other economic activities of capitalist countries, historical political divisions of the world, and World War I. Also covered were astronomy, the history of geographical concepts, exploration and discovery, geology, mineral resources, geomorphology, climates, soils, vegetation, and zoology. The second section presented similar topics at larger scale for the USSR alone. Following the physical-geographical maps, the socioeconomic maps of industry, agriculture, transport, urbanization, and foreign trade made up just over half of the second section.

At the Paris Exposition Internationale des Arts et Techniques dans la Vie Moderne in 1937 the first volume of the *BSAM* received the Grand Prix as a great achievement of Soviet geograpic and cartographic science and technology. Reviews by foreign geographers and cartographers praised it as comprehensive and up-to-date with a very high standard of production and excellent color printing (Taylor 1939).

The second volume of the atlas, published in 1940, was wholly devoted to the USSR and its parts. General geographical and complex economic maps predominated (fig. 87). There were some maps of large industrial regions and centers, as well as political-administrative maps of the USSR, the Russian Soviet Federative Socialist Republic, Ukrainian Soviet Socialist Republic, and the Byelorussian Soviet Socialist Republic. Population density maps of the European and Asian USSR were based on the 1939 census. A series of maps depicted the civil war (1917–23).

The general geographical maps showed rivers, lakes, seas, towns, villages, roads, relief, and other landscape elements. Color hypsometry with a unified scale of contours was used for land, while the seafloor was shown by isobaths with layer tints. Economic maps showed industry, agriculture, power, mineral resources, and transport.

Ironically, the *BSAM*'s relative sophistication and scientific accuracy later became a pretext for censorship and restricted the sale of maps. Stalinist propaganda, seeking blame for Red Army defeats early in World War II, seized upon a few instances when detailed Soviet maps had been consulted by the enemy. Rumors circulated that, on the eve of the war, Soviet maps and atlases, including the *BSAM*, had been purchased en masse by foreign (especially German) embassies. I. V. Stalin's policy makers implied that those maps aided the bombing of Soviet industry, agriculture, and infrastructure.

The consequences were harsh. For instance, large-scale maps and plans of Moscow and the Moscow oblast were banned from free circulation, removed from library map rooms, and even burned. Thematic maps from the *BSAM*'s second volume became scarce. In addition, certain types of information, such as industrial productivity, were abruptly excluded from Soviet thematic maps. Graduated symbols for industrial output henceforth reflected only the population size of the respective towns. Those policies led foreign users to evade the restrictions in various ways. For instance, the U.S. Office of Strategic Services produced a color facsimile in 1943 from one of two copies of the *BSAM* obtained before restriction.

Work on the third volume of the *BSAM*, intended to cover foreign countries, had to be stopped in 1941 due to World War II. It was not continued after the war.

The *BSAM*'s effect on cartographic science, education, and practice in the Soviet Union and Russia was long lasting. Its practices became standard in mapmaking and in cartographic training. The Nauchno-izdatel'skiy institut laid the foundation for the Nauchno-redaktsionnaya kartosostavitel'skaya chast', a scientific editing and map compilation department, later called PKO "Kartografiya," which became the country's main experimental and production cartographic establishment. Subsequent official mapmaking instructions reflected the *BSAM*'s high standards of quality, precision, and scientific thoroughness. Soviet and Russian cartographers developing regional thematic atlases used it as a model (Salishchev 1976). Its influence extended into the twenty-first century in Russia, where map compilation continued to employ multilevel editorial control, supervision of separate maps and series by the chief editor, and proofreading of map originals.

ALEXEY V. POSTNIKOV

SEE ALSO: Atlas: National Atlas; Salishchev, Konstantin Alekseyevich

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***Boundary Disputes.*** During the twentieth century, the development of cartography and the evolution of various international boundary disputes influenced one another, often in unexpected ways. Decolonization accelerated during the century, creating many new countries, multiplying boundaries, and resulting in more disputes. Boundary disputes, as discussed here, include issues of alignment and uncertainty as well as formal diplomatic protest or violent conflict. The wider view is necessary because in some disputes claimants refuse to acknowledge contesting claims and in other disputes both claimants publish conflicting maps, but neither further publicizes the dispute. Maps not only depicted boundary claims, but were used as propaganda and as semiofficial notice of claims. In some regions, especially in portions of Africa and Asia, the only evidence of conflicting claims lies in competing maps.

The boundary between the Republic of the Congo (Brazzaville) and Gabon is an example in which modern maps appear to be the only indication of a boundary problem. Maps at the same scale (1:1,000,000) and projection produced by the Institut géographique national (Paris) for Congo (1993) and for Gabon (1994) depict boundary alignments that differ in six places and encompass a combined area of some 3,570 square kilometers (fig. 88). The only official acknowledgment of a problem is a Gabonese foreign ministry online map that shows an uncertain alignment near Nyanga. Congolese cartographic products show no uncertainty, and no other indefinite sections are depicted elsewhere on


FIG. 87. *EKONOMICHESKAYA KARTA GRUZINSKOY SSR*. From volume 2 of the *Bol'shoy sovetskiy atlas mira* (1940), this economic map of the former Georgian Soviet Socialist Republic is an example of the sort of information leading to Soviet restriction of the atlas shortly after its publication. (See also fig. 941 for a thematic map from volume 1 of the atlas.)
Size of the original: 27 × 45.7 cm. Image courtesy of the Library of Congress, Geography and Map Division, Washington, D.C.

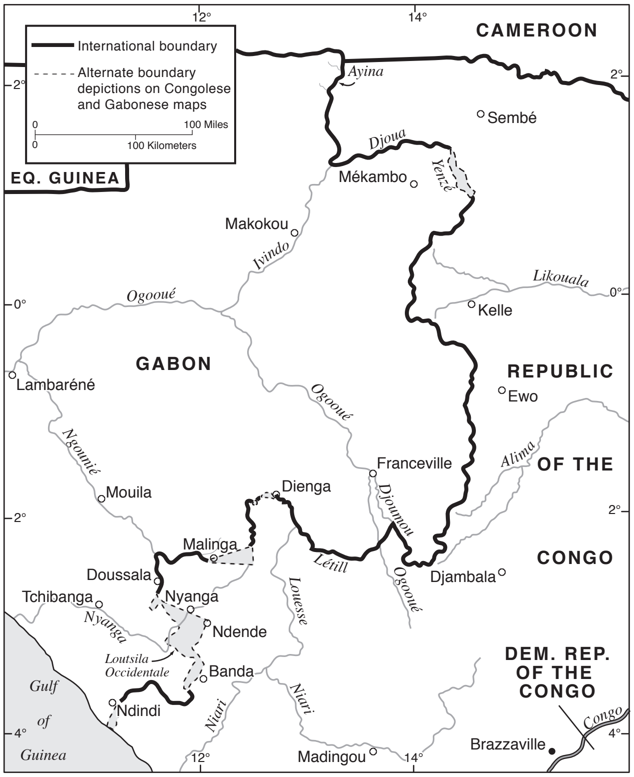


FIG. 88. SKETCH MAP OF REPUBLIC OF CONGO-GABON. Redrafted from original map prepared for Daniel J. Dzurek, International Boundary Consultants, for "Congo (Brazzaville)–Gabon International Boundary Report," 2004. Illustration of the differences in alignment between Congo, *Carte générale au 1:1 000 000* (France: Institut géographique national; Brazzaville: Centre de recherche géographique et de production cartographique, 1993), and Gabon, *Gabon: Carte touristique routière au 1:1 000 000* (France: Institut géographique national; Gabon: Institut national de cartographie, 1994).

Gabon's maps. There appear to be no public statements of differences by the respective countries, and scholarly literature seems to be silent about the problem. Indeed, Ian Brownlie (1979, 657) indicates that there is no significant alignment problem.

During the last century, the value of maps as evidence before international tribunals appears to have become more accepted, perhaps because of improvements in the accuracy and precision of cartography, especially with the use of remote sensing (Kirk 1962, 152; Adler 2001, 23). Toward the end of the twentieth century, geographic information system (GIS) technology has facilitated negotiations of boundary disputes with "fly through" remote travel technology.

Although few comprehensive references focus on the role of maps in the evolution of twentieth-century boundary disputes, there are several revealing studies of particular disputes as well as brief sections in works devoted more generally to international boundaries, as in J. R. V. Prescott (1978, 127–30). More common are boundary compendia that include citations to cartographic evidence for alignments and disputes, such as Brownlie's monumental work on African boundaries (1979) and the International Boundary Studies monographs by the Office of the Geographer in the U.S. Department of State.

Maps may incite or exacerbate disputes. Several disputes have resulted from conflicts between treaty maps and text. Especially during the colonial period, metropolitan powers defined boundaries along water divides and included treaty maps depicting the boundary along the highest mountain range, assumed to be the drainage divide. When the water-parting line was demonstrated to be located elsewhere, a dispute ensued (Khan 1996, 154–55, 172; Kirk 1962, 153–60; Prescott 1978, 107). Similar problems have resulted from the incorrect depiction of rivers (Weissberg 1963, 783; Akweenda 1989, 217–19).

During the nineteenth and early twentieth centuries, countries frequently based territorial claims on ethnic arguments. After World War II and the founding of the United Nations, wars of aggression were technically outlawed under article 2(4) of the UN Charter. The only acceptable justifications for conflict became self-defense, as provided under article 51, or when authorized by the UN Security Council. Even so, the UN Charter placed no time limits on self-defense. Therefore, countries now argue that territorial acquisition is justifiable retaliation for earlier aggression, even if the other country has controlled the territory for a long period. The overarching excuse for territorial expansion has become restitution—justification based on history. As Alexander B. Murphy (1990, 534) has observed, "Maps are a primary tool for this endeavor."

Murphy also noted that the production of detailed maps of an area by one of the claimants indicates familiarity and may suggest effective control of the territory, one basis for a sovereignty claim. Because restitution has become the primary justification for territorial conflict, the regions at risk and spatial extent of potential claims are restricted by historical parameters, especially as depicted on old maps, which also influence possible solutions (Murphy 1990).

As Prescott (1978, 129) wrote, "The phrase 'cartographic aggression' is now commonly used to describe the inclusion on a map by one state of territory which is under the control of a neighbouring state." Countries publish maps to influence domestic public opinion, especially in textbooks, and to persuade other governments. Todd Pierce described several examples of philatelic propaganda whereby countries use maps on postage stamps to buttress territorial claims (1996). Murphy

(1990, 534) lists maps on Ecuadorian postage stamps and a 250-page Guatemalan atlas as examples of propaganda cartography.

Maps provide information about the evolution of disputes. A recurring problem is reconciling treaty language to boundary maps (Khan 1996, 150–88). Prescott emphasized the need to examine maps of the appropriate period to determine what information was available to the negotiators. Some treaties refer to place-names and geographic features that change over time, such as a lakeshore or the course of a river. In these cases, it is necessary to examine maps of the period to locate the features that might have moved. For example, the 1825 Anglo-Russian Convention described the boundary between Alaska and British Canada as following the summits of mountains that were parallel to the coast and no more than 48 kilometers inland. No boundary can fulfill these requirements because the mountain summits lie farther from the coast. The problem resulted because the negotiators were using maps based on George Vancouver's 1792–94 explorations, which were published in a 1798 atlas. Vancouver described a mountain range along the entire Pacific coast, located 16–39 kilometers inland (Prescott 1978, 61, 129). A similar problem arises with the 1867 convention in which Russia ceded Alaska to the United States (discussed below).

Maps are used extensively in negotiations, although information about recent negotiations is often closely held. W. Kirk describes the function of maps in the Sino-Indian disputes, both in clarifying Chinese claims in the absence of clear official statements and in supporting negotiating positions. He discusses the relative importance of maps, both official and unofficial, and the interrelationship between maps and other types of evidence (Kirk 1962, 140–53).

The dispute between the United States and the former Soviet Union over their maritime boundary and its subsequent negotiated settlement is a good example of how maps can condition an international boundary dispute and figure in the parties' negotiations. The framework of the dispute was the 1867 cession of Alaska by imperial Russia to the United States. Under terms of the 1867 treaty, Russia ceded all of its North American territory and islands east of a line of allocation described in article 1 of the agreement. The boundary maritime dispute arose in 1977, when both the United States and Union of Soviet Socialist Republics (USSR) implemented 200–nautical mile exclusive fishery zones. Prior to making their fisheries claims, the countries exchanged diplomatic notes indicating that each side would observe the 1867 line as the limit of their fisheries claims. It soon became obvious that the two countries did not agree on the location of the longest of the line segments, which spans approximately 1,540 kilometers in the Bering Sea. The two countries interpreted the "straight lines" mentioned in the 1867 treaty—and not further defined—by using different map projections. The Soviets were using a straight line on a Mercator projection—a loxodrome, or rhumb line. By contrast, the Americans saw the boundary as a straight line on a conic projection—an approximation of a great circle, or orthodrome. The crescent-shaped difference between the two depictions was significant (approximately 71,580 sq km) and encompassed fishing grounds and prospective hydrocarbon resources. Beginning in November 1981, the United States and USSR held eleven rounds of negotiations (Antinori 1987; Smith 1994).

At the second session, held in Moscow during May 1983, both sides tabled maps that they claimed were used by Edouard de Stoeckl, imperial Russia's chargé d'affaires, and William Henry Seward, U.S. secretary of state, at their negotiations in Washington during March 1867. No map was attached to the treaty or specifically cited in the treaty text. However, the U.S. Coast Survey supported Seward's negotiations, and there is some documentation that a map was dispatched to Moscow for review with the treaty.

Ferdinand Rudolph Hassler, the first superintendent of the U.S. Coast Survey, invented the polyconic projection, and his organization continued to use that projection in slightly modified form until the 1950s. A first edition 1867 Coast Survey map on a polyconic projection and titled *North Western America Showing the Territory Ceded by Russia to the United States* accompanied the secretary of state's report to Congress, and a second edition of the same year was published with Charles Sumner's 1867 speech to the Senate by the Congressional Globe Office. In preparation for the 1983 negotiations in Moscow, the Office of the Geographer in the U.S. Department of State found an early impression of the 1867 Coast Survey map that was incomplete (fig. 89). However, it already showed the straight boundary line. From employment records found in the U.S. National Archives, the Americans were able to date the early impression as having been prepared during the 1867 negotiations. The United States tabled a full-size photocopy of this early impression at the negotiations in Moscow and claimed that Seward and Stoeckl had used it during their talks. Because the map was a polyconic, the straight boundary lines it depicted approximated orthodromes, supporting the American interpretation of the boundary. Nevertheless, the map had no annotations or signatures that would explicitly link it to the 1867 negotiations. (This author was a member of the American delegation to this Moscow session.)

The following day, the head of the USSR delegation tabled a map from their archives. It was a British Admiralty chart of the northern Pacific from the period


FIG. 89. *NORTH WESTERN AMERICA SHOWING THE TERRITORY CEDED BY RUSSIA TO THE UNITED STATES COMPILED AND PUBLISHED AT THE U.S. COAST SURVEY OFFICE*, 1867, 1:5,000,000. Map tabled by the United States during negotiations with the former Soviet Union in Moscow during May 1983. The Americans contended that this map had been used by the negotiators of the 1867 treaty ceding Alaska and that the straight line boundary depicted on the map supported the contention that the treaty line was an arc of a great circle or orthodrome, as opposed to the Soviet interpretation of the line as a straight line on a nautical chart (rhumb line or loxodrome).
Size of the original: ca. 55.4 × 91.4 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C.

with the 1867 boundary drawn in straight lines. The depiction supported the Soviet view that the original line of allocation was a loxodrome. This chart also had no annotations linking it to the 1867 negotiations; however, the Soviets refolded the chart along worn creases and produced a yellowed paper envelope into which they slipped the chart. Written on the envelope was a phrase to the effect that this was the treaty map. The writing might have been persuasive, if the translator for the American side did not point out that the form of Russian used in the envelope's annotation dated to a language reform enacted many decades after the treaty. Neither side was persuaded. Negotiations continued for seven more years, before the United States and USSR agreed on a new treaty, essentially splitting the difference, which was signed on 1 June 1990.

The literature on maps as evidence before international tribunals is more extensive than that on their role in negotiations. Although cartographic products, such as cadastral maps and surveys, are recognized as authoritative evidence in domestic litigation in many countries (Monmonier 1995, 105), that has not been the case in international law. Early twentieth-century international tribunals placed little evidentiary value on maps, as demonstrated in the 1920 *Jaworzina* case (Czechoslovakia-Poland), the 1928 *Palmas Island* case (Netherlands–United States), and the 1933 *Guatemala-Honduras Boundary Arbitration*. However, starting with *Minquiers and Ecrehos* case (France–United Kingdom) in 1953, tribunals began to accord cartographic evidence greater weight. Map accuracy improved due to aerial photography and, later, satellite imagery. In the 1959 *Case Concerning Sovereignty over Certain Frontier Land* (Belgium-Netherlands) the International Court of Justice found that maps prepared by the boundary commission, which showed that the disputed plots belonged to Belgium, had become part of the settlement and had the same legal force as the relevant 1843 boundary convention. The court went even further in the 1962 *Temple of Preah Vihear* case (Cambodia-Thailand), when it ruled that a map less closely tied to a treaty or boundary commission documented Thailand's acquiescence to Cambodian jurisdiction and overrode the treaty language specifying a boundary along the watershed line (Weissberg 1963; Rushworth 1999, 65; Adler 2001, 22; Akweenda 1989, 212, 221–23).

Maps figured prominently in the deliberations of the Eritrea-Ethiopia Boundary Commission. The parties entered 281 maps and a 150-page atlas as evidence. The commission's decision of 13 April 2002 devotes several sections to discussing maps and their legal significance. After noting that a map made part of a treaty shares the legal quality of the treaty, the commission summarized the legal effect of other maps. Its statement epitomizes the views of eminent international jurists at the end of the twentieth century:

> The effect of a map that is not part of a treaty will vary according to its provenance, its scale and cartographic quality, its consistency with other maps, the use made of it by the parties, the degree of publicity accorded to it and the extent to which, if at all, it was adopted or acquiesced in by the parties adversely affected by it, or the extent to which it is contrary to the interests of the party that produced it. A map that is known to have been used in negotiations may have a special importance. A map that emanates from third parties (albeit depending on the circumstances), or is on so small a scale that its import becomes a matter for speculation rather than precise observation, is unlikely to have great legal or evidentiary value. But a map produced by an official government agency of a party, on a scale sufficient to enable its portrayal of the disputed boundary area to be identifiable, which is generally available for purchase or examination, whether in the country of origin or elsewhere, and acted upon, or not reacted to, by the adversely affected party, can be expected to have significant legal consequences. Thus a State is not affected by maps produced by even the official agencies of a third State unless the map was one so clearly bearing upon its interests that, to the extent that it might be erroneous, it might reasonably have been expected that the State affected would have brought the error to the attention of the State which made the map and would have sought its rectification (Eritrea-Ethiopia Boundary Commission 2002, 26 [3.21]).

Because Eritrea and Ethiopia did not permit the boundary commission to demarcate the boundary with pillars, the commission resorted to a novel approach to complete its task. Based on image processing, terrain modeling, and high-resolution aerial photography, it issued a statement on 27 November 2006 that specified the grid and geographical coordinates of points for the eventual emplacement of boundary pillars. The commission also provided the parties with an overview map and forty-five maps illustrating these boundary points. In determining that this action "demarcated" the boundary, the commission referred to the United Nations' demarcation of the Iraq-Kuwait border in 1993 and the use of geographical coordinates to delimit maritime claims as specified by the 1982 United Nations Convention on the Law of the Sea (Eritrea-Ethiopia Boundary Commission 2006, 10–11). Although some scholars would contend that this is boundary delimitation and not demarcation (Blake 1995, 45–47; Prescott 1978, 68–72), the case demonstrates the technical evolution of cartography and its practical application to a difficult boundary dispute.

Developments in the Law of the Sea during the twentieth century placed a heavy emphasis on maps and nautical charts. The 1958 Geneva Convention on the Territorial Sea and Contiguous Zone and Convention on the Continental Shelf required coastal states to publish charts depicting low-water lines, straight baselines, and roadsteads or to use charts as reference for delimiting claims. The 1982 United Nations Convention on the Law of the Sea went further by referring to charts in eleven different articles, which span the many jurisdictional zones countries are permitted to claim. The 1982 convention repeatedly calls on coastal states to give due publicity to charts depicting these claims or to lists of geographical coordinates and to deposit copies of these charts or lists with the UN secretary-general. The emphasis on providing cartographic products as a component of making maritime claims under multilateral international treaties supports their enhanced stature under international law (Prescott and Schofield 2005, 293–99).

A contrary movement is seen in the function of maps or charts for documenting maritime boundaries (Prescott and Schofield 2005, 294). Whereas maps are critical documents in depicting land boundary settlements, charts covering the featureless sea are limited to the function of illustrating boundaries. Nearly all maritime boundaries are delimited with resort to tables of geographic coordinates with, one hopes, relevant information on the geographic reference system (datum).

The end of the twentieth century has witnessed the applications of digital mapping and terrain visualization known as fly-through technology to resolve boundary disputes. The earliest example of this application appears to be its use in negotiating the Dayton peace accords for Bosnia-Herzegovina, as described by Richard G. Johnson (1999). During the November 1995 proximity peace talks at Wright-Patterson Air Force Base near Dayton, Ohio, various components of the U.S. government, including the Defense Mapping Agency and the Army, and private contractors provided cartographic support to the negotiators (fig. 90). This support allowed a single cartographic base to be used in both digital and paper formats. Terrain could be inspected with the visualization system to see the way proposed boundary changes affected military vulnerability or intervisibility or buffer


Agreed Cease-Fire Line

Agreed Cease-Fire Zone of Separation

Inter-Entity Boundary Line

Inter-Entity Zone of Separation

# Proximity Peace Talks
# Representative Map

### 3rd Edition

**This map represents the demarcation of inter-entity boundaries and buffer zone, cease-fire line and zone of separation agreed by the Parties at Wright-Patterson AFB, Ohio on Nov 21, 1995, and corrected after digital map study at 1:50,000 scale on Nov 22, 1995. The authoritative maps are reproduced at scale 1:50,000 and distributed separately. NOTE: Brcko is pending arbitration, see 1:50,000 map sheet 2884-IV.**

0915 25 November 1995

zones. Changes in area were easily calculated. Once registered and digitized, proposed lines could be displayed with absolute consistency at any scale in all subsequent products. The time required to generate a fresh map overlay from a new proposed line was as little as eighteen minutes. More recent use of fly-through GIS technology in negotiations and arbitrations include U.S.-supported efforts for the 1998 Ecuador-Peru boundary treaty and the Eritrea-Ethiopia dispute. In addition, commercial firms adapted the technology for general use in other disputes. This new application of GIS seems to offer significant advantages in resolving boundary disputes.

