# O

***Oblique and Perspective Views.*** Maps that take an oblique or perspective view as if drawn from the air have been a popular means of illustration for centuries. The twentieth century witnessed continued use of such techniques in the form of panoramic or bird's-eye views that provided refreshing alternatives to the conventional orthogonal view offered by most maps. Often colorful, informative, and visually exciting, this cartographic form was typically the product of a highly skilled professional artist, unfettered by the constraints of working in a larger organization and able to combine artistic talent with cartographic discipline. The introduction of digital techniques ensured the future of this genre.

Although perspective mapping, often termed bird's eye or panoramic, had flowered in Europe during the late sixteenth and early seventeenth centuries, North America witnessed a rejuvenation of interest in this style of mapping. Starting in the Midwestern states in the mid-nineteenth century, the panoramic map business flourished into the 1920s, when bird's-eye views became popular in the Middle Atlantic and New England states. Interest in them was immense, fueled by the desire of city fathers to encourage commercial growth and driven by the determination and passion of panoramic map artists such as Albert Ruger, Thaddeus Mortimer Fowler, Lucien R. Burleigh, and Oakley H. Bailey (Reps 1984). Novel and attractive urban panoramas could advertise a city's commercial and residential potential, but as industry in the American heartland waned midcentury, so too did the making of classic bird's-eye views. Oblique aerial photography began to replace the labor-intensive methods of old.

While all panoramic maps of North American cities might be dismissed as simply propaganda, lacking objectivity and of little practical value, many of them evoke the growing vitality of North American cities and demonstrate the effectiveness of blending artistic and cartographic approaches. Most noteworthy is Hermann Bollmann's bird's-eye view of Midtown Manhattan published in 1963 and issued in conjunction with the 1964 New York World's Fair. Capturing the architectural detail of the city down to the individual window and streetlamp, it represents the twentieth-century culmination of the bird's-eye view (see fig. 1048). Another example is the panorama map of Allentown, Pennsylvania (ca. 1922). Drawn painstakingly by Fowler, it presents a vivid impression of the city's energy and vitality (fig. 630).

North American passion for bird's-eye views of cities and towns was mirrored by the infatuation of Alpine Europe with its mountains. The development of the Alpine railways during the late nineteenth and early twentieth centuries brought countless tourists to Central Europe and fostered the development of summer and winter resorts. Artists working through publishers such as Orell Füssli and Baedeker exploited these opportunities to re-create panoramas of the ice-sculpted forms of the Alpine mountains as contexts for holiday destinations. Heinrich C. Berann, who is regarded as the most distinguished Alpine panoramic map painter, successfully combined his skills as an artist with those of a professional cartographer. Berann regarded the panoramic map as an ideal medium for presenting a subjective picture of a mountain scene (Berann and Graefe 1966). The highest peaks, cliffs, and major landforms were emphasized so that readers could instantly recognize the landscape (fig. 631). Sketches and photographs taken from the air were combined with the latest topographic maps and ground-based photographic sources. His panoramic maps gained in popularity during the 1930s, as his area of work expanded from his native Austria to the mapping in 1937 of the famous Jungfraubahn mountain railway in neighboring Switzerland. His fame increased markedly when he was awarded contracts to produce panorama maps of several Olympic games beginning with Cortina in 1956 and ending with Hakuba (Nagano) in 1998. In 1963, Berann began a long-term collaboration with *National Geographic*, painting two Himalayan maps of Khumbu Himal and Mt. Everest.

FIG. 630. BIRD'S-EYE VIEW OF ALLENTOWN BY THADDEUS MORTIMER FOWLER (CA. 1922). With smoke emanating from chimneys, locomotives pulling trains, and cars and pedestrians in the streets, panoramas such as this evoke much of the vitality of the North American city. Size of the original: 72 × 181 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C.


FIG. 631. A PANORAMIC MAP OF YOSEMITE NATIONAL PARK PAINTED BY HEINRICH C. BERANN, 1988. From *Yosemite* National Park Service brochure (Washington, D.C.: National Park Service, U.S. Department of the Interior). Note the striking cloudscape, a feature for which Berann was deservedly renowned. Berann used various techniques to enhance the view. For example, the Yosemite Valley has been straightened and widened to enable a clear view up the valley.
Size of the original: 73.5 × 99 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.

Responsible for illustrating the ocean floor for *National Geographic*, he helped bring universal attention to the oceanographic work of Bruce C. Heezen and his colleague Marie Tharp, now famous for their pioneering physiographic diagrams of the Mid-Atlantic Ridge (see fig. 888).