As events of the twentieth century demonstrate, maps play a part during all the phases of boundary evolution. They may be the genesis of a boundary dispute, either causing the quarrel or contributing to it; they are commonly used by countries to assert or affirm their claims; and they are also critical in dispute resolution. With the legal justification for territorial conflict restricted to restitution, maps have become critical to documenting the historical extent of claimants. Cartographic products are used in negotiations or as evidence in arbitrations or adjudications. Finally, maps are essential products in depicting delimitations and are used for boundary management (Blake 1995, 49).

The twentieth century has witnessed an explosion of new boundaries and a marked increase in the quality of cartographic products that has enhanced their role in resolving boundary disputes. Technical developments have made cartographic products more accurate and surveying more precise. International tribunals place greater weight on maps, both as evidence and as vehicles for delivering their decisions in land boundary disputes. New GIS technology gives negotiators the luxury of exploring frontier terrain without actually traveling there. In so doing, it holds the promise of facilitating better boundary delimitation and more robust solutions to difficult international boundary disputes.

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SEE ALSO: Counter-Mapping; Electoral Map; Geopolitics and Cartography; Law of the Sea; Persuasive Cartography; Redlining

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## *Boundary Surveying.*



*Boundary Surveying in Canada and the United States.* Although there are five international boundaries

(*Facing page*)

FIG. 90. *PROXIMITY PEACE TALKS: REPRESENTATIVE MAP, 3rd EDITION*, NOVEMBER 1995, FROM THE DAYTON ACCORDS. Scale 1:600,000, U.S. Defense Mapping Agency. An example of the maps prepared during the Dayton negotiations, this overview map depicts the complexity of the resulting agreement, including the ethnic boundaries, buffer zones, and demilitarized areas.
Size of the original: ca. 76.6 × 57.6 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C.

in North America (United States–Mexico, United States–Canada, United States–Russia, Canada–France, Canada–Denmark [Greenland]), the focus of twentieth-century boundary surveying was on the first two of these. The surveying of the United States–Mexico boundary was almost complete by 1900, although contention over it led to the U.S. invasion of Mexico in 1915, making its cartographic delineation a challenge and priority for both governments. Another problem was the Treaty of 1884, designating the Rio Grande's deepest river channel as the international boundary. As the river shifted position intermittently on its floodplain, it cut through meanders to isolate bancos, pear-shaped pieces of land that were then on the other side of the preexisting boundary. The Banco Treaty of 1905 resolved the problem by decreeing that present and future bancos on the right bank would pass to Mexico and those on the left to the United States. By 1940 the status of 172 such bancos on the Rio Grande had been solidified. Beginning in the 1930s, projects to canalize and dam the Colorado River and the Rio Grande for flood control and hydroelectric power straightened the rivers and necessitated resurveying, as did exchanges of land between Mexico and the United States during the second half of the century (Utley 1996).

In 1920 the American ambassador to Britain described the Canada–United States border as "the unguarded boundary," reflecting its popular image as geographically stable and friendly (Davis 1922). However, serious issues with negotiating, surveying, and enforcing that boundary arose throughout the twentieth century, and some continue into the twenty-first.

The century opened with a conflict over the location of the Alaska–Canada border. Loosely delineated on maps dating from George Vancouver's eighteenth-century maritime surveys, Hudson's Bay Company cartographers, and officials of the Russian Empire, the boundary between Russia's Alaska colony and British North America was inherited by the United States with the Alaska purchase in 1867, but only became an urgent problem with the discovery of gold in the Yukon in the late nineteenth century (Penlington 1972, 34–38).

New general surveys of the entire Alaskan Panhandle were conducted under the supervision of the Alaska Boundary Tribunal in the late nineteenth and early twentieth centuries, and an agreement on the theoretical location of the international boundary was reached in 1903, which left Canada without access to the North Pacific coast and resentful of Britain's failure to consult the government of Canada when negotiating with the United States. The survey of the boundary itself was completed in 1920 under the auspices of a joint Canadian-American panhandle boundary commission.

The second challenge with this northern boundary was the rugged environment along the 141st meridian, which formed the 1,041 kilometer border from Mount Saint Elias to the Arctic Ocean (fig. 91). The survey conducted from 1906 to 1914 by the panhandle boundary commission cost three lives and required several innovations in field equipment, but it captured public imagination with vivid accounts and maps in the geographical journals of the time (Nesham 1927). It was among the first boundary surveys to use photographic technology to document boundary marker locations.

Another major North American boundary survey of the early twentieth century extended between Minnesota and Ontario from Lake Superior to Rainy River (Lass 1980). Although negotiated in nineteenth-century treaties, the actual boundary line had not been precisely surveyed because the unsuitability of the area for agricultural settlement made it a lower priority than the international boundary across the northern Great Plains. However, by the early 1900s large logging companies, having depleted the forest on the American side, wanted to cut the white-pine stands on Hunter Island (now part of Quetico Provincial Park, Ontario). Backed by Congressman Charles A. Towne of Duluth, Minnesota, strong public arguments revived in the United States to move the international boundary north of Hunter Island. After a long political battle, which also led to the creation of both the Boundary Waters Canoe Area and Quetico Provincial Park, the original 686-kilometer boundary was maintained, surveyed, and marked with 1,279 bronze posts from 1908 to 1926, followed by an official report published in 1931.

Meanwhile, the boundary through the northern Great Plains was resurveyed, replacing the original curved lines with straight lines between new boundary markers. The entire terrestrial Canada–United States boundary was formally accepted in 1925 in the first treaty directly negotiated by the government of Canada without British involvement (Classen 1965, 362–63). That treaty also created the International Boundary Commission, charged with maintaining the entire 8,893-kilometer boundary.

Challenges to the maritime portions of the United States–Canada boundary grew during the twentieth century, and several remained unresolved at century's end, especially in places like the Gulf of Maine, where the boundary impacts fishing and other economic pursuits (Marshall 2004) (fig. 92). Such challenges were exacerbated by global expansion of territorial waters after midcentury, as the traditional three-mile limit was increased first to twelve miles and then to a 200-mile Exclusive Economic Zone (Gray 1997).

One particular maritime-boundary challenge in the north concerns Canada's claim to the waters of the northern archipelago which, with the expansion of territorial waters, includes the Northwest Passage (McDorman

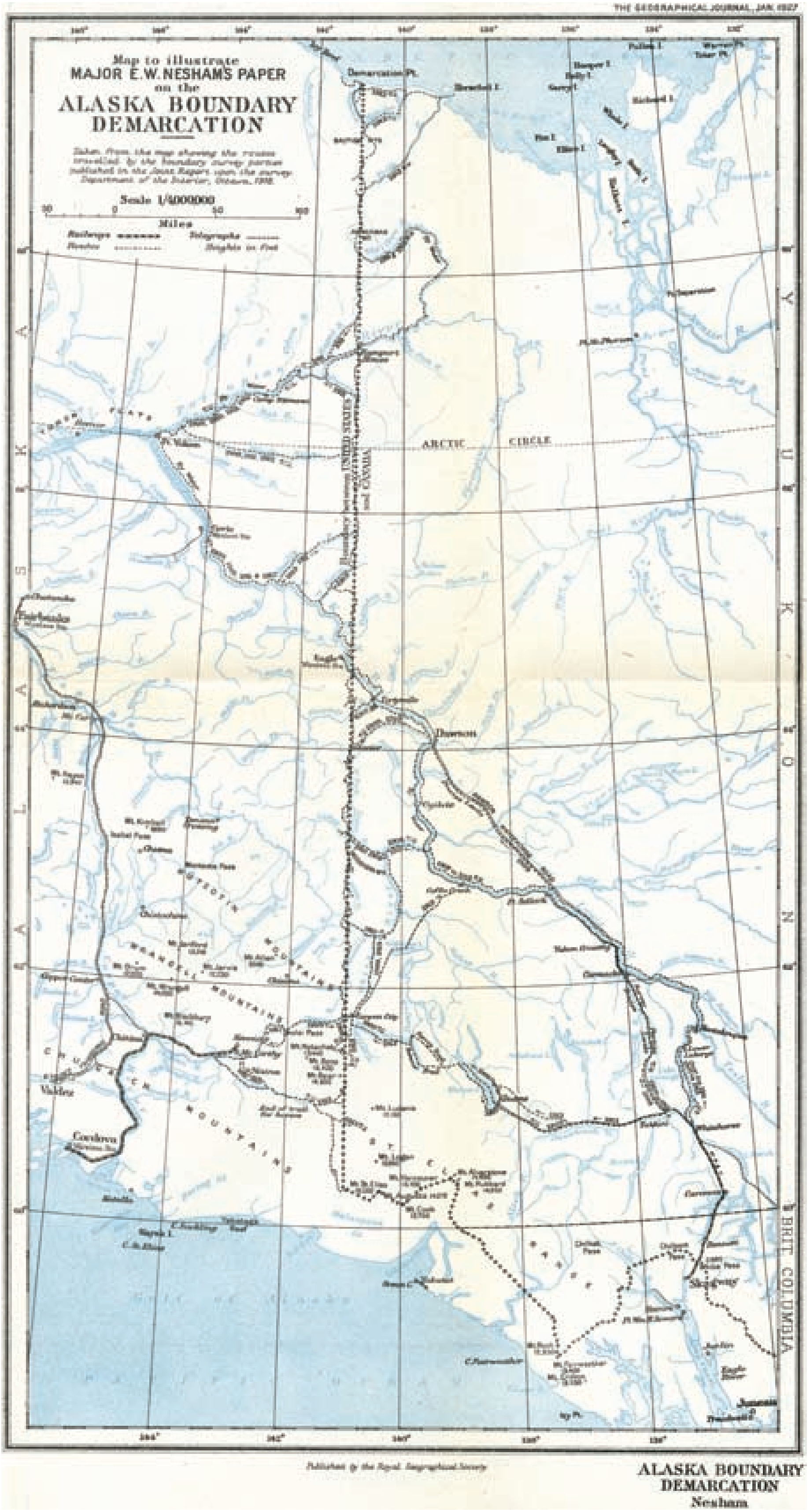


FIG. 91. *MAP TO ILLUSTRATE MAJOR E. W. NESHAM'S PAPER ON THE ALASKA BOUNDARY DEMARCATION.* The northwestern Canada–Alaska border was surveyed from 1906 to 1914 across mountains, muskeg, tundra, and arctic rivers by the panhandle boundary commission.
Size of the original: 34.6 × 18.7 cm.
From Nesham 1927, following 96.
Permission courtesy of John Wiley & Sons, Inc.

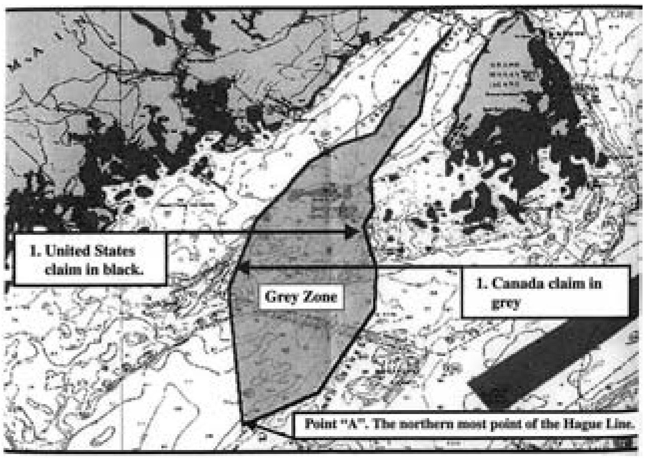


FIG. 92. THE GREY ZONE BETWEEN CANADA AND THE UNITED STATES. In the Grey Zone, boundary claims were still unresolved in 2004.
Size of the original: 9.8 × 13.9 cm. From Marshall 2004, 270 (fig. 2). Copyright © 2004, John Wiley & Sons, Inc.

1986). The United States has never accepted this claim, arguing that the passage is an international waterway. If climate change and the resulting arctic warming were to make the Northwest Passage a more attractive route for global shipping, the unresolved conflict might worsen. Rapid technical advances in the use of submarines and remote sensing revolutionized northern cartography in general and boundary surveying in particular throughout the Arctic.

Almost all the United States' significant internal political boundaries had been surveyed by the early twentieth century. By contrast, several Canadian provinces still did not even exist in 1900 (Kerr and Holdsworth 1990), and the surveying of new provincial boundaries continued into the late twentieth century, following the creation of the northern province of Nunavut. In addition, even the theoretical boundaries between Canada and various mostly northern First Nations remain subject to ongoing negotiation into the twenty-first century. While the early boundary surveys across North America used traditional methods of the nineteenth century, late twentieth-century national level boundary surveying increasingly made use of the latest digital and satellite technologies.

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SEE ALSO: Boundary Disputes; Indigenous Peoples and Western Cartography

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*Boundary Surveying in Latin America.* While most of Latin America had gained independence from Spain and Portugal during the nineteenth century, boundaries remained ambiguous, a frequently contentious legacy of colonial rule. Since the wars of independence, many territories established were the result of military conflict and relied on *uti possidetis* (the acceptance of former colonial administrative boundaries for the new independent states). Within that legal framework, old and new boundaries were drawn and redrawn during the twentieth century. Colonial boundaries had been notoriously vaguely defined, and the demarcation required many revisions of colonial documents and negotiations between parties. Frequently, the colonial record was not conclusive. Moreover, as it had happened from early colonial times, in controversial areas (for instance, unexplored territories) some boundaries were defined as straight lines. However, effective occupation, tensions between de facto control and de jure claims, and disagreements about the interpretation of previous treaties altered those straight lines and multiplied boundary conflicts in the region during the twentieth century.

This fluid situation was extremely complex: by the beginning of the century, there were "29 boundaries between Latin American republics, and 6 boundaries between a Latin American country on the one side and the United States, the Canal Zone, or a European colony on the other. There are two more boundaries between European colonies in the Guianas" (Boggs 1938, 409). Further difficulties arose through many so-called "triple points," the convergence of three countries and three boundaries. Geographer to the U.S. State Department Samuel Whittemore Boggs determined thirteen such instances in South America (1940, 81).

Some disputes were settled by direct negotiation between the parties. In those cases, regular procedure implied a treaty of limits and a joint delimitation commission to mark it on the spot. In 1938, Mexico and Guatemala, for example, cooperated in a joint border commission to repair broken monuments or place new ones, if necessary, to ensure the stability of the boundary line. This cooperation continued and was further consolidated in the formation of the Comisión Internacional de Límites y Aguas entre México y Guatemala in 1961, which finalized the riverine borders between the two countries. Other conflictive cases required arbitration; for example, Costa Rica and Panama submitted to arbitration several times to define the line running from the Cordilleras to the Atlantic (to France in 1900; to the United States in 1909 and 1914).

In South America, Argentina and Chile both prepared diplomatic documents accompanied by photographs and maps to support their territorial claims on the most southern part of the continent in the Andes Mountains. Argentina presented six volumes titled "Argentine Evidence" (1091 pages with 71 maps, 182 photos, 175 folded panoramic photos, 12 gravures, and 15 grids) including the *Preliminary Map of the South-Western Region of the Argentine Republic Showing the Different Points from which Photographs, Reproduced in the "Argentine Evidence," Have Been Taken*, which was drawn on stone and lithographed by W. & A. K. Johnston, Limited, Edinburgh and London, in 1901. Chile made its own map in 1901 (also published by Johnston): *Demarcación de límites entre Chile i la República Arjentina*, surveyed between 1894 and 1900 at a scale of 1:100,000 but reduced for publication purposes. Both cases reveal the huge efforts in topographical mapping at a very detailed scale to resolve boundary disagreements (fig. 93).

Sooner or later, it was expected that most of the borders described in these new agreements would be demarcated on the terrain. And very often that has been a matter of discord and sometimes a reason and motivation for new surveys and maps.

The American Geographical Society's (AGS) Hispanic America map project, begun in 1920 and concluded in 1945, became the most important private initiative to complete mapping the entire Latin American territory during the twentieth century (fig. 94). A compilation work, it relied on over 8,000 cartographic sources, each sheet taking more than 1.5 years to compile. Since each sheet included a graphic showing "relative reliability" (where, although varying from sheet to sheet, it distinguished among some of the following categories: "coast surveys," "triangulation with precise topographical survey," "adjusted from compiled maps," "approximate traverses and compass sketches," and "reconnaissance air surveys"; see fig. 993), it is possible to discern that the most reliable information corresponded to major rivers, national borders, and areas of agricultural settlement. However, there were variations and contradictions among the sources. The AGS also undertook survey work directly, such as in Peru's Cerro de Pasco region in 1927–28. Led by O. M. Miller, the expedition carried out geodetic triangulation to draw up more accurate maps, as well as provide detailed accounts of topographical, climatological, meteorological, and geological features (Miller 1929). The expedition frequently used triangulation stations placed by mining companies in the region. To deal with the difficult and uneven terrain, a plane table, with paper on special aluminum sheets, was mounted on a tripod. The heaviest piece of equipment was the theodolite and its tripod, but the total weight of the survey equipment was kept under 150 pounds (Miller 1929, 36–37).

Three geographers led the Hispanic America map project: from 1920 to 1923, Alan G. Ogilvie was in charge; from 1923 to 1938, Raye R. Platt, who initially joined the AGS as a cartographer; and Charles B. Hitchcock, who saw it through to its completion from 1938 to 1945 (Pearson and Heffernan 2009, 219). Platt reported on progress and challenges of the project, surveying expeditions in Latin America, and the state of cartography on the continent in the *Geographical Review* (1924, 1927, 1930, 1931, 1933, 1943).

The Inter-American Geodetic Survey (IAGS), founded in 1946, also contributed to the determination of borders in the region, even though its main objectives lay elsewhere. One significant contribution in this particular realm was its participation in the 1962 negotiations concerning the definitive border between Honduras and Nicaragua. IAGS also provided training for surveyors, which was crucial to improving national mapping capabilities (Wood 1974). In Ecuador, for example, IAGS's introduction of aerial photogrammetry consolidated the Servicio Geográfico Militar into an independent organization, the Instituto Geográfico Militar, which provided more advanced training for its graduates. Ironically, IAGS's topographic survey of the Cenepa River and its extension ran counter to the results of previous surveys and particularly the results of the agreement of the Protocol of Peace, Friendship, and Boundaries (better known as the Rio Protocol) in 1942, thus sowing the seeds for further boundary controversy (Capello 2010, 103).

The United Nations (UN), beginning in 1976 in Panama, has held regional cartographic conferences focused on surveying and the transfer of mapping technologies and techniques every four years. Since 1985 they have been held at the UN headquarters in New York. Mainly, these meetings allowed national mapping agencies and other governmental organizations that employed mapping techniques to present their projects in progress, many of them in Latin America, and discuss their mapping activities, training, and education and the latest technological advancements in surveying and mapping. They also established three committees to coordinate the transfer of technological advances, with much of the focus on geographic information science in the last two

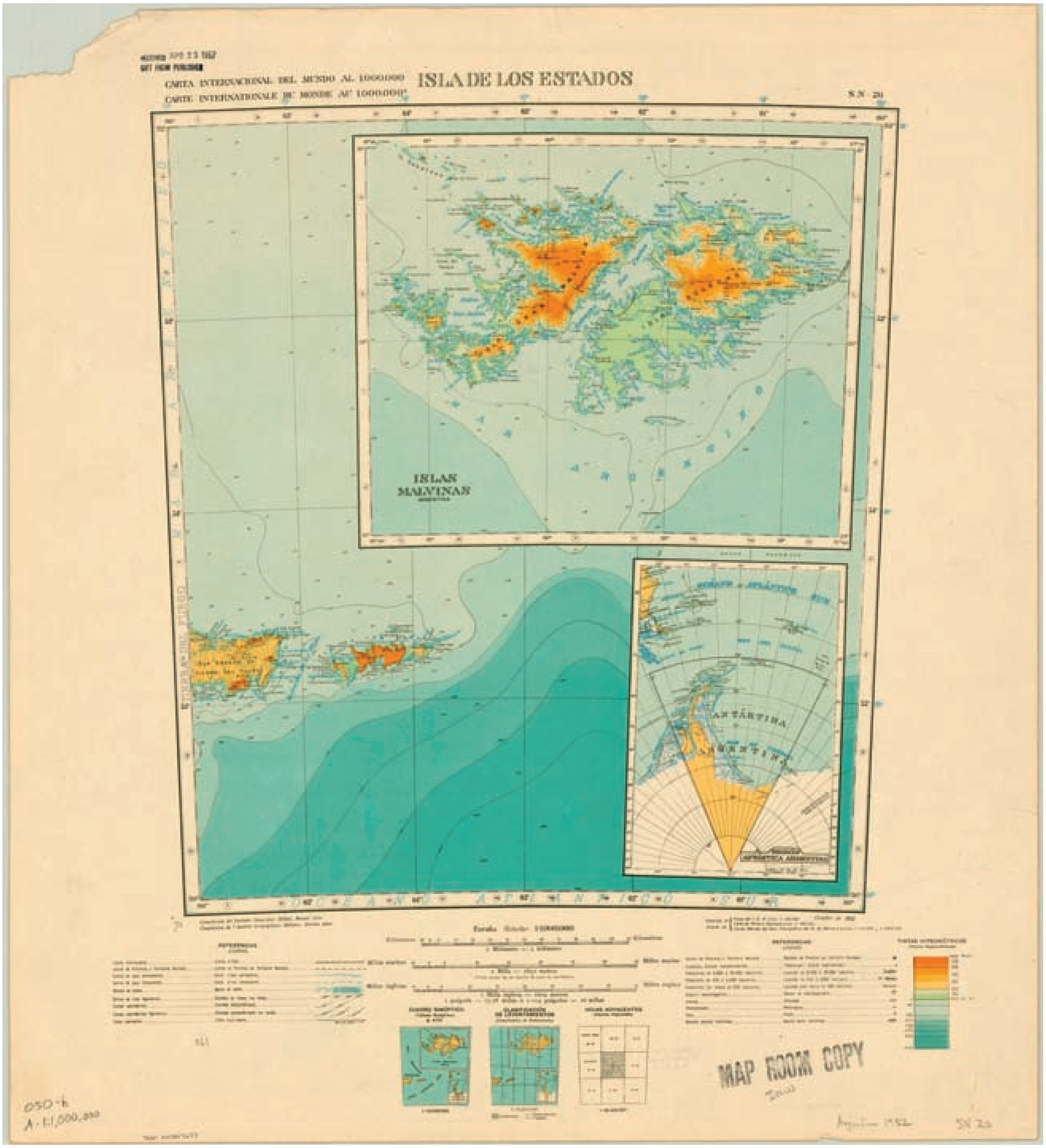


FIG. 93. *ISLA DE LOS ESTADOS*, 1952. Sheet 20 of the International Map of the World, produced by Argentine Instituto Geográfico Militar. Size of the original: ca. 61.1 × 49.9 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries. Permission courtesy of the National Geographic Institute, Buenos Aires, Argentine Republic.

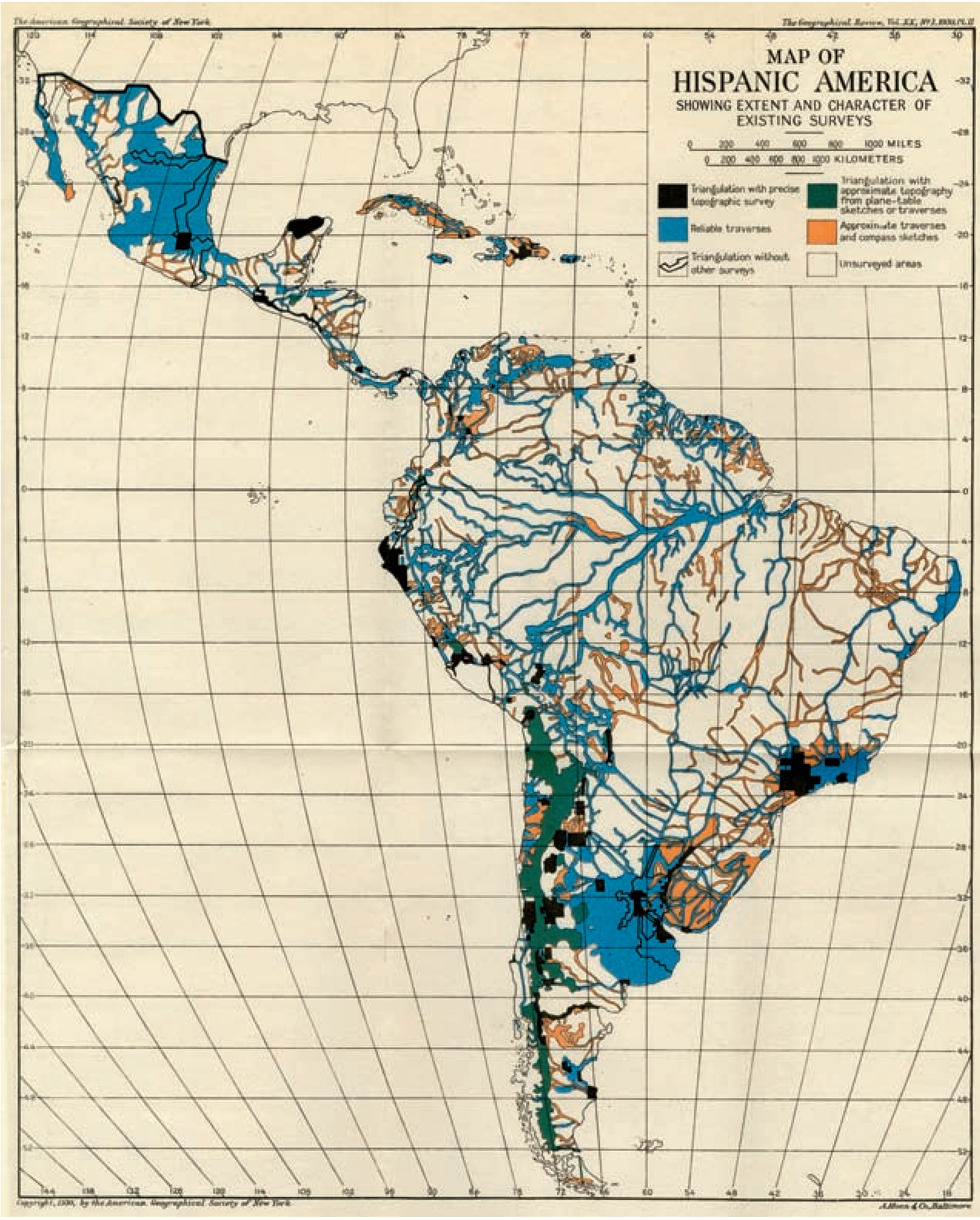


FIG. 94. *MAP OF HISPANIC AMERICA SHOWING EXTENT AND CHARACTER OF EXISTING SURVEYS*, 1930.

Size of the original: 34.4 × 27.7 cm. From Raye R. Platt, "Surveys in Hispanic America: Notes on a New Map Showing the Extent and Character of Surveys in Hispanic America." *Geographical Review* 20 (1930): 138–42, pl. II (facing 142). Permission courtesy of the American Geographical Society, New York.

decades of the century. One early regional project, financed by the Dutch government, was the Centro Interamericano de Fotointerpretación (CIAF), established in Bogotá, Colombia, in 1967. The project provided training in photo interpretation and other remote sensing techniques for professionals from the region. Over time, CIAF also was involved in various consulting projects, including a program to map Colombia's Amazon region (UN 1984, 448–52).

With the establishment in 1993 of SIRGAS (Sistema de Referencia Geocéntrico para Las Américas), a singular geodetic system for Latin America, subsequent UN meetings stressed the importance of the steady and sustained development of this project. By 1997, the geodetic network had become highly accurate and reliable, and a definition of the geodetic reference system for the region had been agreed upon. A vertical regional reference system was achieved in February 2001 (UN 2001, 6–7).

Another development in boundary surveying was the emergence of various national boundary commissions in different parts of Latin America throughout the century. The first objective of the boundary commissions was to complete fieldwork in areas that had not yet been surveyed. Commissions typically consisted of a commissioner in charge, an engineer, and a surveyor. Commissions worked with their counterparts in joint commissions to carry out surveys. Once a treaty or protocol was signed, the governments appointed the commission officials. One example is the Brazilian-Argentine border commission, which jointly demarcated the countries' boundaries from 1900 to 1904. The efforts of the joint Brazilian-Argentine commission resulted in a conclusive act, signed in October 1910 at Rio de Janeiro. The first steps for the commission were to decide during which season to carry out the survey, in what order to proceed, and what margin of surveying error could be tolerated (*La Frontera* 1910, 2:173). If necessary, the foreign ministries of both countries could authorize further auxiliary commissions to assist the principal commission in surveying any contentious border areas, and accompany the main commission into the area (*La Frontera* 1910, 2:177). The committees were also tasked with placing landmarks and corner markers for future surveys, drawing illustrative plans of the terrain they covered, and establishing the geographic determination of the main points. Generally, these expeditions also included a naturalist, who recorded the natural phenomena in the newly surveyed area and collected data for statistical surveys. There was also a repairman on hand who was in charge of looking after the surveying instruments, such as the theodolite, plane table, and chronometer, crucial in ensuring the equipment would not fail in frequently treacherous terrain. All the equipment was kept in wooden boxes that were heavily padded for protection. Transport was inherently difficult, as the commissions typically had to rely on mules and canoes. Apart from the technical-scientific staff, military personnel were also members of the expedition and were paid overtime for their services. In addition, for less technical tasks there were several laborers, a secretary and clerk who facilitated communication between the subcommittees and the governments, a doctor, a pharmacist, and numerous technical aides.

The United States and Mexico established the International Boundary Commission in 1889 with an agency on each side of the border, one based in El Paso, Texas, and the other in Ciudad Juárez in Chihuahua. In 1944, the commission's responsibility and name was broadened to International Boundary and Water Commission and addressed how waters from the Colorado, Tijuana, and Rio Grande rivers should be distributed between the two countries. In the early twentieth century, the commissions also set about replacing broken boundary markers, which proved difficult given the harsh desert conditions of most of the boundary. The Chamizal Convention of 1963 finally resolved this boundary dispute that dated to the nineteenth century (fig. 95).

Brazil and Venezuela formed the Comisión Mixta Venezolana-brasileña, Demarcadora de Límites in 1929. It reinstated its efforts in 1994, at its fourth preparatory meeting to resume fieldwork. Even though Brazil had placed 2,682 milestones along the border, there were still gaps in the demarcation of the boundary in the late twentieth century (Briceño Monzón 2007, 89–90).

Not infrequently, the United States was in charge of demarcation commissions, such as in the case of Guatemala and Honduras in 1933 and thus acted as a de facto arbiter (see table 6 for a summary of border disputes in Central America during the twentieth century). Other arbiters have been the Organization of American States


FIG. 95. THE CHAMIZAL SETTLEMENT, 1963, AND THE DIVISION OF TERRITORIES ALONG THE RIO GRANDE.

Size of the original: 10.7 × 19 cm. From J. J. Bowden, *The Ponce de Leon Land Grant* (El Paso: Texas Western Press, 1969), 40. Permission courtesy of Texas Western Press, University of Texas at El Paso.

Table 6. Boundary disputes in Central America during the twentieth century

| Countries | Year(s) started | Boundary characteristics | Dispute | Treaties/resolution |
|---|---|---|---|---|
| Belize–Guatemala | 1946 | 266 km | Independence movement in 1963 | Independence in 1981, resolved in 2001 |
| Colombia–Honduras–Jamaica–Nicaragua–United States | 1869, 1879, 1986 | 280 km southwest of Jamaica (Serranilla Bank) and Bajo Nuevo Bank 110 km east of Serranilla Bank | Bajo Nuevo Bank; Serranilla Bank | 1972, 1986, 1999 |
| Colombia–Nicaragua | 1881 | Maritime boundary 775 km northwest of Colombia, 220 km off the coast of Nicaragua | Archipelago of San Andrés, Providencia, Santa Catalina | 1903, 1928 |
| Costa Rica–Nicaragua | 1981 | 309 km land, 129 km riverine | Las Crucitas 1985<br>San Juan River 1997, 1998 | Resolved in 1985<br>Ongoing |
| Costa Rica–Panama | 1879 | 639 km | Punta Burica–Central Cordillera<br>Open conflict 1921 | 1910, resolved in 1941 |
| El Salvador–Honduras | 1910 | 342 km | Soccer War over Gulf of Fonseca 1969 | Resolved in 1999 |
| El Salvador–Honduras–Nicaragua | 1854, 1913, 1981 | 342 km, 922 km | Gulf of Fonseca, fishing rights; maritime rights and access | Ongoing |
| Guatemala–Honduras | 1845, 1986 | 256 km, land and water divides | 1928 Cerro Brujo–Cerro Obscuro line, 1999 | 1895, 1914, 1933, unclear status |
| Honduras–Nicaragua | 1912, 1986, 1999 | 922 km | 1957 Coco-Segovia river boundary line<br>1986 maritime boundary, disputed between 15° and 17° parallel | 1931, 1937, resolved in 1963, however, maritime dispute ongoing |

Sources:
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(OAS) and the International Court of Justice (ICJ) in The Hague.

There have been several persistent boundary disputes in Latin America. One of the longest boundary conflicts in South America during the twentieth century occurred between Peru and Ecuador. One of the territories in dispute, Maynas, involved more than 100,000 square miles of treacherous terrain surrounding the tributaries of the Amazon River. Various wars, invasions, arbitrations, and diplomatic efforts took place before both governments signed the Protocol of Peace, Friendship and Boundaries in 1942, the Rio Protocol (with the guarantee of Argentina, Brazil, Chile, and the United States). In this case, the demarcation survey reopened the dispute: the new treaty was based on geographical features such as watersheds, which can be very ambiguous and impossible to apply (for instance, the disputed area included two different watershed lines). With the intention of clarifying the correspondence between the treaty and the real geography, both countries agreed to the request for a photogrammetric map complied by the U.S. Air Force. The involvement of foreign powers in the dispute helped to dispel armed conflict in the early 1980s. Nevertheless, Peru and Ecuador did briefly go to war over

Table 7. Boundary disputes in South America during the twentieth century

| Countries | Year(s) started | Boundary characteristics | Dispute | Treaties/resolution |
|---|---|---|---|---|
| Argentina–Chile | 1881 | 5,308 km | Andean Southern Ice Field | 1902 treaty, 1991, 1998, 50 km of boundary still not defined, joint boundary commission 2001 |
| Argentina–United Kingdom | 1833, 1908 | Falkland Island 12,173 $km^2$, South Georgia, 3,903 $km^2$, South Sandwich Islands 310 $km^2$ | Falkland Islands, South Georgia, South Sandwich Islands | 1982, 1995 |
| Bolivia–Brazil | 1867, 1958 | 3,423 km with Brazil | Isla Suárez/Ilha de Guajará-Mirim in the Río Mamoré which marks the border | 1968 |
| Bolivia–Chile | 1879 | 860 km | War of the Pacific; access to the Pacific | Ongoing, Bolivia still seeks access to the sea |
| Bolivia–Paraguay | 1932–35 | 750 km | Chaco War | 1938 |
| Brazil–Paraguay | 1872, 1960, 1966 | 1,365 km | Guaira/Itaipu | 1966, 1973 |
| Brazil–Uruguay | 1852 | 985 km | Brasilera Island | 1909, 1913, 1933, dispute ongoing |
| British Guyana–Suriname | 1936 | 600 km | Territorial sea boundary and Upper Corantyne River | 1989, 2004 |
| Chile–Peru | 1884 | 171 km | Latitudinal maritime boundary | 1952, 1954, ongoing |
| Colombia–Venezuela | 1881 | 2,050 km, 1,760 km in the Caribbean Sea | Los Monjes Archipelago; Guajira Peninsula | 1941; Colombia has rescinded the islands, but still claims maritime access |
| Dominica–Venezuela | 1895 | Maritime boundary | Bird Island | Maritime boundary dispute ongoing |
| Ecuador–Peru | 1939–41, 1995 | 1,420 km | Location of boundary between the countries, dating back to independence | 1999 |
| French Guyana–Suriname | 1861, 1911 | 510 km | Marouini River and Itany River | 1891 partial settlement, ongoing |
| Guyana–Venezuela | 1841,1981, 2000 | 743 km | Ankoko Island and Essequibo River | Ongoing |

Sources:
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their disputed border territories in 1995 (see table 7 for a summary of border disputes in South America during the twentieth century).

While many boundary surveys were conducted in Latin and Central America throughout the twentieth century, boundary disputes persisted, though technological advances and particularly assistance from the United States improved the quality of the continent's boundary surveys. Even so, the difficult terrain, frequent political instability, resistance to surveying from indigenous populations, and financial and technical constraints on the nations of South and Central America periodically impeded progress in boundary surveying during the twentieth century.

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SEE ALSO: Boundary Disputes; Holdich, Thomas Hungerford; Law of the Sea; Photogrammetric Mapping: Geodesy and Photogrammetric Mapping; Property Mapping: Property Mapping in Latin America

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*Boundary Surveying in Africa*. Boundary surveying was introduced into Africa by colonial powers that divided the continent into "spheres of influence" and "possessions" in the late nineteenth century. Because they wanted to avoid unnecessary conflict as the interior was opened up, many agreements were reached that depended on very general descriptions of the boundaries involved. This initial "scramble for Africa" occurred at a time when the topography was little understood, especially in the hinterland far from the coast. Travel into the interior was difficult and slow, and boundaries tended to be in the least accessible areas. Treaties between colonial powers were couched in general terms and related to a few known settlements or natural features. The 1898 convention between Great Britain and France divided West Africa in a characteristically arbitrary and crude manner: "The frontier shall follow this median line [of the Dallul Mauri] until it meets the circumference of a circle drawn from the centre of the town of Sokoto with a radius of 100 miles (160.932 metres). From this point it shall follow the northern arc of this circle as far as its second intersection with the 14th parallel of north latitude. From this second point of intersection it shall follow this parallel eastward for a distance of 70 miles (112.652 metres); then proceed due south until it reaches the parallel of 13°20′ north latitude, then eastward along this parallel for a distance of 250 miles (402.230 metres) . . ." (Brownlie 1979, 620).

However, in most cases, it was realized that this coarse level of precision was unsatisfactory, and that a proper survey was necessary to achieve a more sensible division that accorded with conditions on the ground as well as with the actual topography. At the start of the twentieth century, much work had already been done and more was in progress, as described by Ian Brownlie (1979) in his comprehensive general history of African boundaries.

A reading of the treaties and instructions for demarcation suggests that the colonial powers did not consider it necessary to define boundaries with great precision. These were agreements between friendly powers, and a pragmatic approach to such matters was the norm, as exemplified by the boundary delineated in 1927 between the Belgian Congo and Northern Rhodesia: "The present position of the boundary pillars shall be accepted where they lie not further than 200 metres from the ideal watershed. In exceptional circumstances, and in areas of no particular known economic value, errors of position up to 500 metres may be allowed" (Brownlie 1979, 709).

These early treaties gave the demarcation teams the power to vary the delimitation line within set limits to take account of local needs, as in the Congo-Uganda Agreement of 1910: "In demarcating this section of the frontier the commissioners appointed for the purpose may deviate from the straight line up to a distance of 3 kilom. on either side in order to make use of natural features where it is of advantage to do so, but it is to be understood that the total area of British or Belgian territory is not to be affected" (Brownlie 1979, 696).

The primary role of boundary survey in the twentieth century was to provide a base map of the country through which the boundary passed so that a more detailed description of a more suitable boundary line could be chosen and described in sufficiently accurate detail for the subsequent treaty. When the surveyors had authority to proceed with demarcating the boundary, they would also build the pillars and mark the chosen line and pillar positions on the map. A survey was rarely if ever carried out prior to delimitation and was often omitted for internal boundaries between adjacent territories of the same colonial power. The definition of administrative divisions within a colonial empire relied almost entirely on written descriptions set out in administrative orders. These descriptions were rarely supported by boundary marks or maps of any form, which sometimes led to confusion when, upon or after independence, the boundaries became international.

In the first phase of establishing spheres of influence in Africa, the only maps available were travelers' sketch maps showing major rivers, mountains, and traveling routes, and these were often used to support treaties. The delimitation of the frontier between Eritrea (then an Italian colony) and Ethiopia in 1900 is a classic example. A traveler's map was the sole (and unsatisfactory) evidence of the location of the two confluences that defined the straight-line section of the boundary. The lack of any subsequent survey and demarcation of this border can be claimed to have resulted in the 1999 war between Eritrea and Ethiopia and the subsequent unhappy history of adjudication and demarcation that followed.

Boundary surveying in Africa was completed, for the most part, in the first thirty years of the twentieth century and reflected the techniques of the period, normally triangulation and plane tabling. The degree of accuracy achieved was a reflection of these techniques as well as the resources available for what could be a very daunting task, carried out in remote country, and involving long foot safaris. Because the colonial powers were not willing to pay for more expensive work, much use was made of natural features such as watersheds and rivers. Beacons were widely spaced on prominent hilltops, at river junctions, or where well-used tracks crossed the boundary. As was remarked at that time, "the question then to be answered is, not what is the best possible frontier line to select, but what is the best line that can be surveyed and laid out within a stated period of time and with a definite limit of cost?" (Hills 1906, 146).

Boundary maps were often confined to a strip extending up to five kilometers each side of the border, and the surveyors had to work hard. The work involved is well described by the surveyor attached to the Anglo Portuguese Boundary Commission appointed to demarcate between 1899 and 1901 the boundary between what eventually became Malawi and Mozambique (Binnie 1900, 60):

> The triangulation was not carried out with that degree of accuracy which I should have liked, owing to my being alone, and also (chiefly) to the necessity of getting on with the work of delimitation as rapidly as possible, since the stretch of boundary to be traversed was very great. For instance, on making observations to hill peaks on the probable line of boundary, I had to take the highest point of the peak without having first sent laborers to clear a space on top and to erect a beacon. I should then, under ordinary circumstances, have sent a linesman with heliotropes, and taken angles to rays of light as shown by them at the beacon. All these things I had of necessity to do without, time being so precious. Still, I managed to keep within my limit of error (100 feet), and only once was I compelled to go back to a hill to take fresh observations.
>
> Camp was broken up at daybreak, and having received from the Commissioner of the British section the previous evening the name of the next camping ground, I sent off my loads under the charge of a native capitao (Headman) to the arranged point. I then marched to a hill to which I had taken observations the previous day, surveying my course as I went along, climbed this hill, and took observations to hills on the probable line of the next day's march.
>
> After taking these observations, I had breakfast, and before descending the hill I would calculate the positions, and then fix and plot on my plane table as many intersected hill peaks as would be useful to me on that day's march.
>
> Then descending the hill, I would go on surveying towards the camp, using these peaks to orientate my plane table every mile or so. I did not go straight to camp, but went in a zig zag direction in order to get as much country surveyed as possible.
>
> On reaching camp I would start computing again in order to get more peaks fixed for the next day's march.
>
> Every second or third night I would observe stars for latitude, and this was always a check on my work.