World War II provided ample subject matter for enlightened journalistic cartographers to experiment. Richard Edes Harrison, the best-known exponent of using perspective views to illustrate wartime events, had no doubt that maps were the chief tool for portraying the war's geography. Leafing through wartime issues of *Time* and *Fortune* magazines, one can sense the drama of the time and can appreciate the new perspective that Harrison's maps provided. By contrast, tight deadlines, limited resources, and strict editorial control provided little opportunity for cartographic innovation by those working for daily newspapers (Ristow 1957). Charles Hamilton Owens's work for the *Los Angeles Times* is therefore recognized as an exceptional example of cartography that was imaginative, highly pictorial, and dynamic (Cosgrove and della Dora 2005). The maps of Harrison and Owens articulated the changing scale of war and exploited the new perspective of the Air Age.

Maps that took a perspective view of the ground provided a valuable alternative to conventional air charts, particularly for navigators conducting wartime operations during World War II. Target perspective charts were designed to depict a cockpit view of the terrain encountered while flying toward a target. The charts were prepared in sets describing several different directions of approach. Each set was based on a circular map generally at a scale of 1:50,000 and centered on the selected target. The first target perspective charts were produced by the Ordnance Survey, using models prepared by the U.S. Bomber Command. Later charts were produced by the Americans, who expedited production by photographing the center map with a tilted camera (Clough 1952, 565).

North American geographers and physiographers such as William Morris Davis, Erwin Raisz, and Armin K. Lobeck, who used available contour data to produce block diagrams and landform maps, made effective use of the perspective view. Few other geographers had their exceptional combination of artistic talent and technical aptitude; it was not until surface plotting programs such as SYMVU and SURFACE II were developed in the late 1960s and early 1970s that oblique views of statistical surfaces appeared with any regularity (Monmonier 1978). Incorporating recently developed hidden-line-removal algorithms, these software packages opened up new opportunities for viewing statistical surfaces. Gradually, these capabilities became more sophisticated and were embedded within geographical information systems that allowed other data layers to be draped over surface models. Perspective views of statistical surfaces became an important part of exploratory data analysis and are now common in geographical and statistical journals.

Technological innovations during the second half of the twentieth century have therefore ensured that the perspective view has not only survived but thrived. The presentation of such subjects as university campuses, architectural plans, golf courses, civic buildings, and recreational amenities are often made more attractive by taking the perspective view. For example, the U.S. National Park Service, an early adopter of electronic cartography for making bird's-eye views, employs a digital process that includes setting viewing parameters in a three-dimensional scene, preparing digital elevation models, modeling buildings, designing trees, and creating environmental special effects (Patterson 2005).

The future of maps that take perspective or oblique views appears to be secure given the growth of online maps of this type. The growing tourist economy has continued to drive its development, and three-dimensional maps of ski areas and summer resorts are as prevalent at the end of the century as they were at its beginning. Furthermore, the ability to explore three-dimensional landscapes interactively through such packages as Google Earth promises to continue this trend.

ALASTAIR W. PEARSON

SEE ALSO: Harrison, Richard Edes; Relief Depiction: Relief Map; Tanaka, Kitirō; Viewshed Mapping

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## Oceanography and Cartography.

**Oceanography and Cartography.** It can be argued that most of the world maps drawn before the twentieth century showed the oceans and seas as a characterless blue reserved for the legend, the names of coastal towns, bays, gulfs, and water bodies, and sometimes sketches of sea monsters. The events of the twentieth century changed all that, as concerted efforts to map the 70.8 percent of the planet covered by oceans was enabled by technologies from the two world wars, and the subsequent Cold War. That century saw an exponential increase in knowledge about the ocean, particularly its floor, as well as the ease with which the ocean's bathymetry can be represented on maps. It involved great progress in navigation, submarine acoustics, space science, digital computation, and the cartographic leap from vector to raster presentation.

Tracing the progress in mapping the deep oceans required an understanding of the technical advances that made it possible. These were in large part due to the impact of submarine and antisubmarine warfare. These advances enjoyed a symbiosis with the blooming of geological understanding of the origins of the oceans, and thus the contribution to hydrographical studies of the earth science community.

### Navigation

All observations at sea depend on a precise knowledge of location. Hydrographic surveys, which began in the early seventeenth century, were limited to shallow waters inshore where ships could run aground. Navigation was based on observation of known objects on shore. On the high seas, celestial navigation was the only source of position fixes, with deduced navigation (dead reckoning) between fixes. Nautical almanacs allowed latitude to be determined at local apparent noon, but relatively accurate measurements of longitude became possible only with the drawn-out development of the ship's chronometer by John Harrison, and its acceptance by the British Navy in 1773. With ephemeredes, sun lines could be taken and good star fixes obtained at nautical twilight when the horizon was still visible.