Not every boundary commission was quite so short of manpower. Most British parties were made up of military surveyors from the Royal Engineers. One such example was the Anglo-German boundary demarcation between Cameroon and Nigeria in 1912–13. A narrow chain of triangulation was run from Yola to the Cross River (a distance of 350 miles) to provide a framework for the mapping, which was carried out by plane tabling and published at a scale of 1:125,000 (figs. 96 and 97). To the south of the Cross River, Captain Charles Frederick Close, R.E. (who, in later years, became director general of the Ordnance Survey and was a huge influence on the development of surveying and mapping in the United Kingdom), produced a remarkably detailed

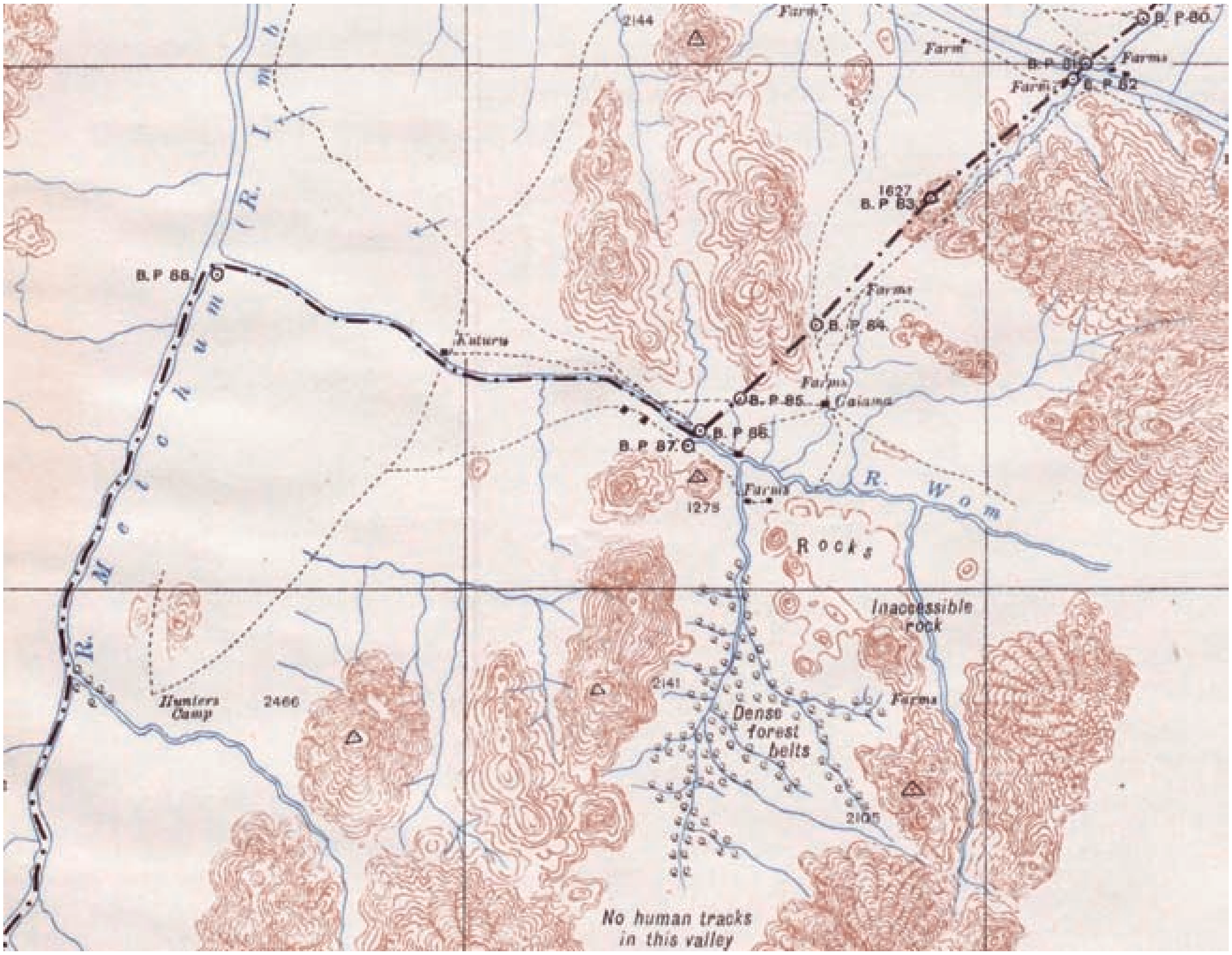


fig. 96. DETAIL FROM THE *DEMARCATION OF THE NIGERIA CAMEROON BOUNDARY: YOLA–CROSS RIVER*, 1912–13, 1:125,000 (SHEET 6). Signed by W. V. Nugent, Royal Engineer and chief commissioner. Printed by the Ordnance Survey Office, Southampton. Size of the entire original: ca. 44.6 × 77.2 cm; size of detail: ca. 13.4 × 17.3 cm. Image courtesy of The National Archives of the U.K. (TNA), Kew.

map of the part of the boundary that ran through dense rainforest to the sea.

By contrast, the boundary between the British and French Cameroons, which replaced a large section of this boundary after World War I, was delimited by administrative officers from both sides in 1919 and 1931 using a 1:300,000 map of the area produced in 1908 by a German cartographer named Moisel. This map was a masterful effort of its time but contained discrepancies, one of which was even knowingly used as part of the boundary description in article 25 of the 1931 declaration: "Thence running due south between Mukta (British) and Muti (French) the incorrect line of the watershed shown by Moisel on his map being adhered to" (Brownlie 1979, 572).

Further inconsistencies along what would become the Cameroon-Nigeria boundary were introduced by the preference of the administrators to drive along a road at the foot of the escarpment, along the top of which the boundary was to run, without at any stage going up to look at the ground. Although there was an intention to proceed to demarcation, both colonial governments complained of a lack of funds, and it was never carried out. This omission eventually led to an expensive arbitration at the International Court of Justice in 2002.

Many parts of Africa were not favorable for triangulation. In flat and forested terrain, it was sometimes necessary to resort to astronomical observations to obtain the positions of boundary pillars. One such case is the Ghana-Togo boundary, demarcated between 1927 and 1929 under the auspices of the League of Nations. The length of the boundary is 997 kilometers and the com-

FIG. 97. BOUNDARY BEACON ON THE NIGERIA-CAMEROON BOUNDARY. Built during the Anglo-German Demarcation of 1912–13 and recovered in 1999. Note the masonry pillar to the left of the pole and the finger post on the pole indicating the boundary direction to the northeast from the beacon.
Image courtesy of Alastair Macdonald.

missioners built 149 pillars. Astronomical observations were taken at twenty-four stations at intervals along the length. The boundary record consisted of a detailed verbal description of the route of the boundary and the locations of pillars and a series of fourteen maps for a strip extending four kilometers from each side of the boundary. However, loss of the pillars over time and the difficulty of replacing them from the recorded information led to a redemarcation, begun in 1970.

In the case of Ghana's northern border with what is now Burkina Faso, the original 1904 demarcation consisted mostly of blazed trees, which were marked "with the letters F and E with a chisel and tar" (Brownlie 1979, 291). No observations for position were made, and a redemarcation might have taken place during the 1970s.

After World War II, aerial photography brought a more complete understanding of the topography and the potential for a more detailed and precise definition of borders. The long-disputed boundary between Kenya and Ethiopia was settled with the use of medium-scale mapping produced during the war. In many cases, newly independent territories were eager to remove inconsistencies inherited from the colonial period and carried out redemarcations based on modern and complete mapping. They took their national interests more seriously than the colonialists, as one would expect, and wanted more precisely defined boundaries together with the ability to replace destroyed beacons in the original position without dispute. Elsewhere in the world, boundaries were being marked by inter-visible beacons so that local people knew exactly where the boundary lay. With the arrival of the Global Positioning System (GPS) and satellite imagery, these expectations could be met relatively easily, though at considerable expense. The United Nations–led demarcation between Nigeria and Cameroon, initiated in 2004, used high-quality satellite imagery based on a GPS network of control points and a spacing of 250 meters between pillars. In the arbitration of the Ethiopia-Eritrea conflict, the commission had access to 1:25,000 color orthophotomaps of superb quality.

There is no doubt that lack of effort at the time of the original delimitation and the reluctance of colonial powers to demarcate the borders of their possessions prior to granting independence led to expensive and time-consuming litigation in the later years of the twentieth century and into the twenty-first. This has occurred in spite of a 1964 declaration by the Organization of African Unity that "all Member States pledge themselves to respect the borders existing on their achievement of national independence" (Brownlie 1979, 11)—the principle referred to by lawyers as *uti possidetis juris*. With hindsight, it does seem negligent to have granted independence without giving the new nations "title deeds" to their territory at the same time.

As time passed after the original delimitation (and even demarcation), a desire for greater clarity and the removal of anomalies led to a process of redemarcation of some borders. The watershed boundary between Nyasaland (now Malawi) and Mozambique became problematic because Malawi needed the watershed as the most economical road route between its major cities of Blantyre and Lilongwe. A more detailed demarcation carried out in 1956 produced large-scale maps showing where the boundary passed each Mozambican store on the side of the Malawi road (fig. 98).

Meandering boundary rivers are a constant source of trouble in the tropics because large changes of course can occur during a single rainy season. Oxbows are cut off and the sovereignty of significant areas of fertile land is transferred. In 1975, a new straight-line boundary along the course of the Songwe River—the boundary between Tanzania and Malawi—was surveyed with the

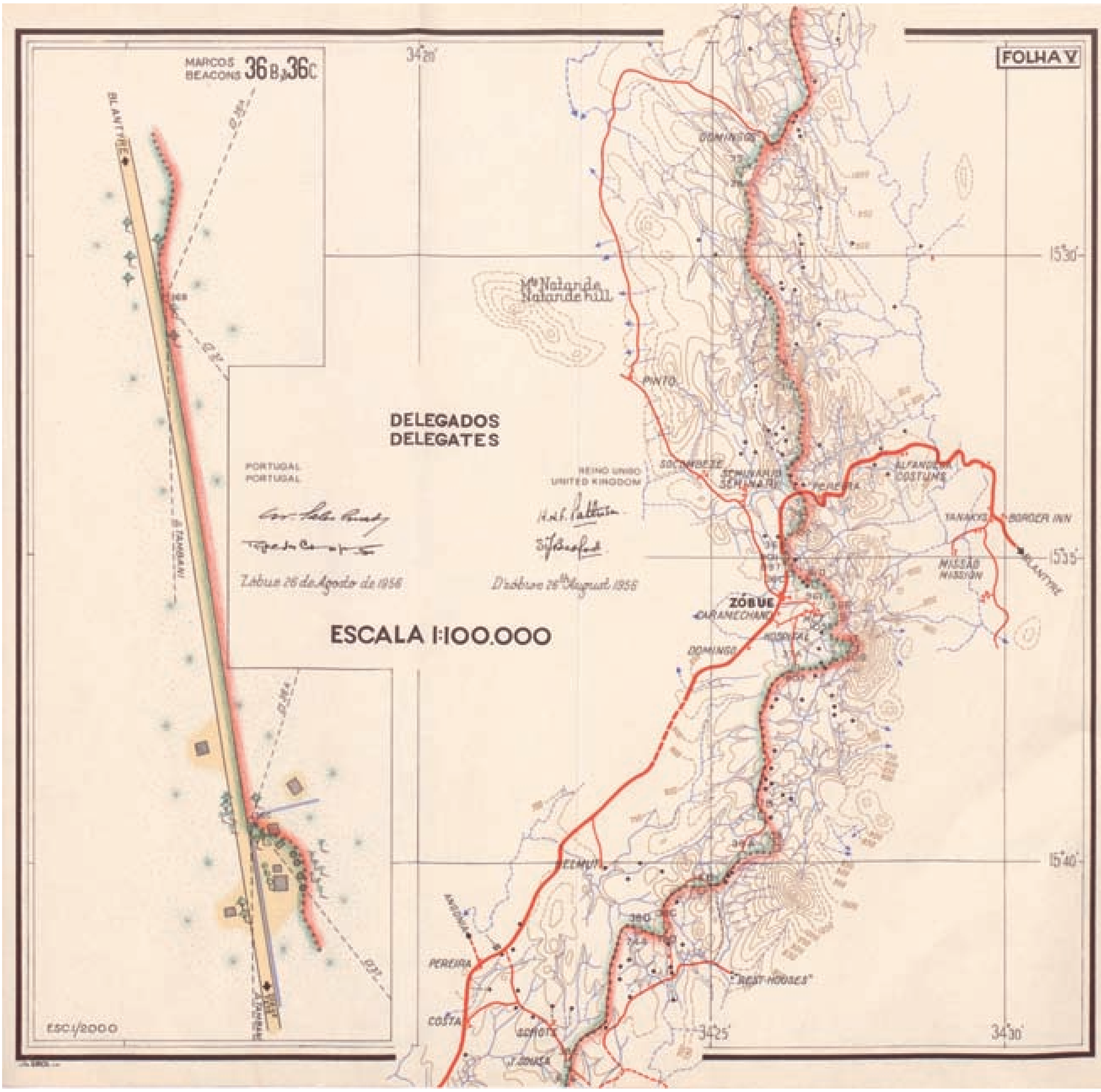


FIG. 98. MAP V PREPARED BY THE NYASALAND (MALAWI)-MOZAMBIQUE BOUNDARY COMMISSION. Signed at Zobue on 26 August 1956. Size of the original: ca. 33.3 × 33.2 cm. Image courtesy of The National Archives of the U.K. (TNA), Kew.

intention that the land on each side of the line would not change sovereignty whatever the river did. Even though the alignment was chosen in such a way that equal initial transfers of land were involved as a one-off exercise, the local Tanzanian farmers rejected the plans and the proposal was never ratified.

The straight-line Botswana-Namibia border was marked in the 1960s by a double cattle fence to inhibit the spread of cattle diseases. The border ran through flat country for much of its length, and a series of towers was erected so that a traverse could be measured.

At the end of the twentieth century, Africa had a nearly complete set of boundaries of colonial origin. Many of these reflected the fact that the colonial powers had brought a pragmatic and cooperative approach to boundary negotiations. Compromises and exchanges of land had been easy to achieve when population densities were far lower and the feelings of local residents could be easily ignored. Unless there was conflict between neighboring countries, boundary areas rarely attracted political interest in the early twenty-first century—when there was peace, borders were left in their colonial state and few politicians were willing to spend money to improve the demarcation. When disputes did arise in later years, trust and cooperation evaporated, and neither side was willing to compromise. And if either side sought to squeeze the last square meter out of a dispute, boundary surveys had to be very detailed, very precise, and much more expensive.

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SEE ALSO: Boundary Disputes; Decolonization and Independence; Law of the Sea; Property Mapping: Africa

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*Boundary Surveying in Europe.* The evolution, nature, and characteristics of administrative boundary surveying in Europe were distinctive, particularly when considering internal boundaries or interstate borders. The former were related to cadastres and property registration, undertaken throughout the nineteenth century by both national and local authorities. The latter were affected by the various geopolitical circumstances the continent experienced throughout the twentieth century.

The basic administrative units provided a suitable framework for collecting geographic information needed by the state. Thus, these boundary delimitations were prioritized. This was a continuous task, shaped by budgetary constraints and the technical means available at that time. In Spain, for example, the delimitation of municipal boundaries took place between the late nineteenth and mid-twentieth centuries. The undertaking served to provide an initial assessment of the land and to design the Mapa Topográfico Nacional at a scale of 1:50,000. To achieve this, the topographical brigades of the Instituto Geográfico Nacional summoned neighboring municipalities to decide the layout of the boundary lines that separated them; these were then formalized in an official record. Later, the demarcation line was set by placing signs as agreed upon and using a polygonal survey made with a compass and supported with geodetic and topographical triangulation networks. All measurements were recorded in the official field books and later developed into maps at a scale of 1:25,000 (fig. 99). Subsequent work permitted the addition of planimetric details and contours. Pressure on the land and the need to share information at the end of the century made new surveys necessary to update and improve the accuracy of Spanish municipal boundaries (Capdevila Subirana 2005).

The boundaries between states in Europe underwent significant changes during the century. Almost half of their length was established after 1945 and more than a quarter defined after 1990. We can distinguish three major periods of boundary changes: after World War I, the Paris Conference of 1919 and subsequent treaties that were derived from it; after World War II, the Yalta-Potsdam accords of 1945; and after the fall of the Berlin Wall in 1989 and the disintegration of the Soviet Union in 1991.

Until the 1910s, the geopolitical dynamics of the continent followed the logic of the nineteenth century, based on a European-dominated world political space. Boundaries were determined at the negotiating tables in the metropolis. But with the fall of the great empires and the rise of nationalist and ethnic claims that characterized World War I, the way of conceiving sovereign territorial areas changed radically. English geographer Thomas Hungerford Holdich's book *Political Frontiers and Boundary Making* (1916) was one of the first attempts to address the issue of boundary making in a logical way. The best example of this change is the United States' great effort in its participation in the Paris Conference of 1919. Given the necessity to rearrange Europe territorially, President Woodrow Wilson convened a group of mostly political and social scientists drawn from universities to develop proposals based on the identification of European peoples through social and cultural features, such as language, religion, sense of belonging, etc. This group, known as the Inquiry, used statistical techniques and thematic mapping developed during the previous century. The result was a large document and a series of territorial distribution proposals that were not always welcomed by Wilson's European colleagues (Crampton 2006). The successive discussions and agreements generated a considerable amount of cartographic production, both private, as in the case of the *Carta-Base della Futura Europa Politica* (fig. 100) published in 1919 to illustrate the changes that were taking place, and official, as countries participating in the talks used the maps to support and justify their territorial claims.

However, the detailed delimitation and demarcation of the new borders was left in the hands of a series of ad hoc border commissions. British geographer and astronomer Arthur R. Hinks had the opportunity to observe the work of the boundary commission between Belgium and Germany agreed in the terms of the Treaty of Versailles in 1920. The commission began its work in early 1922; however, it did not have specific instructions or a detailed description of the boundary to be delimited. They assumed that the border was based on local administrative borders, which usually coincide with

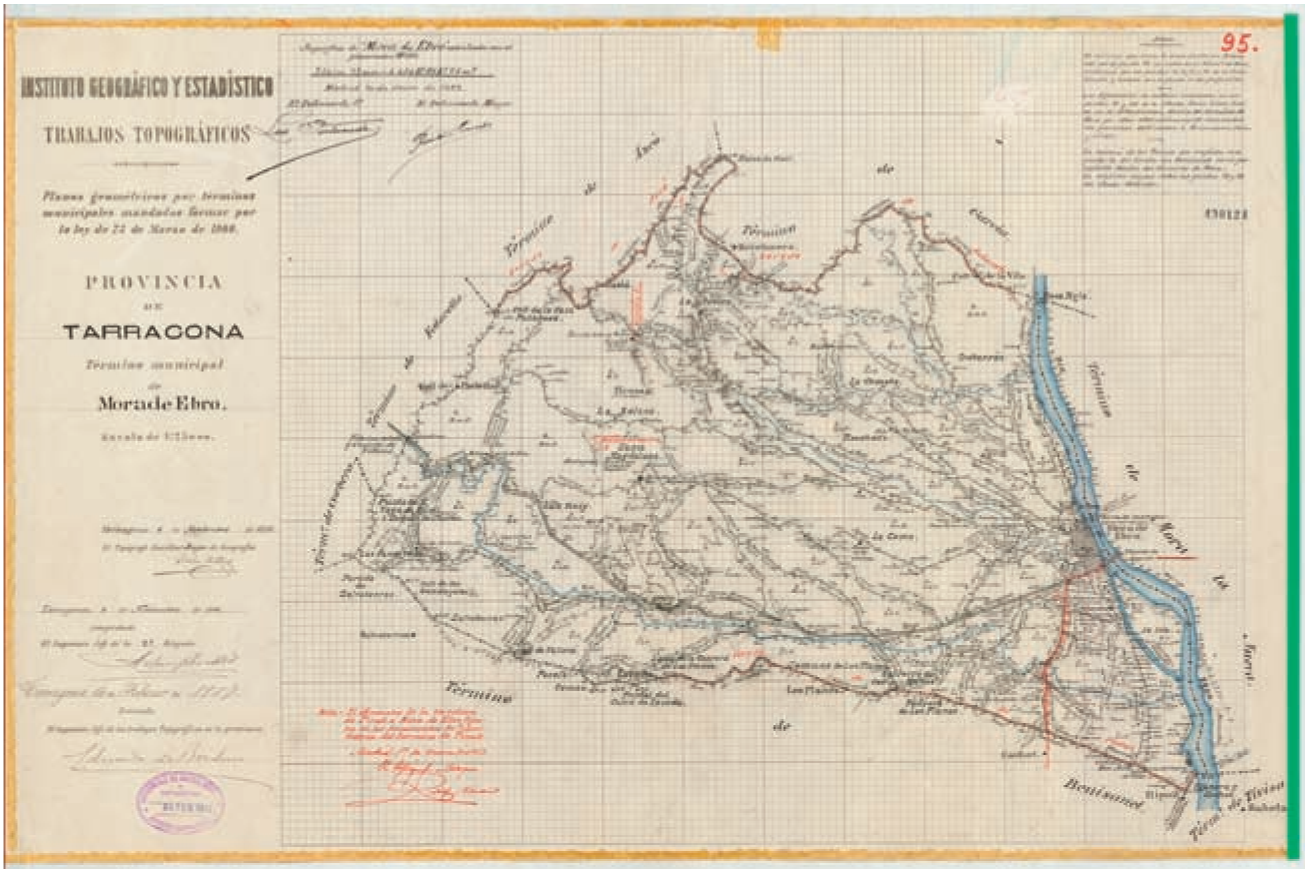


FIG. 99. INSTITUTO GEOGRÁFICO Y ESTADÍSTICO, *PROVINCIA DE TARRAGONA, TÉRMINO MUNICIPAL DE MORA DE EBRO*, 1:25,000, 1919. Example of municipal planimetry with developed polygons and interior details of the municipality. Updates are shown in red.

Size of the original: 43 × 65 cm. Image © Instituto Geográfico Nacional de España, Madrid.

property boundaries. With the help of local inhabitants, many boundary markers were located, but they were not always sufficient to describe the entire line. The boundary commissioners had to work to a level of accuracy equivalent to cadastral mapping. To achieve this end, topographical triangulation was applied based on the German geodetic network. The network was observed by both the Belgians and the Germans using theodolites. A traverse was then observed along the boundary line between triangulation points. The positions of the individual boundary pillars were determined by offsets from the traverse. Hinks (1921) commented on the problems encountered due to the use of two different geodetic systems in calculation and control.

Many other boundary commissions, however, did have detailed instructions. American political geographer Stephen B. Jones (1945) reproduced "Instructions to Demarcation Commissions, Pursuant to the Paris Treaties: Instructions Relative to Boundary Commissions" (translated from the French) as an appendix to his manual for the delimitation of borders. From the boundary-making experience gained in the first four decades of the twentieth century, Jones defined terminology and systematized procedures that were applied until the end of the century. His text is considered the main reference for boundary practices and dispute settlement (Donaldson and Williams 2008). The boundary commission should delimit the border, demarcate it on the ground, and after inspecting the results, incorporate them into official records. To achieve this, they should establish a work plan consisting of the compilation of all existing topographic mapping, consulting local authorities with potentially contentious claims and considering the proposals made by interested parties. If existing information was insufficient, the commission should carry out a topographical survey of the area to an appropriate scale, before completing the operation. The commission should then oversee the demarcation operations and record everything cartographically. The cartographic record should be returned with a description of the boundary and the


FIG. 100. ISTITUTO GEOGRAFICO DE AGOSTINI, *CARTA-BASE DELLA FUTURA EUROPA POLITICA*, 1:9,000,000, 1919. Commercial map showing the new European borders agreed at the Paris Peace talks after World War I. Size of the original: 56 × 68 cm. Image courtesy of the Map Collection, Yale University Library, New Haven.

minutes of the meetings. It was further stipulated that the border markers should have serial numbers, sectors, or subsectors to which they belonged, the orientation of adjacent markers and the initials of neighboring countries. To position the markers, the following methods were proposed: through adjustment with respect to natural landmarks; using geographical coordinates (and height, if necessary); using rectangular coordinates (in a known projection); through measures relative to neighboring markers and finally, by a simple mark on the map. The markers should be visible and should be placed at points where there may be traffic (important places, roads, railways, etc.). For rivers, the median line should serve as the normal boundary line depending on whether the river was navigable or not. For land lines the use of existing administrative boundaries was recommended, such as cadastral boundaries, straight lines, or lines based on natural features. Surveying should be carried out so as to follow the axis of the border agreed in the treaties, with the necessary width for all the above-cited elements to appear in them. The maps should be planimetric and represent the terrain with contour lines. All elements that would help to place border signs and markers need to be represented. The surveying methods should be adapted to the terrain; therefore, it was recommended that topographic triangulation should be constructed using all points on the ground, provided with geographic coordinates as well as base points and angles. In areas where it was not practicable to carry out the survey by usual means, a theodolite or tacheometer and numerous measures of longitude and latitude were to be taken to complete the polygons. Large-scale mapping should show the boundary line continuously, along with the boundary markers and landmarks that defined it (Jones 1945, 229–39).

Colonel D. Cree (1925) describes the delimitation between Yugoslavia and Hungary following these instructions. The border was agreed in the Treaty of Trianon of 1920 and the Yugoslav-Hungarian Boundary Commission was established in Paris in the summer of 1921. The main difficulty was obtaining the necessary reference maps. They used updated general reference and travel maps at 1:200,000 scale for travel and general study, and topographic maps at 1:75,000 scale for the boundary work. The commission also used maps made by the Austro-Hungarian Empire at 1:25,000 and smaller-scale maps based on them. However, these maps had not been updated since about 1850. Cadastral maps, at a scale of 1:2,800, were at the commission's disposal, but these too had not been updated. It could also draw on various locally available maps. The commission party listened to local proposals and conducted fieldwork, according to the agreed procedure. Having decided on the border, it was described in words and labeled in red on a 1:75,000-scale map, which was signed by the commissioners. Due to disagreements between the countries, the delimitation was not adopted until 1924. The subsequent boundary marking and mapping work was supervised by Cree. This was done relying on the existing topographical triangulation, where possible using third- and fourth-order triangulation points. The distances between border markers was limited to 300 meters, ensuring visibility between adjacent markers (fig. 101), and, in the case of fluvial border points, boundary markers were placed on both sides of the river, with the center of the principal channel at the time of the survey serving as the boundary, even if the channel should subsequently move. The maps and plans of the border consisted of large-scale drawings giving details of measured distances and angles between them, made at scales between 1:1,000 and 1:5,000 depending on the detail to be shown. Additionally, updated cadastral maps were included, usually at a scale of 1:2,800, showing a strip of 500 meters on each side of the border. Finally, the border and border markers were drawn on 1:25,000-scale maps.

At the time there was great interest in measuring and representing new borders through cartography. For example, two booklets, *Instruction technique* and *Instruction particulière sur les travaux géodésiques et topographiques*, established the operational guidelines for delimiting the border between Hungary and Romania (U.S. Department of State 1965, 8). In defining boundaries, previous property and administrative boundaries were widely used. The existence of updated cadastral mapping was very useful and made the work easier. It also took strategic factors into consideration, such as the presence of a railway line or a navigable river (U.S. Department of State 1965, 6). In all these cases large-scale maps were produced, ranging in scale from 1:1,000 to 1:5,000. There were also some special procedures for small segments of borders, as in the case of the division of Schleswig between Denmark and Germany in 1920, which were reflected in the series of eighteen sheets at 1:5,000, the *Kort over Landgrænsen mellem Tyskland (Prøjsen) og Denmark*. In this case, the border alignment was decided by plebiscite (U.S. Department of State 1968, 7).

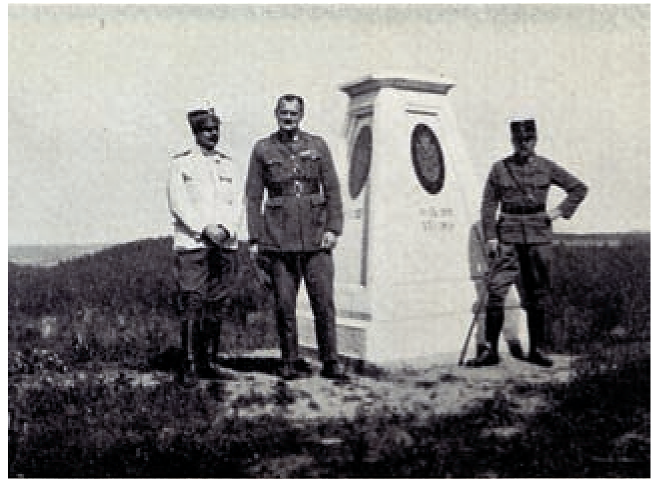

FIG. 101. TRIPLE-POINT BOUNDARY MARKER AT THE CONFLUENCE OF THE BORDERS OF YUGOSLAVIA, AUSTRIA, AND HUNGARY.
From Cree 1925, portion of photograph opposite 93. Permission courtesy of John Wiley & Sons, Inc.

Mapping scales varied according to the method used in defining the border. In the case of the border between Finland and the Soviet Union, the use of straight lines between border markers made it necessary for the Mixed Fenno-Russian Boundary Survey Commission in 1925 to create a series of eight sheet maps at a scale of 1:20,000 (U.S. Department of State 1967, 4). If the border had been based on natural features, the markers could have been further apart and would not have needed to be as stringently defined. For example, the Greek borders, defined after the Greco-Turkish war of 1919–22, were represented in a series at 1:50,000 scale in the *Carte de la frontière Gréco-Turque* from 1926 (U.S. Department of State 1964b).

The work of boundary commissions was not always successful. Historian Nicola C. Guy (2008) recounts the political and technical difficulties that five boundary commissions encountered between 1878 and 1926 before successfully defining the borders of Albania.

The second great period of new border delimitations came after World War II and the agreements of Yalta and Potsdam. Between 1945 and 1949, fourteen new borders were defined, with a total length of about 7,630 kilometers. In this case, the rationale was largely political. Different nationalities and ethnic groups were divided into two great spheres of influence, separated by the Iron Curtain. The division of the two Germanys emerged out of a British proposal for defining the geographical areas of control of the Allies (Foucher 1991, 474–83). For the delimitation of the borders, in some cases old administrative boundaries were used (the division into the two Germanys; the Curzon Line between Poland and the Soviet Union), in others new boundary lines were based on strategic geographic features (the Oder-Neisse line, as the border between Germany and Poland, defined by the course of the two rivers). In many cases, there was a return to the 1938 borders, in others existing borders were simplified and refined. In 1953, when France and Switzerland reworked many points on their border, this was reflected in fourteen new maps, with scales between 1:1,000 and 1:5,000, which accompanied the agreement. It is noteworthy that contrary to normal practice, it was agreed that these maps had formal precedence over the legal text of the convention (U.S. Department of State 1961). Another boundary for which detailed cartography was produced was between the Netherlands and Germany. This boundary was agreed in 1949 and revised in 1960. Forty-three maps were drawn with scales ranging from 1:500 to 1:50,000, although the majority are at scales of 1:2,000 and 1:10,000 (U.S. Department of State 1964a, 10).

Boundary lines with larger adjustments resulted in more detailed maps. The documentation of the boundary between the Soviet Union and Norway, agreed on in 1947, is remarkable. It consists of an album with detailed maps and triangulation diagrams. As a result a series of eighteen sheets at a scale of 1:25,000 was published (U.S. Department of State 1978, 6).

The fall of the Berlin Wall in 1989, the breakup of the Soviet Union in 1991, and subsequent conflicts in the Balkans again changed the political map of Europe, generating more than 26,600 kilometers of new frontiers. Since German reunification in 1991, there has been a return to the Europe of emancipated nations, an idea already present in the Bonn Treaty with Poland (Foucher 2007, 133). One example is the delimitation work done by the Joint Diplomatic Expert Commission on the border between the former Federal Republic of Yugoslavia and the Republic of Macedonia between 1996 and 2001, which resulted in an atlas of 1:25,000 sheets (Milenkoski and Talevski 2001). The century ended with many cases still unresolved.

The majority of new boundaries were based on old demarcations, demonstrating the longevity of boundaries. However, measurement and representation techniques were completely transformed. Geographic information based on digital technology was already used in the 1995 Dayton Accords (Johnson 1999). Requirements also became more stringent. At the end of the century, several European projects had emerged to gather different layers of geographic information, including administrative boundaries. EuroGeographics, the association that encompasses the geographical institutes of the European states, did a survey in 2005 among its members regarding the technical and legal state of their border boundaries. It concluded that despite the existence of legal agreements and official delimitation, existing cartography was not always jointly agreed upon or sufficiently precise. A shared common geodetic system was a minimum; an interoperable data model and precise measurements of coordinates corresponding to a scale of 1:5,000 or higher was deemed desirable (EuroBoundaries Project 2006).

JOAN CAPDEVILA SUBIRANA

SEE ALSO: Boundary Disputes; Military Mapping by Major Powers; Military Mapping of Geographic Areas; Paris Peace Conference (1919)

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*Boundary Surveying in the Middle East.* The early twenty-first century international boundaries in the Middle East originate directly from arrangements following World War I. These modern boundaries of the Middle Eastern countries, and also the root of their problems, can be traced back to historical boundaries existing at the sunset of the Ottoman Empire and its disintegration.

The first international boundary in the Middle East in the twentieth century was established as a line dividing the Khedivate of Egypt and the Ottoman Vilayet of Hejaz. For military purposes the British, who de facto governed Egypt, were anxious to secure the Suez Canal, leaving the Sinai Peninsula to Egypt. Britain issued an ultimatum in May 1906 demanding a delimitation and demarcation running approximately straight from Rafah to a point on the Gulf of Aqaba, not less than three miles from Aqaba (Akaba). The actual process of delimitation and demarcation is a first-class professional and logistic achievement, even viewed from a 100-year perspective.

The commissioners and surveyors met in Aqaba in May 1906. The surveyors, led by E. B. H. Wade, established sites for astronomical observations, A1 at Taba and A2 at Aqaba, with an auxiliary point B1 near Taba. The course of the boundary was decided, and the party advanced northwest, establishing thirteen astronomical stations and making topographical surveys. On 1 October 1906, an agreement was signed at Rafah delimiting the boundary. On the return to Taba, the commissioners and surveyors marked the boundary points by telegraph poles, to be replaced later by masonry pillars. They arrived at Taba on 17 October 1906.

In 1916, Britain and France arrived at the secret Sykes-Picot agreement, which further divided the areas south of Turkey and north of Egypt. The Levant was given to France; Transjordan, Mesopotamia, and part of the Holy Land to Britain. Another part of the Holy Land was intended to become an international protectorate (fig. 102).

At the Paris Peace Conference following World War I, Britain and France obtained mandates over these lands and decided that the time had come to put into effect the division of the Ottoman Empire in the spirit of the Sykes-Picot agreement. In the Franco-British Convention of 23 December 1920, signed in Paris, the two countries agreed that the mandate over Lebanon and Syria be given to France and the mandate over Palestine and Mesopotamia to Britain. The convention included the appointment of a joint boundary commission led by Lt. Col. Stewart Francis Newcombe (Britain) and Lt. Col. N. Paulet (France) to demarcate of the frontier from the Mediterranean Sea to El Hamma (in the lower valley of the Yarmuk River). Between the Great Lebanon and Syria on one side and Palestine on the other, France and Britain established a geodetic control by triangulation and monumented the agreed upon boundary by seventy-one cairns from Ras Nakura on the shores of the Mediterranean to the bridge on the Yarmuk, east of El Hamma. Other parts of the boundary followed natural or artificial features. The boundary was shown on a map at 1:50,000 in three sheets, signed by members of the commission and communicated to the League of Nations. Almost all the boundary points can still be located (fig. 103).

After the disintegration of the Ottoman Empire, France created the states of Syria and Lebanon; Britain created the states of Palestine, Transjordan, Iraq, and Kuwait, with an Arab state on the Arabian Peninsula based on the Ottoman sultanates of Nejd and Hejaz.

Effective September 1923, the League of Nations gave Britain mandate over Palestine, and the 1906 line was left as the boundary between Egypt and Palestine. This situation remained during the mandate period and even the postmandate period, when Israel was proclaimed an independent state.

A joint demarcation of the international boundary followed the 1979 Egypt-Israel Peace Treaty. Of the ninety-one pillar locations of the 1906 boundary, fourteen were disputed, and the parties signed a compromise establishing an International Arbitration Tribunal on 11 September 1986. Two years later, 29 September 1988, the tribunal made an award that was accepted by both sides. The boundary, some 210 kilometers long and comprising ninety-nine agreed boundary markers connected by straight lines, was jointly demarcated, monumented, and surveyed using GPS (Global Positioning System) by Israel and Egypt, establishing precisely the coordinates of all the boundary points with reference to the boundary datum established, known as the Israel Egypt Boundary Datum 1992 (IEBD92).

In the almost eighty years of the boundary's existence,


FIG. 102. THE SYKES-PICOT AGREEMENT OF 1916. *Map of Eastern Turkey in Asia, Syria and Western Persia*; A—zone under French influence, B—zone under British influence. Size of the original: 71 × 74 cm. Image courtesy of The National Archives of the U.K. (TNA), Kew (MPK 1/426).

there were several wars in the area—in 1948, 1967, 1973, 1982 and 2006—each ending in a cessation of hostilities and the creation of military lines not seen as permanent boundaries by the countries involved. It is noteworthy that the location of the international boundary between Israel and Lebanon is almost stable, which is not the case between Syria and Israel.

The boundary between Iraq and Kuwait is special because its demarcation was the result of a 1991 United Nations (UN) Security Council resolution, which asked the secretary-general "to make arrangements with Iraq and Kuwait to demarcate the boundary between Iraq and Kuwait" (Schofield 1993, 151). The delimitation formula was the 1932 exchange of letters between the prime minister of Iraq and the ruler of Kuwait. The boundary was demarcated with reference to its own geodetic datum, known as the Iraq Kuwait Boundary Datum 1992 (IKBD92) and twenty-five control points

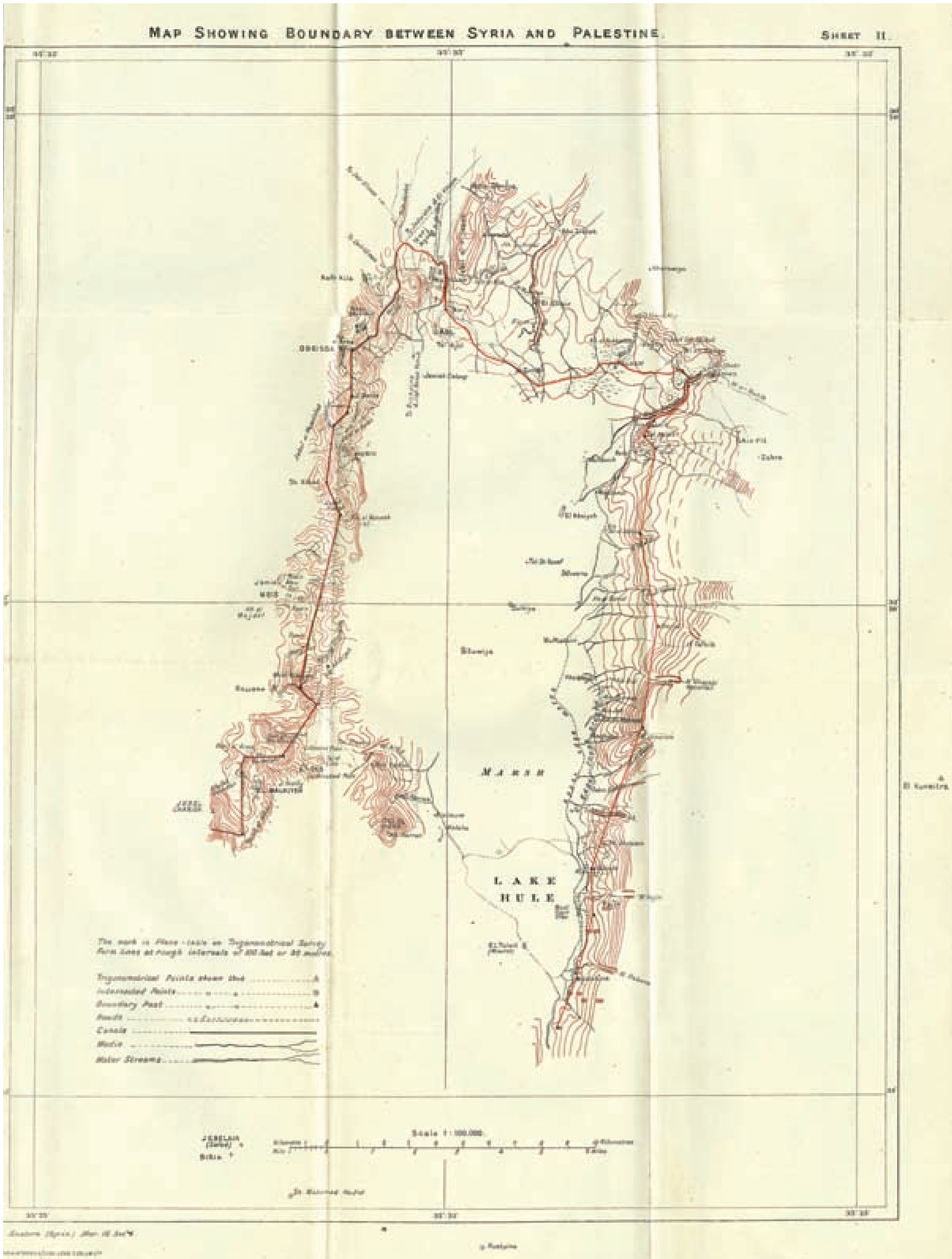


FIG. 103. PART OF THE BOUNDARY LINE BETWEEN SYRIA (AND GREAT LEBANON) AND PALESTINE. *Map Showing Boundary between Syria and Palestine*, scale 1:100,000. Size of the original: 45.8 × 33.8 cm. From United Kingdom, Treaty Series, No. 13 1923, sheet II (of three sheets).

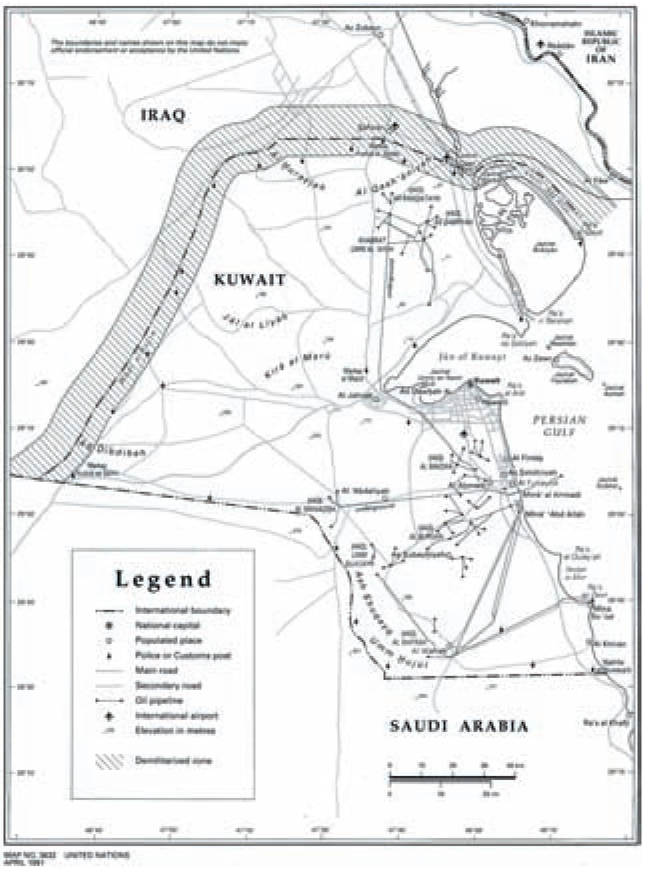


FIG. 104. IRAQ-KUWAIT BOUNDARY DEMARCATED BY THE UNITED NATIONS, 1991. The demilitarized zone is shown in a stripped band along the international boundary. Image courtesy of the Cartographic Section, Dag Hammarskjöld Library, United Nations, New York (map no. 3632, April 1991).

by a team of experts appointed by the secretary-general (fig. 104).

On the old road south of Safwan there was a notice board marking the boundary, the position of which apparently had not been measured, and two different versions existed regarding its location, namely, 1,609 meters and 1,250 meters from the southwest extremity of the old customs post. The UN Iraq-Kuwait Boundary Demarcation Commission decided to establish the boundary halfway between the two versions at a distance of 1,430 meters. This location was determined by GPS observation and a subsequent computation of coordinates, producing a latitude of 30°06′13.3181″. This fixed the parallel of latitude for the boundary between the end of the boundary in Wadi Al-Batin and the point south of Safwan (boundary pillar no. 72). Looking at the coordinate of the parallel, one notices that the estimate of the GPS location accuracy must have been in the order of single centimeters as compared with the hundreds of meters in estimating the location of the notice board! These, however, are the realities of boundary making—that the purely technological data of the late twentieth century are, as a rule, much more accurate than any earlier estimates (Adler 2001, 71).

The section of the boundary between the turning point south of Safwan and the final land boundary point was defined by the commission as being "along the geodesic" ("United Nations: Letter" 1993, 1455). This is perhaps the first use of the term *geodesic* in land boundary definition (Adler 2001, 71). (A geodesic is the shortest line between two points on the surface of the ellipsoid of reference. Only experts in geodetic science are capable of determining such a line on the ground or defining it by geographical coordinates.)

The commission decided that the western section of the boundary would terminate at the intersection of the line of the lowest points in the Wadi Al-Batin with the line of the latitude of the boundary point south of Safwan. The final report of the UN Iraq-Kuwait Boundary Demarcation Commission is the list of geographic coordinates (latitude and longitude) of the 106 boundary pillars, 28 intermediate boundary markers, and 56 points defining the position of the low-water line and the median line at sea (Adler 2001, 70, 72).

The boundary between Israel and Jordan originated in the British mandate over Palestine, defined in September 1922. Following the British tradition, the line was defined along natural features. Its weakness was the imprecision of natural delimitations (e.g., the definition of centers of changing rivers, lakes, or a valley ten miles wide). This imprecision contributed to misinterpretation on maps in subsequent years. In addition, de facto physical installations on the ground and agricultural cultivations did not coincide with the ceasefire lines.

Israel and Jordan arrived at a logical and fair line acceptable to both sides on the basis of supportive evidence of the "middle of the valley" that was in favor of Israel and enabled modifications in the line considering the practical use of the areas involved. The final line was fixed in the peace treaty between Israel and Jordan, signed 26 October 1994. The treaty included a number of innovations ("Israel-Jordan" 1995, 55):

(1) For the first time in international boundary agreements orthophotos and rectified satellite images were used to delimit the boundary.
(2) The treaty included the procedure for demarcation, the method of surveys, including the use of GPS, a joint boundary reference datum called the Israel Jordan Boundary Datum 1994 (IJBD94), and a method of recording the surveys. The record docu-

ment, including coordinates, was declared a part of the peace treaty itself.

(3) The execution of the treaty included the demarcation of 123 pillars and an innovative demarcation of a maritime boundary at a head of a gulf involving countries with both adjacent and opposite shores (Srebro 2005).

The Joint Team of Experts (JTE) composed of members from both sides prepared a documentation record formally adopted in the peace treaty. This has been used by both sides with great success in the proper maintenance of the boundary since the signing of the treaty.

The mandate powers' decisions were, however, often haphazard and in some cases expressed as "line of longitude" or "line of latitude," ignoring the realities of life along the boundary. In the Middle East this often ignored areas absolutely essential to the existence of tribes. For example, the absence of fences or blocks in many areas and the custom of local inhabitants to settle and build houses and cultivate land according to availability of water and soils rarely accorded with artificially created boundaries.

Such cases required states established after the departure of the mandate powers to rearrange reasonable practical boundaries with neighboring countries. This necessitated exchange or adjustment of territories. One such rearrangement was between Jordan and Saudi Arabia. In 1965, Saudi Arabia exchanged 6,000 square kilometers of land with 19 kilometers of sea shore along the Gulf of Aqaba in return for 7,000 square kilometers near Wadi Sirhan in southeastern Jordan for the benefit of Bedouin tribes. Similarly, in 1981, Jordan signed a boundary adjustment agreement of almost 200 square kilometers with Iraq in the area of Ruwashid. There were boundary adjustments of some 80 square kilometers in the Israel-Jordan peace treaty of 1994, and in 2004 Jordan and Syria negotiated an exchange of territories along their boundary.

A different kind of adjustment of former mandate boundaries was the division of the neutral zones that had existed between Saudi Arabia, and Kuwait and Iraq since 1922. The adjustment with Kuwait involving some 5,770 square kilometers was carried out in 1969. The adjustment with Iraq, which took place in 1981, involved 7,044 square kilometers.

An example of a boundary problem arising from a discrepancy between boundary and sovereignty and between ownership and rights to cultivate land involves Syria and Lebanon. The area of Shibaa farms was within Syria (since its independence in 1946) and outside Lebanon (since its independence in 1943). But since 2000 Lebanon has claimed sovereignty over the area based on ownership and land use. In the Golan Heights, the boundary between Syria and Israel remains in dispute.

In the Persian Gulf, a potential for disputes over maritime boundaries exists between Iran and Gulf states with a background of oil interests. These interests make it uncertain whether once Iraq emerges strengthened, the boundary between Iraq and Kuwait will again become disputed.

The boundary between Israel and the Palestinian entity is one of the most explosive issues, with no emerging solution. It is not only a boundary question, but an issue deeply rooted in ethnic, religious, refugee, and resource history.

Other areas where a significant potential for boundary disputes lie are (1) Kurdish areas in Turkey, Iraq, Syria, and Iran, where tens of millions of Kurds strive for independence; (2) Iraq, with its instability, ethnic conflicts between Kurds and Arabs, and religious problems between Shiites and Sunnis; and (3) Iran, including the fundamentalist tendencies of Shiites and Sunnis, which may lead to political and boundary instability (fig. 105).

RON ADLER AND HAIM SREBRO

SEE ALSO: Boundary Disputes; Paris Peace Conference (1919)


FIG. 105. MIDDLE EAST BOUNDARIES AT THE END OF THE TWENTIETH CENTURY.
Image courtesy of the Survey of Israel, Tel-Aviv.

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*Boundary Surveying in East and Southeast Asia.* International boundaries in East and Southeast Asia were generally settled by agreements between the imperial powers of Britain, France, and China in the last two decades of the nineteenth century, although some modifications occurred in the first decade of the twentieth century. Agreements since World War I, including those by independent postcolonial states after World War II, have, for the most part, confirmed the colonial boundaries, simply refining the detail and toponomy with which they were mapped, described, and demarcated. Almost all the boundaries follow watercourses and watersheds through remote and rugged country and use few straight line segments, certainly none of any great length; nor, apart from the short-lived Vietnamese demarcation line (fig. 106), do they use meridians or parallels as did colonial boundaries in North America, Africa, and Australia. In postcolonial resurveys, the boundaries generally

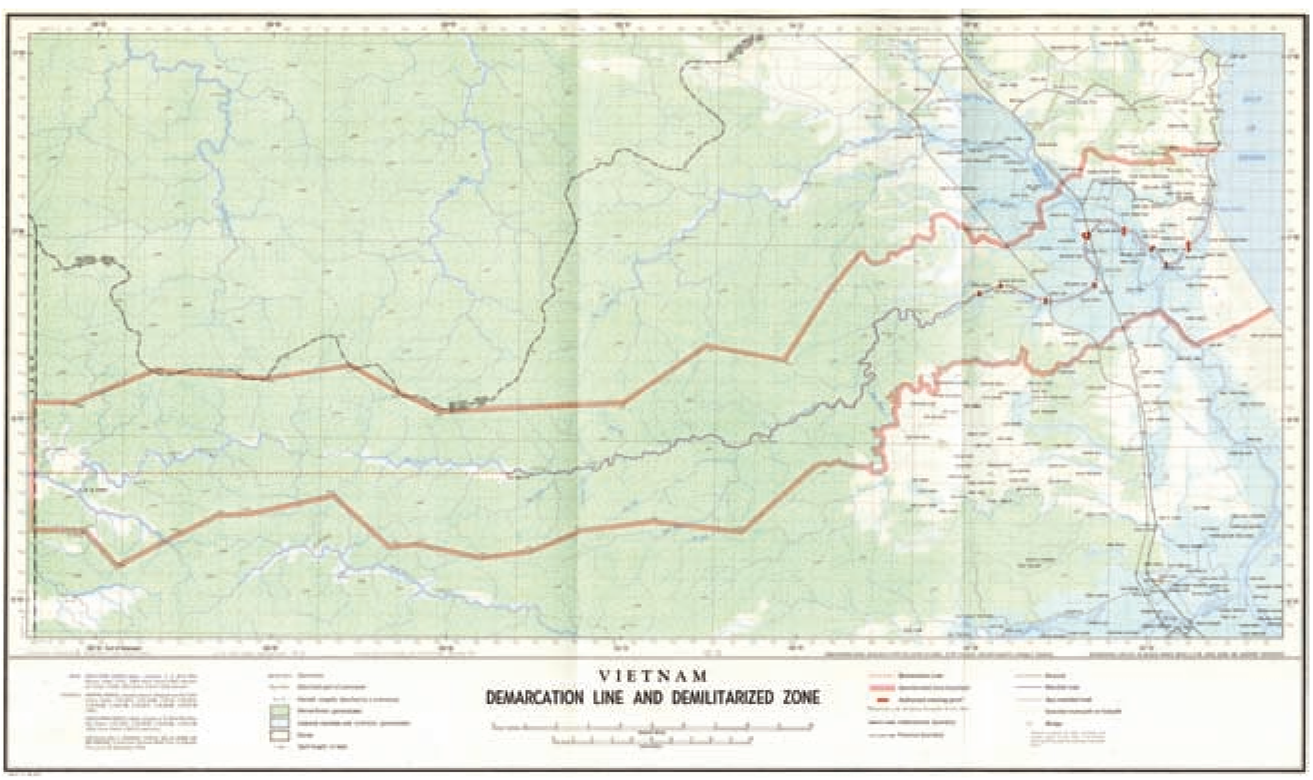



FIG. 106. *VIETNAM: DEMARCATION LINE AND DEMILITARIZED ZONE*, CA. 1:161,000. An official U.S. depiction of the 1954–76 demarcation line between North and South Vietnam.
Size of the original: 24.2 × 41 cm. From U.S. Department of State, Office of the Geographer, "Viet-Nam 'Demarcation Line,'" *International Boundary Study* 19 (1962).

follow the thalweg in navigable watercourses and the median line in nonnavigable ones.

The British and French colonies in Southeast Asia and the independent states of Siam and China developed around sedentary rice-cultivating civilizations in major river valleys such as the Mekong and Irrawaddy. These civilizations had fluctuating control over the tribal polities subsisting on slash-and-burn practices in the forested hills. Rival British and French attempts to find commercial routes into Yunnan from Burma and Tonkin respectively resulted in the imposition of permanent, surveyed, and pillared boundaries that reflected a combination of the projection of military strength coupled with appeals to the contemporary, and sometimes past, allegiances of the tribal polities. However, in some cases local polities were divided when a boundary following a watershed or river was considered more practical in terms of recognition, policing, and defense.

The general process for the establishment of a boundary began with exploration into the interior of coastal colonies by private or official expeditions, such as those led by Holt S. Hallett from Burma for the British and Auguste Pavie from Cochin China for the French, seeking resources such as timber or minerals, as well as investigating the potential for trade routes into central China. The maps and reports from these expeditions were generally the only sources of information available to colonial or foreign office officials when initial boundary treaties were drawn up, and maps based on those of the explorers were attached to the treaties. In at least one case, however, lack of geographic knowledge was acknowledged. In the Burma-China agreement of 1 March 1894 (London Convention), only the southern section of the boundary was defined; the line north of latitude 25°35′ was explicitly left undefined until the geography of the area was better known (U.S. Department of State 1964, no. 42, 6). The subsequent unwritten de facto line of control was confirmed and defined only in 1960.

Internal French Indochinese colonial boundaries were made by gubernatorial decree and while usually surveyed, were rarely demarcated. However, the alignments were officially indicated on mapping such as the 1:100,000 *Carte de l'Indo-chine*, and were generally accepted by the three postcolonial Indochinese states.

Most regional boundary treaties contained clauses requiring the two sides to survey and demarcate the boundary as soon as possible, usually within a specified period of time. Monsoonal climates generally restricted the survey work to the dry season only, utilizing native porters, mules, or even elephants. In the survey work to demarcate the Burma-China boundary in 1960, which was forced by political factors to work through the monsoon, the Burmese side alone used 2,400 mules and 5,600 porters (Nu [1960], 8–9). Additionally, hostile tribes and bandits were not uncommon. As late as 1900, a surveying party on the Yunnan border lost two British officers to headhunters. Aerial photography greatly aided surveying in such terrain and was used at least as early as 1925 during surveys of the Franco-Siamese boundary in the Mekong. Personnel resurveying the Thai-Malaysian border since the 1970s have also been injured by booby traps laid by guerillas.

The Chinese could generally match Britain and France in surveying expertise, but Siam, whose Royal Survey Department was only established in 1885 with British assistance, sometimes could only supply observers, leaving the technicalities of surveying and mapping to the colonial establishments. For example, the production of maps during the demarcations following the Franco-Siamese boundary treaties of 1904 and 1907 was left entirely to the French (International Court of Justice 1962, 1:20). Particularly because of the lack of geographic knowledge of frontier areas, survey and demarcation parties were also given authority, where circumstances warranted, to change the boundary from that defined in the treaty text.

When the expanding British and French territories met in the 1890s, a diplomatic rather than military solution was sought via a series of discussions. Alastair Lamb (1968, 57) notes that all the boundaries of mainland Southeast Asia derive, directly or indirectly, from these talks. Despite this, disputes emerged in the interwar period between China and Britain over the Wa states in Burma and between Siam (renamed Thailand in 1939) and France over lands ceded to the latter in 1904 and 1907. China and Britain reached a compromise under League of Nations auspices in 1935, which was ratified in the face of joint fear of the Japanese in 1941 and published with two detailed maps in the United Nations *Treaty Series* (1947) (figs. 107 and 108). Nevertheless, China's Nationalist and subsequent Communist governments maintained semiofficial claims to much of Southeast Asia until well into the 1950s at least (see Lamb 1968, 29–30), with the publication of semiofficial maps by, for example, Liu Peihua (1954) indicating irredentist claims as far as the Andaman Islands, Singapore, and the Sulu Archipelago.

Meanwhile, Siam's semifascist military government, attempting to assert its legitimacy after a coup against the absolutist monarchy in 1932, demanded France "return" various territories. A series of maps of the supposed extent of Thai territory under various historical kingdoms was issued by the Royal Thai Survey Department in 1935–36 (Thongchai 1994, 150–56). These maps, reproduced almost unchanged in school atlases seventy years later (e.g., Wirot, Somkiat, and Sarita 2006, 17, 19, 21, and 24), simplistically and incorrectly imply definite and exact boundaries of the Thai kingdoms of the

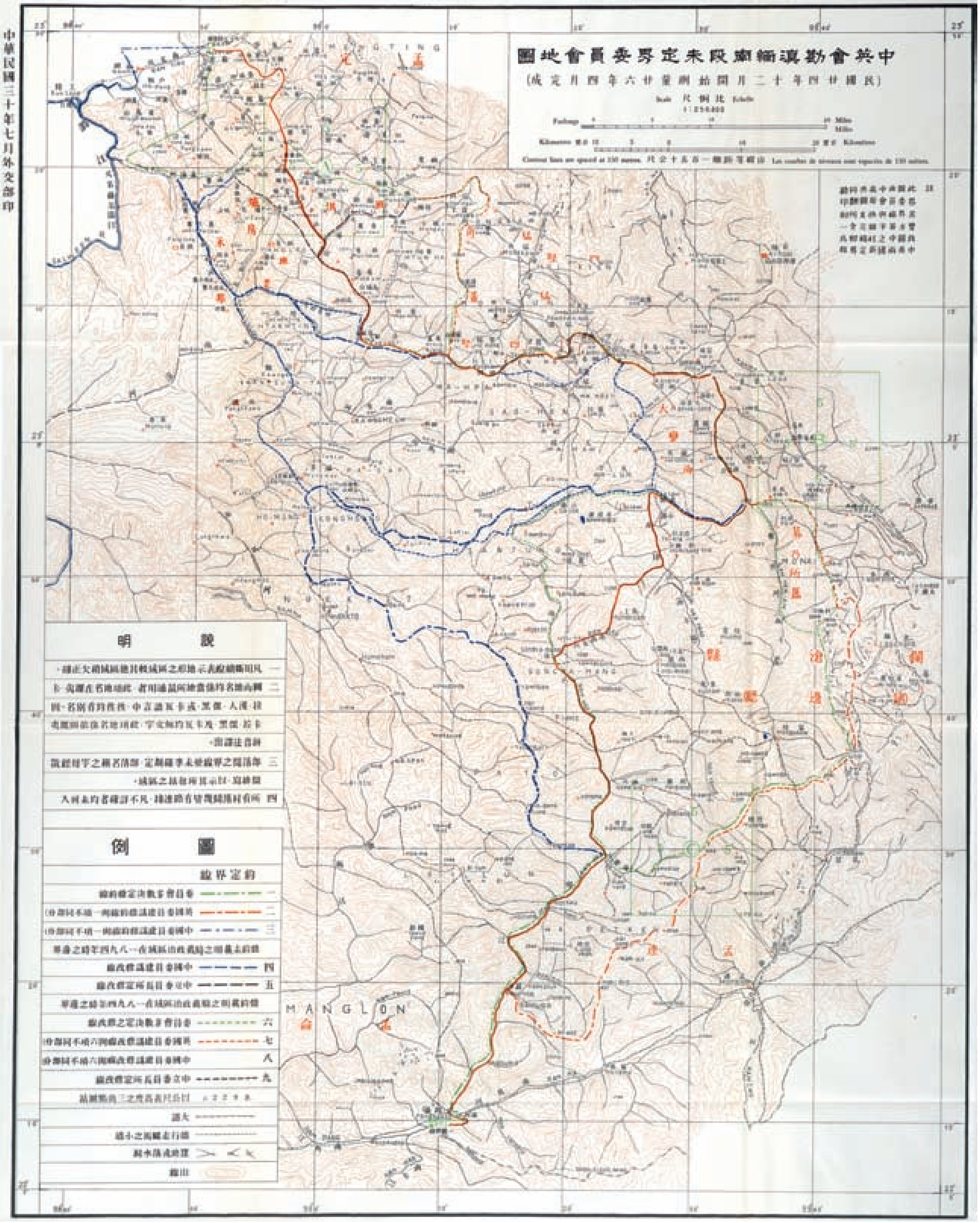
MAP OF THE CHINESE-BRITISH JOINT BOUNDARY COMMISSION FOR THE INVESTIGATION OF THE UNDEMARCATED SOUTHERN SECTION OF THE YUNNAN-BURMA BOUNDARY

CARTE DE LA COMMISSION MIXTE ANGLO-CHINOISE DE FRONTIERE CHARGEE DE PROCEDER AUX INVESTIGATIONS NECESSAIRES SUR LA SECTION MERIDIONALE NON DELIMITEE DE LA FRONTIERE ENTRE LA BIRMANIE ET LE YUNNAN

Surveying commenced in the twelfth month of the twenty-fourth year of the Chinese Republic (December 1935) and completed in the fourth month of the twenty-sixth year (April 1937).

Levés commencés le douzième mois de la vingt-quatrième année de la République chinoise (décembre 1935) et achevés le quatrième mois de la vingt-sixième année (avril 1937).

中華民國三十年七月外交部印



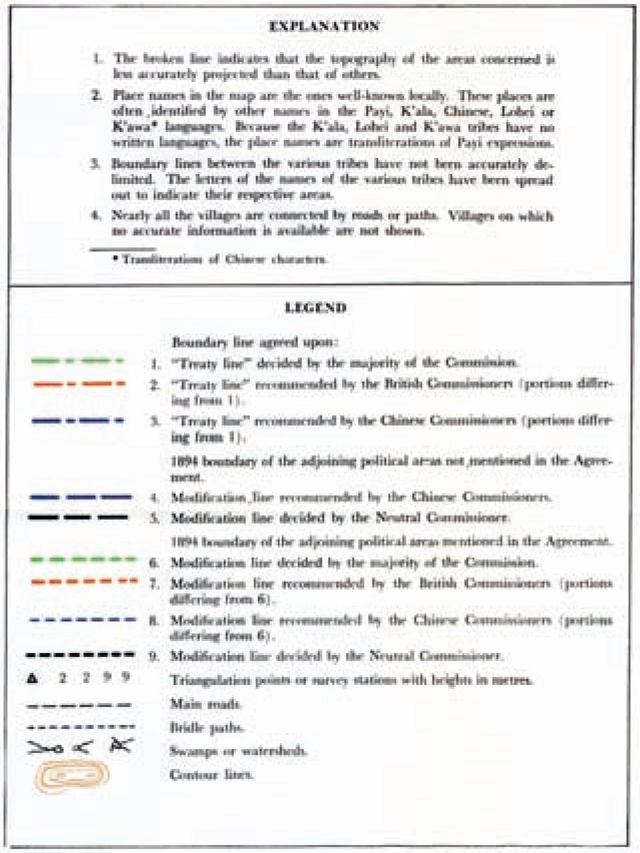



FIG. 108. ENGLISH LEGEND FROM THE MAP OF THE CHINESE-BRITISH JOINT BOUNDARY COMMISSION. See figure 107.
Size of the detail: 20.4 × 14.9 cm. © 1947 United Nations.

past, rather than a complex feudal hierarchy of tribute based on people rather than territory. Another map from 1935, also still reproduced (e.g., Wirot, Somkiat, and Sarita 2006, 84), shows territories "lost" to Britain and France by date from a mythical territorial zenith. The domestic popularization of Thai claims via these maps enabled the Thai government, encouraged by Japan, to mount a successful border war with French Indochina in 1940–41, which gained for Thailand parts of Laos and Cambodia. In 1943 Japan also ceded to Thailand parts of occupied British Malaya and Burma; but all the Thai gains were returned upon Japan's defeat in 1945.

The independence of former British and French colonies since World War II led to no major boundary changes, although most of the boundaries have been resurveyed and redemarcated in light of the greater geographical knowledge produced by the military needs and technological advances of both World War II and the Vietnam War, the needs of the new nations to assert their authority on border tracts, often home to guerilla groups, or to eliminate the potential for border incidents with neighbors due to increasing transboundary development and trade. Internal and external politics often played a role in the timing of these resurveys, for example, China's boundary treaties and redemarcations with postcolonial Burma (1960–61), Laos (1990–93), and Vietnam (1993–2008) all occurred during times of internal or external threats for the ruling Chinese Communist Party or its clients such as the Khmer Rouge (Fravel 2008, 86–91, 144–48).

The Burma-China boundary, defined in several colonial agreements between 1886 and 1941, was confirmed with only minor changes by a 1960 treaty between independent Burma and Communist China. The treaty, one of few regional postcolonial boundary treaties whose maps have been publicly distributed, was only issued in the United Nations *Treaty Series* a quarter-century later (UN 1984). It has a general description of the boundary accompanied by fifteen 1:250,000 and ten 1:50,000 maps, of which ten and five respectively were to Burmese specifications, in Burmese and English, and five and five respectively to Chinese specifications, in Chinese and English. The treaty authorized a resurvey of the boundary, resulting in a protocol that defined the boundary very precisely (the 2185.74575-km length being measured to the nearest half-decimeter). Fifty-seven Burmese and seventy-four Chinese maps at a scale of 1:50,000 accompanied the protocol. Both sets of maps only depict terrain within a few kilometers of the boundary, though whether this was for simplicity or reasons of secrecy is not clear. A further sixty maps at 1:5,000, again in two parallel national sets of thirty, depict two complicated sections of the boundary across relatively densely populated river flats (fig. 109). In forested areas, flowering trees were planted to help indicate the boundary, and rows of trees were planted across cultivated areas. The treaty and protocol have remained uncontested since, and the boundary was tied to the China-Laos boundary, originally demarcated in 1895 and redemarcated 1991–93, by a trilateral agreement signed on 8 April 1994 to erect a trijunction pillar. Rather than a map,

(*Facing page*)
FIG. 107. MAP OF THE CHINESE-BRITISH JOINT BOUNDARY COMMISSION FOR THE INVESTIGATION OF THE UNDEMARCATED SOUTHERN SECTION OF THE YUNNAN-BURMA BOUNDARY, 1937, 1:250,000. On the *Zhong ying huikan dian mian nanduan weidingjie weiyuanhui ditu* 中英会勘滇缅南段未定界委员会地图, colored linework shows the various claims and the final decision of the neutral commissioner regarding the Sino-Burmese boundary in the Wa states.
Size of the entire original: 91 × 50.5 cm (including English and French legends, not shown here, but see fig. 108); map: 66 × 50.5 cm. From UN 1947, facing 232. © 1947 United Nations.

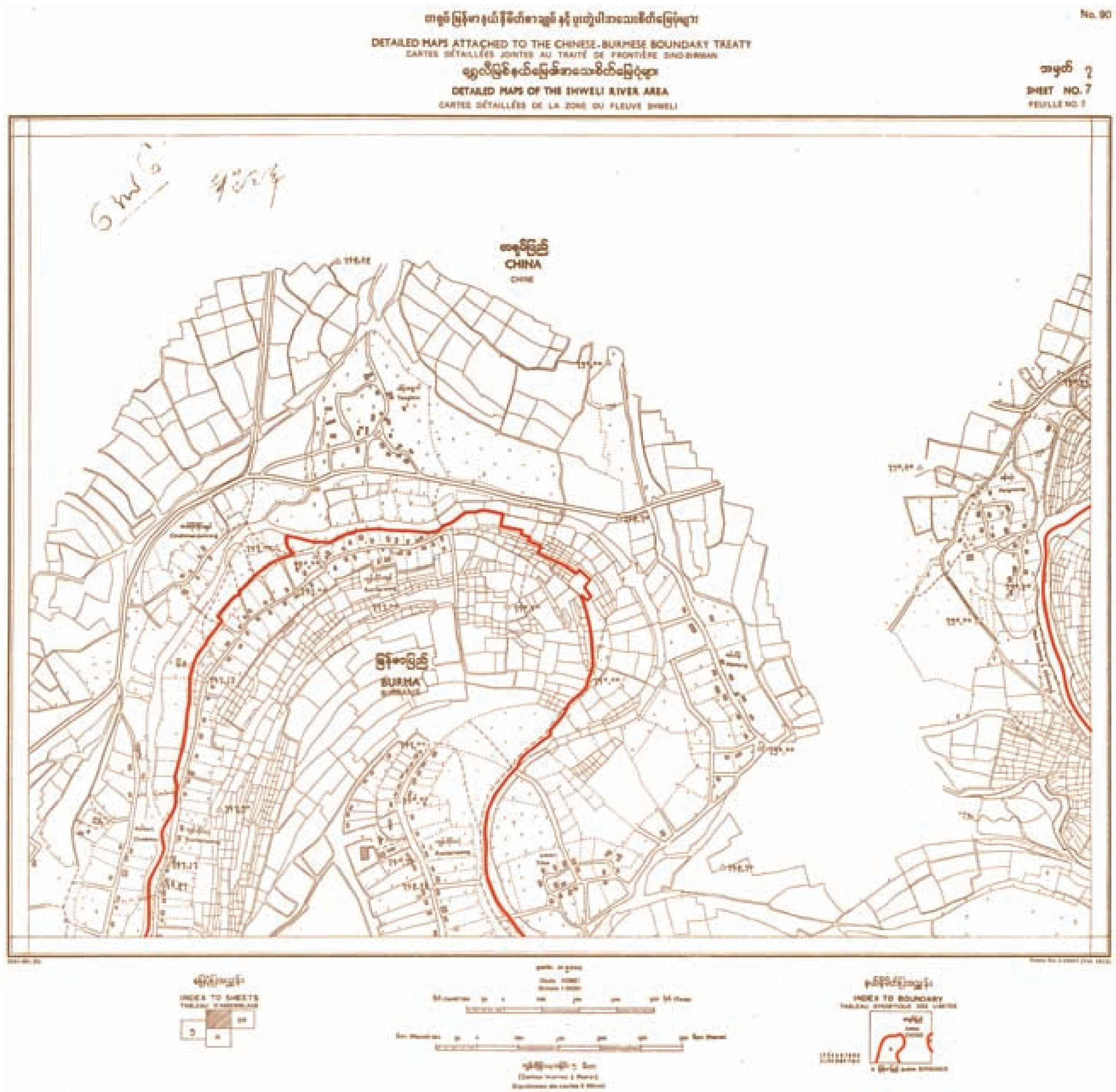



FIG. 109. DETAILED MAP ATTACHED TO THE CHINESE-BURMESE BOUNDARY TREATY. Map of the Shweli River area, sheet 7, original scale 1:5,000. One of a series of large-scale maps accompanying the 1961 Sino-Burmese Boundary Protocol and showing the boundary following a former bed of the Shweli River.
Size of the original: 52.4 × 53.4 cm. From UN 1984, vol. 1012, no. 90. © 1984 United Nations.

this agreement included an aerial photograph at 1:5,000 to indicate the locations of the trijunction in the river and of two reference pillars on opposite banks (Whyte 2013).

The Thai-Malaysian boundary was originally mapped in 1909 on a single sheet at 1:250,000 (fig. 110), and marked in 1910–11 with 109 pillars, about one every six kilometers. A second survey and demarcation were carried out on the land section of the boundary between 1973 and 1985, with 12,169 additional pillars in four classes erected (more than one every 50 m), and a set of 1:2,500-scale field plans of the entire boundary produced. The ninety-five-kilometer riverine section was resurveyed beginning in 1993 to precisely determine the thalweg; by 2006 over 7,500 pillars and reference markers had been emplaced.

American, and later Soviet, mapping of Indochina during and after the Vietnam War revealed more ac-

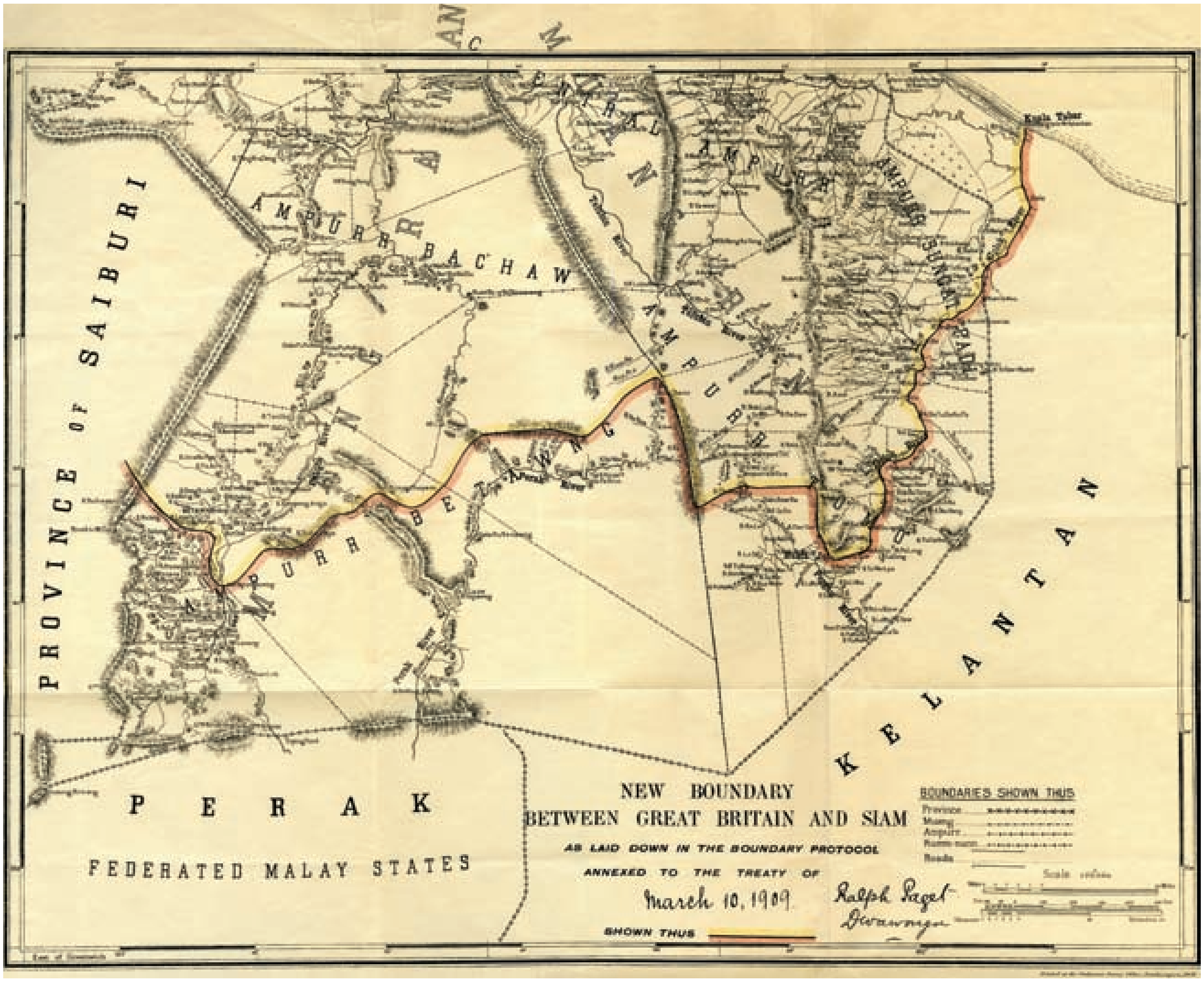



FIG. 110. *NEW BOUNDARY BETWEEN GREAT BRITAIN AND SIAM AS LAID DOWN IN THE BOUNDARY PROTOCOL ANNEXED TO THE TREATY OF MARCH 10, 1909.* Black and white with colored boundary line, 1:320,000. Map accompanying the 1909 Malaya-Siam boundary treaty and revealing the limited geographical knowledge of the area. Size of the original: 42.1 × 51.7 cm. From *Despatch from His Majesty's Minister in Siam, Forwarding a Treaty between Great Britain and Siam, Signed at Bangkok, March 10, 1909, Together with an Explanatory Memorandum [with Map]* (London: Printed for His Majesty's Stationery Office, by Harrison and Sons, 1909), map following 8.

curate alignments of watershed and drainage systems in Indochina than earlier French colonial mapping. This led to realignment of the remote northern section of the Vietnam-Cambodia boundary, which until then had been defined only by lines drawn on French-period mapping without any accompanying textual description (U.S. Department of State 1976, no. 155).

Compared to the boundaries of India-Pakistan, India-China, China-Russia, and the two Koreas, Southeast Asia has had few boundary disputes since 1945, and those that still exist mainly involve Thailand. The most serious is the question of ownership of the temple of Preah Vihear, located on an escarpment of the Dangrek range overlooking the Cambodian plains. The ownership of the temple itself was decided in 1962 by the International Court of Justice (ICJ), based on evidence that the set of 1:200,000 maps of the Franco-Siamese boundary survey of 1904–8 had left the temple in Cambodia (fig. 111). Thai arguments that the line shown on the maps contradicted the treaty text, and that the maps had been unilaterally produced by the French were both rejected. The ICJ held that if the text, defining the boundary along a watershed, was meant to be definitive, the maps would not have been necessary. The creation of the maps thus implied that a verbal description of the boundary was insufficient. Thailand itself had acknowledged at the time its technical inability to contribute to mapping and had asked France to prepare the maps.

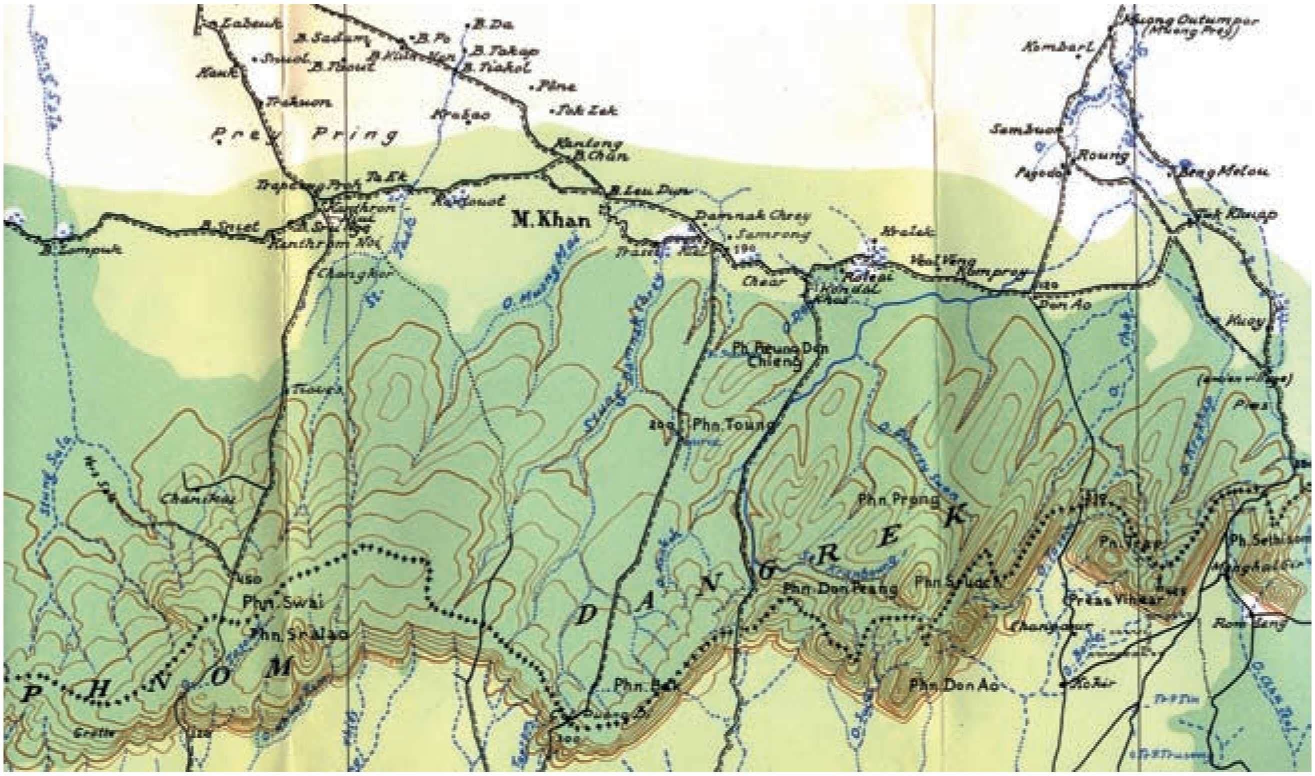



FIG. 111. DETAIL FROM *DANGREK: COMMISSION DE DÉLIMITATION ENTRE L'INDO-CHINE ET LE SIAM*, CA. 1907. H. Barrere, Paris, 1:200,000. French-produced map of the boundary of Siam and Cambodia submitted to the ICJ by Cambodia in 1959 and which caused the ICJ to rule in favor of Cambodian possession of the temple of Preah Vihear in 1962.
Size of the entire original: 50.3 × 63.7 cm; size of detail: 17.3 × 29.4 cm. From International Court of Justice 1962, map in back pocket of vol. 1. © 1962 United Nations.

Thailand had then accepted the maps and used them for official purposes for several decades without complaint. Despite the ICJ award of the temple itself, the land immediately around the temple remains in dispute, and official maps from both sides, including Cambodian planning maps associated with the elevation of the temple to World Heritage status in 2008, continue to cause diplomatic complaints. Due to ongoing boundary disputes not only with Cambodia but also with Laos and Burma, Thai topographic maps of the disputed areas, even its civilian 1:250,000 series 1501S, remain unavailable to the general public. Apart from these few remaining active disputes, boundary surveying in East Asia in the early twenty-first century is mainly limited in each country to maintenance and repair of boundary vistas and existing pillars, the erection of additional auxiliary pillars, and the tying of its national boundaries to the increasingly comprehensive national cadastre (table 8).

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SEE ALSO: Boundary Disputes; Law of the Sea; Military Mapping by Major Powers

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Table 8. East and Southeast Asian boundaries in the twentieth century

| Countries | Boundary Characteristics | Treaties |
|---|---|---|
| Burma-Bangladesh | Ca. 193 kilometers | Colonial treaties and demarcation. Burma-Pakistan agreements 1964 and 1966. |
| Burma-India | Ca. 1,460 kilometers: 60% watersheds, 33% watercourses, 7% straight lines between pillars from 1894 | Various treaties and surveys 1826–96, demarcations to 1901, and minor alterations 1921 and 1922, all replaced by comprehensive treaty 1967. Final demarcation based on the 1967 treaty does not appear to have been completed. Due to the India-China boundary dispute, the India-Burma-China trijunction remains indeterminate. |
| Burma-China | 2185.74575 kilometers: mainly watersheds and watercourses | Colonial treaties 1886, 1894, 1897, 1914, 1941. UN-published agreement and treaty 1960 and protocol 1961 (with maps). Trijunction with Laos demarcated in 1994. Trijunction with India remains indeterminate. |
| Burma-Laos | Ca. 235 kilometers: entirely along thalweg of Mekong River | Franco-British agreement 1896. Trijunction with China demarcated 1994. |
| Burma-Thailand | Ca. 1,800 kilometers: mainly watercourses and watersheds | Anglo-Siamese agreements and treaties 1828, 1868, demarcation 1889–92, minor modifications 1931–32, 1934, 1937, 1940. Modifications by Japanese 1943, annulled 1945. Treaty 1991. Resurvey and demarcation of Mae Sai River from late 1980s, mapped at 1:50,000 with 1:5,000 field plans. Three Pagodas Pass dispute remains unresolved. |
| Laos-Thailand | Ca. 1,754 kilometers: 55% Mekong (in two sections), 8% other watercourses, 37% watersheds (in two sections) | Franco-Siamese treaties 1893, 1904, 1907 (surveyed 1905–8 with five 1:200,000 maps), 1925, 1926 (Mekong River survey with 1931 atlas of 1:25,000 maps), 1939, 1941, 1946. Several areas disputed after Lao independence in 1949 and remain unresolved. Demarcation of majority of both land segments from late 1990s. |
| Laos-Cambodia | 541 kilometers: 62% watersheds, 38% watercourses | Colonial treaties and agreements 1863, 1867, 1893, 1902, 1904, 1905. Some minor disputes remain, reflected by large-scale Lao maps remaining restricted in these areas. |
| Laos-Vietnam | 2,067 kilometers: 85% watersheds, 11% water courses, 4% straight lines (in three segments) | An internal colonial boundary, textually described in part by a 1916 decree. Surveyed but lacking textual documentation. Postcolonial treaties 1977, 1986/87 with 173 1:25,000 maps and 1:5,000 and 1:10,000 maps for precise location of pillars. Demarcation 1976 to 1986 with 214 pillars. 1995–2004 1:50,000 mapping of boundary produced. Trijunction with China demarcated 2006. |
| Laos-China | Ca. 425 kilometers: follows watersheds for entire length, except for the crossing of a single river | Colonial treaties 1885, 1895 with demarcation by 15 pillars. Postcolonial treaty 1991, boundary redemarcated 1992–93 with 45 pillars. |
| Vietnam-China | 1,406 kilometers: 64% watersheds, 28% watercourses, 3% straight line segments, 6% other features | Colonial treaties 1885, 1887, 1895, with demarcation by 341 pillars. Postindependence incidents from 1974 on, leading to war 1979, and firefights until 1989. Agreement 1993, aerial survey agreement 1996, treaty 1999. Demarcation 2001–8 with 1,533 pillars. |
| Cambodia-Vietnam | 1,137 kilometers: straight lines following cultural features (roads, canals) are used in the Mekong Delta. Then watercourses and watersheds predominate to the Lao trijunction | Franco-Cambodian demarcation 1868–69, revised in 1870. Further agreements in 1873/74. French decrees with some demarcation 1897, 1899, 1904, 1914, 1932, 1933, 1935, 1936, 1942. Border incidents 1975–79, postcolonial treaties 1983, 1985, 2005, anticipating demarcation by 375 pillars 2006–8. |

(*continued*)

Table 8. (*continued*)

| Countries | Boundary Characteristics | Treaties |
|---|---|---|
| Cambodia-Thailand | Ca. 798 kilometers: 65% watersheds, 26% water courses, 9% straight lines | Franco-Siamese treaties 1867, 1902, 1904, 1907 (partially demarcated 1905–8 with 73 pillars, and six 1:200,000 maps), 1925, 1941, 1946. Cambodia took Thailand to the ICJ in 1959 over the ownership of Preah Vihear temple. The 1962 judgment ruled the temple Cambodian, based on cartographic evidence, however the boundary remains mainly undemarcated, and actively contested in several places. |
| Thailand-Malaysia | 646.5 kilometers: 85% watersheds, 15% water courses | Treaty and protocol of 1909, with map. Modification by Japan 1943, annulled 1945. Memorandum of Understanding on resurvey 1972, watershed survey and demarcation 1973–85, maintenance resurvey began 1993; riverine resurvey and demarcation from 2000. |
| North Vietnam–South Vietnam | Ca. 76 kilometers: 68% watercourse, 32% following a parallel | Defined by 1954 Geneva Conference as provisional military demarcation line, within 6–11 kilometer wide demilitarized zone, mapped at 1:25,000. Boundary removed by Vietnamese reunification 1976. |

Historical and geographical descriptions and maps of the various boundaries of East and Southeast Asia have been made by the U.S. Department of State, Office of the Geographer (1961–85), Prescott (1975), and Prescott, Collier, and Prescott (1977). More recent studies of specific boundaries include Lafont (1989), Gay (1995), and Fravel (2008).

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***Bundesamt für Kartographie und Geodäsie (Federal Office for Cartography and Geodesy; Germany).*** The Bundesamt für Kartographie und Geodäsie (BKG) was founded in 1997 by the German federal government to provide basic cartographic information and geodetic reference frames for national tasks, to carry out applied research and technological development, and to represent Germany internationally in the areas of applied GIScience and geodesy. The BKG has three departments: geoinformation (applied GIScience including cartography), geodesy, and central services including information technology (IT). The headquarters are in Frankfurt am Main with a branch office in Leipzig and a geodetic observatory in the Bavarian forest. After a reorganization in 2000, the BKG had about 300 staff. Administratively, it is under the Bundesministerium des Innern.

The BKG had three predecessors in more than a century of development in official German topographic cartography: from 1875–1919, the Königliche Preußische Landesaufnahme (PLA); from 1919–45, the Reichsamt für Landesaufnahme (RfL); and from 1950–97, the Institut für Angewandte Geodäsie (IfAG).

The PLA, a military institution founded by order of the central board of directors of surveying and mapping in Prussia, carried out geodetic, topographic, and cartographic work in Prussia and the northern German states for both military purposes and the country's development (e.g., railways, roadways). After World War I, in compliance with the Treaty of Versailles, the PLA was transformed into the RfL in Berlin. This civil organization, established by a Reich President's decree and advised by the surveying board, the Beirat für das Vermessungswesen, promoted basic geodetic work and the production of topographic maps of the northern German states, while the survey offices of the southern German states continued to work independently. The RfL was under the Reichsministerium des Innern.

After the Nazis' rise to power in 1933, official surveying and mapping were declared a matter to be centrally controlled by the Reich. Hence the responsibility of the RfL was extended to the southern German states, and the Beirat was dissolved. In 1938, a certain decentralization occurred when fourteen surveying divisions—Hauptvermessungsabteilungen (HVA)—were established in the provinces to carry out topographic mapping for the official map series at 1:25,000 and the new German base map, the Deutsche Grundkarte DGK 1:5,000. Both used cadastral maps, photogrammetry, and plane tabling to uniform specifications and technical instructions issued by the RfL. At the same time, the geodetic work and production of the official map series at the RfL served the preparations for World War II, during which the RfL was also ordered to carry out geodetic and cartographic work in the conquered countries.

After 1945 official surveying and mapping developed differently in East and West Germany. In the former East Germany the production of map series had to be carried out according to the directions of Soviet Russia whereas the Grundgesetz of West Germany again made the states responsible for official surveying and mapping of their territories, and the remainder of the HVA were transformed into state surveying offices, Landesvermessungsämter (LVA). The *Länder* voluntarily established an advisory committee, the Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder (AdV), to ensure uniform quality of geodetic work for the official map series (Krauß and Harbeck 1985, 19–21). The AdV develops and endorses by consensus standard specifications for all official map series to be applied by the LVA (1:5,000–1:100,000) and the IfAG (1:200,000–1:1,000,000).

The BKG's direct predecessor, the IfAG, developed from the remainder of the RfL after the end of World War II. While the cartographic division remained in Berlin, the geodetic division had been moved to Bamberg in Bavaria. The former RfL staff worked for almost five years as a private land survey office (LSO) for the U.S. Army, later renamed the Institut für Erdmessung. Thus, Nazi Germany's geospatial intelligence about Eastern Europe and Russia was transferred to the United States (Cloud 2002). In 1950 the institute's headquarters was established in Frankfurt, and, renamed IfAG, it became division II of the DGFI (Deutsches Geodätisches Forschungsinstitut). Its mission initially was to carry out applied research in geodesy, photogrammetry, and cartography, but after 1952, according to an agreement with the *Länder*, the IfAG was also charged with producing the official map series at smaller scales partly carried out in the Berlin-based branch office established in 1956. In October 1990, following the treaty on the reunification of Germany, most of the staff both of the Forschungszentrum Geodäsie und Kartographie in Leipzig and of the Kartographischer Dienst of the VEB Kombinat Geodäsie und Kartographie located in Leipzig and Potsdam were integrated into IfAG's branch offices in Berlin and one newly opened in Leipzig.

In 1996, due to the transition from analog to digital cartographic technologies, the GeoDatenZentrum (GDZ) was set up in the Leipzig office to provide the federal institutions with harmonized geodetic and topographic information on Germany's territory. For this purpose the GDZ regularly collects the digital data sets of the official topographic cartographic information system (Amtliches Topographisch-Kartographisches Informationssystem [ATKIS]) established and maintained by the state surveying offices. From 2000 the ATKIS basic landscape model of Germany at 1:10,000 (Basis-DLM) served as the reference map for the Geodateninfrastruktur Deutschland (GDI-DE).

Like its predecessors, the BKG concentrated on delivery of the highest-quality topographic information for Germany in terms of content, accuracy, timeliness, and map design through well-coordinated and cost-efficient acquisition of topographic information and the employment of state-of-the-art technologies for the production of the map series. The PLA worked out useful guidelines for cartographic generalization of the 1:25,000 map to provide cost-effective content for the maps at 1:100,000 and 1:200,000. In addition, a topographic overview map at 1:800,000 of Central Europe and the Middle East was published. The RfL continued updating the 1:25,000 map and modernized its design using three-color offset printing, and it also published a new map series at 1:200,000 and 1:300,000 of Central Europe (fig. 112) as well as sheets of the International Map of the World (IMW); work on the overview map at 1:800,000 was discontinued.

In the early years IfAG continued to investigate analog cartographic technologies. It also contributed significantly to the IMW including organizing the technical United Nations conference in Bonn 1961 with IfAG's director Erwin Gigas as conference president. From the late 1960s research and development concentrated on computer-assisted cartography. IfAG procured an experimental hardware and software system for map digitization in both raster and vector formats and for cartographic data processing funded by Deutsche Forschungsgemeinschaft (DFG), the German science foundation. Thus IfAG became the center of cartographic research in Germany until 1997 when it closed down. Both researchers of IfAG and universities carried out coordinated basic research into the calculation of graticules, cartographic pattern recognition, cartographic database design, generalization, and name placement; effective procedures for raster data–based updating of topographic maps were also developed. Between 1981 and 1999 aerial and satellite map imagery of the Antarctic region from 90°W to 15°E and 62°S to 83°S at scales 1:250,000 and 1:1,000,000 were produced.

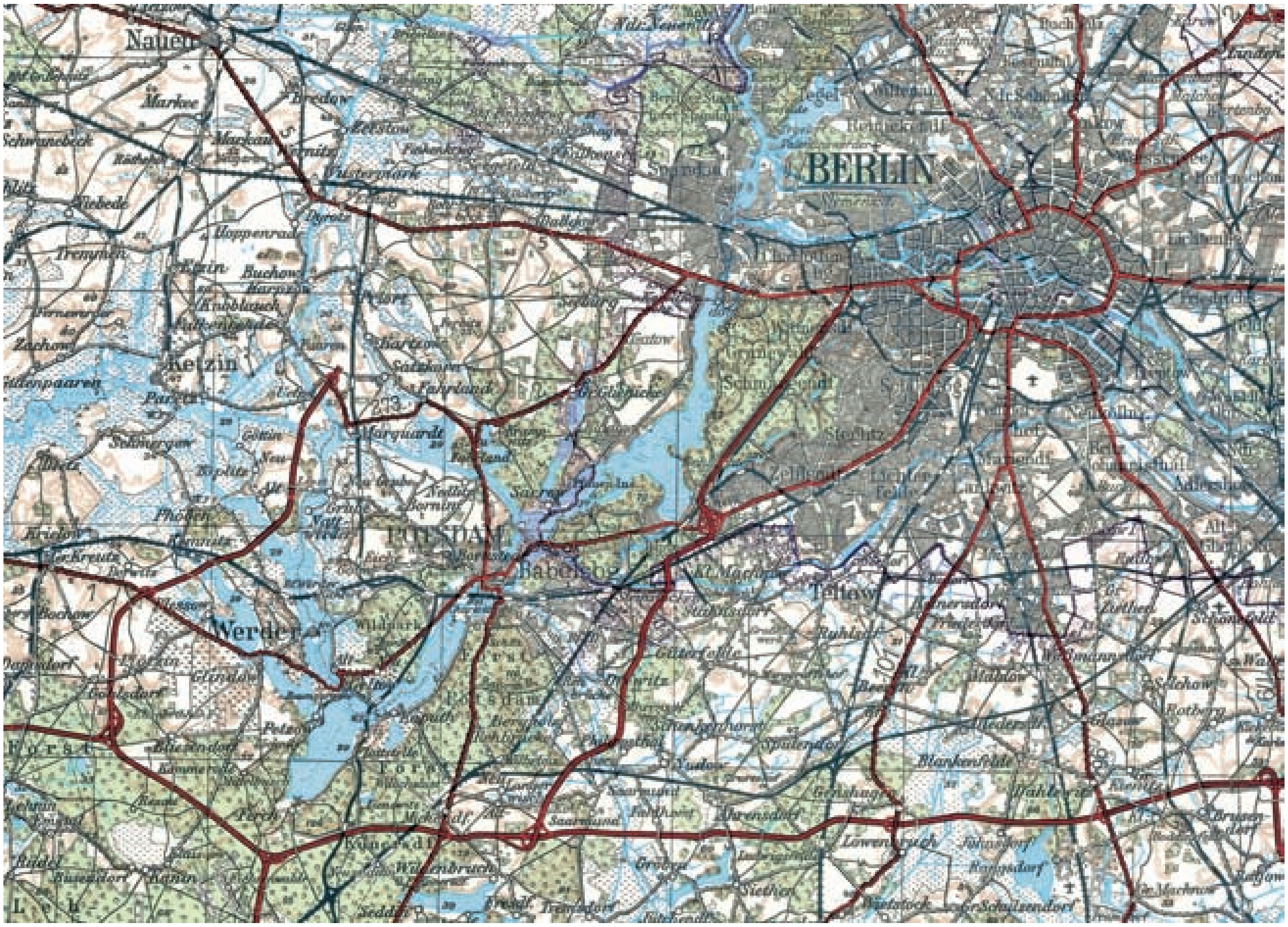


FIG. 112. DETAIL FROM THE GENERAL MAP OF CENTRAL EUROPE, 1:300,000, 1942; EDITORIAL CHANGES 1962. Übersichtskarte von Mitteleuropa, sheet N 53 *Berlin*, in six colors.

Size of the entire original: 46.5 × 54.8 cm; size of detail: 13.2 × 18.4 cm. © Bundesamt für Kartographie und Geodäsie, Frankfurt am Main.

From the late 1980s IfAG concentrated on the digital production of the topographic map series at 1:200,000, 1:500,000, and 1:1,000,000 in the context of the ATKIS project (fig. 113). The BKG continued with these activities focusing on database-driven map production in spatial data infrastructure (SDI) environments aiming at high-quality cartographic design that allows the portrayal of topographic information on all modern media.

IfAG/BKG was a strong supporter of official topographic cartography in Europe. IfAG was a founding member both of CERCO (Comité European des Responsables de la Cartographie Officielle) and of MEGRIN (Multipurpose European Ground-Related Information Network). BKG contributed significantly to the management and production of the EuroBoundaryMap (EBM, 1:100,000 and 1:1,000,000), EuroRegionalMap (ERM, 1:250,000), and EuroGlobalMap (1:1,000,000) products.

DIETMAR GRÜNREICH

SEE ALSO: Akademie für Raumforschung und Landesplanung (Academy for Spatial Research and Planning; Germany); Geodetic Surveying: Europe; Preußische Landesaufnahme; Topographic Mapping: Western Europe

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***Bundesamt für Landestopographie (Federal Office of Topography; Switzerland).*** On 20 September 1832, Guillaume-Henri Dufour from Geneva was appointed Oberstquartiermeister and assigned the task of creating a general map of Switzerland. Based on the baseline observations in the Grosses Moos between Walperswil and Sugiez (in 1791, 1797, and 1834), a so-called primordial triangulation was carried out across the Alps. In 1838, Dufour founded the Eidgenössisches


FIG. 113. DETAIL FROM THE GENERAL TOPOGRAPHIC MAP, 1:200,000, 1994. Topographische Übersichtskarte, sheet CC 3942 *Berlin*, in eleven colors.

Size of the entire original: 48.6 × 70.7 cm; size of detail: 13.2 × 18.4 cm. © Bundesamt für Kartographie und Geodäsie, Frankfurt am Main.

Topographisches Bureau in Geneva, which marked the beginning of the Bundesamt für Landestopografie swisstopo, its official name since 2002 (earlier names were Abteilung Landestopographie [1908], Eidgenössische Landestopographie [1968], and Bundesamt für Landestopographie [1979]) (Gugerli and Speich 2002).

The topographic surveys initiated by Dufour were conducted by the cantons beginning in 1839. These surveys led to the *Topographische Karte* 1:100,000 (monocolor copper engraving), which was printed in twenty-five sheets between 1845 (sheet XVI) and 1865 (sheet XIII). For terrain representation Dufour used shaded hachures and rock engravings with arbitrary lighting from the northwest to enhance details.

Dufour, who was named general in the wake of the Sonderbund War, began reaping honors from the federal government for his successful maps. The highest peak in Switzerland, the Höchste Spitze, was renamed Dufour Spitze, which required a correction of the Dufour map even before the first edition was published. At the Exposition Universelle in Paris in 1855, the Dufour map won a gold medal. Numerous other awards at international exhibitions followed.

The sheets of the Dufour map were revised about every ten years. The third edition was printed using lithography instead of the original engraved copperplates. Over the years the graphic map elements were modernized: a second color, blue, was introduced for hydrographic features between 1908 and 1910. A green forest tint and a red-violet kilometer grid were added later for military use.

The central committee of the Schweizer Alpen-Club (SAC), founded in 1863, published that same year the first excursion map at the scale 1:50,000 for the Tödi-Clariden region. The organization made a request to the Bundesrat for the publication of further topographic maps at that scale, as had the geologists of the Schweizerische Naturforschende Gesellschaft.

On 22 November 1867, Colonel Hermann Siegfried, Dufour's successor, was commissioned to design a na-


FIG. 114. DETAIL FROM *LUZERN*, 1:25,000, 1890. This is from the first edition the Siegfried map, sheet 205. Copper engraving in three colors.
Size of the entire original: 33.2 × 40.9 cm; size of detail: ca. 10.2 × 8.4 cm. © swisstopo. Reproduced by permission of swisstopo (BA13119).

tionwide set of maps at the scale 1:25,000 for the Jura Mountains, the Central Plateau, and southern Ticino and at the scale 1:50,000 for the Alps. The *Topographische Atlas der Schweiz*, now known as the Siegfriedkarte, was published in three colors: black for location and lettering, brown for contour lines, and blue for hydrographic features (fig. 114). The sheet divisions set by Dufour were retained, and the sheet size was refined to 35 × 24 centimeters (Dufour map = 70 × 48 cm).

Copper engraving was chosen for the maps at the scale 1:25,000 (with a contour interval of 10 m), whereas lithography was used for the maps at the scale 1:50,000 (with a contour interval of 30 m). For financial reasons it was decided to forgo the use of hill shading. Thereafter, private cartographic firms used the official base maps for publishing their own tourist relief maps. The first thirteen sheets of the Siegfriedkarte series were published in 1870, and the last of the 604 sheets appeared in 1926.

In 1903, the Bundesamt für Landestopographie started its own printing shop with presses for copperplates and lithographic stones. Before then, private printing firms (Gebrüder Kümmerly and Heinrich Müllhaupt und Sohn) had printed the maps. Beginning in 1910, maps that were originally engraved on stones were transferred to copperplates and revised sporadically. Offset technology was introduced in 1912.

Along with the development of new technologies, such as terrestrial photogrammetry (tests began in 1892, production in 1926) and aerial photogrammetry (1928), the request for a replacement of the heterogeneous Siegfriedkarte grew. The Siegfriedkarte had become a mosaic consisting of older and newer sheets, sheets of varying accuracy, and sheets with varying richness in content. A further point of criticism was the use of two scales, 1:25,000 and 1:50,000. In addition, a precise leveling line had been observed and the point of origin for the vertical reference, the Repère Pierre du Niton in the harbor of Geneva, was assigned a new elevation of 373.60 meters above sea level, which was 3.26 meters lower than before.

Between 1903 and 1925 a total of twenty-five test sheets were created for a new topographic map. The future scales of the maps were a heatedly debated point, and finally four options were chosen for final discussion: (1) a single map scale 1:50,000; (2) 1:25,000, 1:50,000, and 1:100,000; (3) 1:10,000, 1:33,333, and 1:100,000; and (4) 1:20,000, 1:40,000, and 1:80,000 (which was abandoned early in the discussion).

The SAC, together with scientists and technical and military institutions, was very active in supporting a new national map, and in 1934 Professor Eduard Imhof was commissioned to explore the question of establishing a new official national map of Switzerland. The result was Imhof's *Denkschrift zur Frage der Neuerstellung der offiziellen Landeskarten der Schweiz* (1934) (SAC and Eidgenössische Landestopographie 1979, 17–24).

On 21 June 1935, the federal council passed a law governing the production of the new national map series at scales from 1:25,000 to 1:1,000,000. Due to World War II, top priority was given to the 1:50,000 scale. The sheet divisions were kept as defined by Dufour, whereby each sheet was four times the size of each Siegfried sheet (Jeanrichard 1991). The first offset machine, a Color-Metal (CO 38) with two printing units, began operating in 1940. After Professor Simon Bertschmann assumed the office of the director of the Bundesamt für Landestopographie on 1 January 1952, there was a decisive change in reproduction techniques. In 1953, copper engraving was replaced by glass plate engraving. The engraving instruments were constantly being improved during the retraining period and were, along with the in-house-developed engraving layer, eventually patented and sold to other interested institutions.

Even before all of the maps at all scales were completed (table 9), a six-year revision cycle was introduced.

At first, new map elements were laboriously individually engraved, then copied into the existing map image, and retouched. In the 1970s an employee developed a method by which all of the outdated elements were removed from the positive plate and the remaining elements were etched into a new layer to which the new elements were added. Until the year 2000, about sixty map sheets were revised each year using this method.

TABLE 9. Publishing dates of the different map scales of the Swiss national map series

| | | |
|---|---|---|
| 1:25,000 | 249 sheets | 1952–79 |
| 1:50,000 | 78 sheets | 1938–63 |
| 1:100,000 | 23 sheets | 1954–65 |
| 1:200,000 | 4 sheets | 1971–76 |
| 1:500,000 | 1 sheet | 1965 |
| 1:1,000,000 | 1 sheet | 1994 |

Beginning in 1997, the transition from glass plates and engraving instruments to the screen and mouse was accomplished using a CAD (computer-aided design) system (fig. 115). After extensive evaluation, the vector-graphic software Dry-Nuages was chosen for revising the scanned map originals, and Intergraph components were selected for the raster-based application. The advantages in the graphic quality, in securing and storing the existing map originals, and in increased efficiency were substantial (Hurni and Christinat 1996).

Because there are no vector data produced in a raster-based system, project OPTINA (Optimierung der Nachführung), a geographic information system (GIS)–based cartographic production system, was launched in 2003 for developing a new series of national maps. In 2013, the first sheet at the scale of 1:25,000 was published.

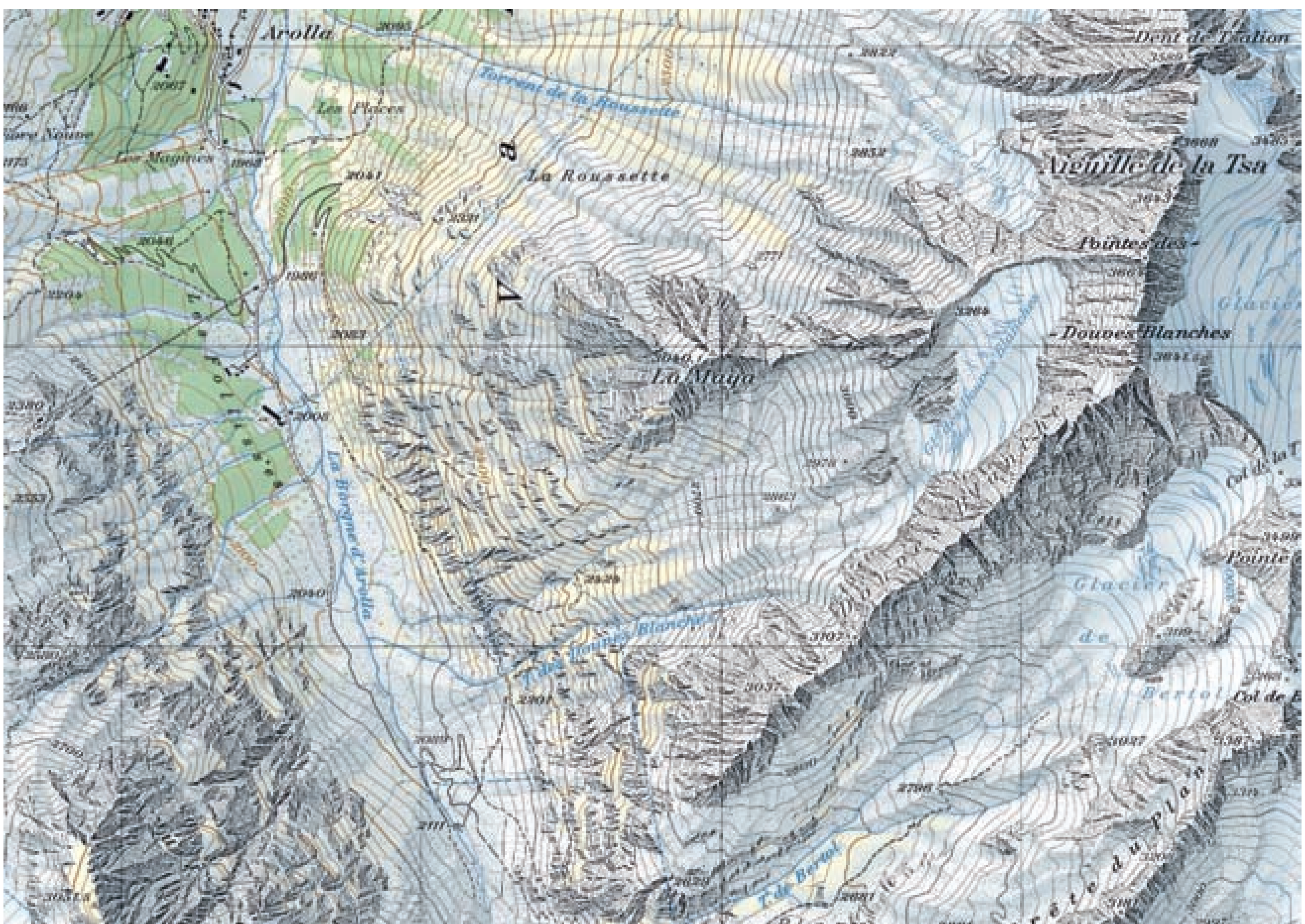


FIG. 115. DETAIL FROM *MATTERHORN*, 1:25,000, 2003. The National Map Series, sheet 1347. Originally scribed on coated glass plates and offset printed in eight colors. Size of the entire original: 48 × 70 cm; size of detail: 12.4 × 17.3 cm. © swisstopo. Reproduced by permission of swisstopo (BA13119).

VECTOR25 and VECTOR200 together make up the digital landscape model of Switzerland. Their content and geometry are based on the printed national map series 1:25,000 and 1:200,000 respectively, and the elements (roads, railway, houses, etc.) are stored in layers.

The Swiss national map series (Swiss Maps 25/50/100), are also available as raster data (on a CD or a DVD, hybrid Mac/PC). Swiss Map 25 is divided into eight regional sectors, each consisting of about forty-five sheets, with large overlaps. In addition to the conventional search and symbol functions, tourist information is available: hiking routes in three categories; Alpine trails; locations of castles, forts, and places of patrimonial heritage. Thanks to the combination of vector data with the digital height model, height profiles as well as distance and time schedules can be calculated for any route.

All of the published maps as well as the original drawings (manuscript maps) were scanned at 220 lines per centimeter (508 dots per inch) and rectified. These data are available as single sheets or as an entire data set. There are over 4,000 sheets of the Siegfriedkarte series alone.

Since 1935 swisstopo has operated its own airplane. All of the aerial photographs taken are cataloged in the swisstopo archives and made available to the public. Since 2000, an orthophoto (SWISSIMAGE) covering all of Switzerland has been produced and revised every six years. In 1999 the Eidgenössische Vermessungsdirektion staff, formerly part of the Eidgenössisches Justiz- und Polizeidepartement, joined swisstopo.

Beginning on 1 January 2002, swisstopo was no longer overseen by the general secretary of the minister of the Eidgenössisches Departement für Verteidigung, Bevölkerungsschutz und Sport, but instead by the Kompetenzzentrum des Bundes für die Beschaffung von technologisch komplexen Systemen und Materialien (armasuisse), which founded a new technology and research division. On 1 January 2006 the Bundesamt für Wasser und Geologie was dissolved and the Geologische Landesaufnahme joined swisstopo. One of the main tasks of the Geologische Landesaufnahme is producing the geological atlas of Switzerland at 1:25,000.

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SEE ALSO: Geodetic Surveying: Europe; Topographic Mapping: Western Europe

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