Electronic navigation at medium ranges followed development of the British Gee (short for "Grid") for directing aerial bombing in World War II. Later, hyperbolic navigation systems like Decca, Loran, and Loran-C allowed continuous positioning using specially printed overlays on navigational charts (Bowditch 1995, 189–206). The first global system was the U.S. Navy's Omega, operated from 1968 to 1997, again with chart overlays, and offering ±2.2-kilometer accuracy.

Following the launch of Sputnik in 1957, navigation by space-borne satellites became possible. The impetus was accurate navigation of missile submarines. The U.S. Navy's Transit or Navsat system operated between 1967 and 1991. It used five satellites in polar orbit, which allowed Doppler-based fixes several times a day. Observations at sea required reception of the transmissions for from two to twenty minutes and allowed ship positioning to within 100 to 400 meters. In the early 1970s, the U.S. Defense Department began development of the Global Positioning System (GPS), which became functional in the mid-1980s. When line-of-sight observation of four or more satellites was available, positions could be obtained up to ten times per second anywhere on earth. Positions were good to 100 meters and then improved to 5 meters with the removal of Selective Availability in 2000. A similar Russian system, GLONASS (Global'naya Navigatsionnaya Sputnikovaya Sistema), was developed on the basis of an early GPS design. New Chinese and European constellations were launched in the early twenty-first century, and by 2010 GPS receivers could track up to 216 satellite channels.

## Underwater Acoustics and Observations from Space

Hydrographic surveys through the 1930s were primarily based on lead line soundings in shallow water. Although expeditions by the Royal Navy from the mid-1700s had shown that the oceans were mostly deep, if not very deep, it was the 492 deepwater soundings by the 1872–76 expedition of the HMS *Challenger*, using a piano wire sounding apparatus along with the specimens collected by nets and dredges, that raised interest in the great depths. The sinking of the RMS *Titanic* in 1912, after its collision with an iceberg, raised interest in using underwater acoustics for object detection. Canadian Reginald Aubrey Fessenden of Boston's Submarine Signal Company (later acquired by Raytheon) is credited with the invention of the first fathometer in 1913–14. However, production of the company's echo sounders only began in 1923. In 1917, during World War I, French physicist Paul Langevin developed an echo ranging system using the piezoelectric effect (electrically producing acoustic pulses in a crystal and vice-versa) that by war's end could locate submarines at a range of 1,500 meters.

The first real use of acoustic echo sounding was the German navy's first *Meteor* expedition, 1925–27, considered the first modern oceanographic expedition. It made some thirteen east-west crossings of the South Atlantic with 67,400 acoustic soundings and showed the rugged nature of the Mid-Atlantic Ridge, the parallelism of its flanks, and its continuation around the Cape of Good Hope into the Indian Ocean.

World War II saw the widespread use of fathometers for inshore navigation as well as ASDIC, developed by the Anti-Submarine Detection Investigation Committee and now called sonar, for the detection of submarines and the targeting of ships by submarines. These systems had been in development following the submarine-caused carnage of World War I. After the war, scientific echo sounders with large (19 inch or 48.26 cm) graphic recorders were developed. By the late 1950s they consisted of huge systems weighing many hundreds of kilograms. In the 1960s, an American engineer at North American Aviation, Thomas H. Gifft, developed and patented a transistorized echo sounder transceiver occupying just three inches of rack panel and a lightweight electrosensitive wet-paper helical recorder that rapidly revolutionized the collection of bathymetric and seismic profiles. At about the same time in 1964, a sonar with multiple narrow beams was developed to fulfill the need for accurately mapping out swathes of seafloor so that Polaris, and later Poseidon, missile submarines could silently patrol above the seafloor and avoid detection while awaiting orders to launch. The first commercial swath or multibeam sonar was installed in 1977. It had sixteen beams covering a bottom swath sector of 45°. In the ensuing years, systems were developed by companies in the United States, Germany, Norway, Denmark, and Finland, and by 2008 there were some 1,098 systems in sixty-nine countries. The bulk of these systems were for inshore mapping in depths of less than 200 meters. They could map swath sectors of over 150° with up to 700 beams with beam-widths of 3° to 0.5°. Probably less than one hundred were for depths to 7,000 meters and fewer still were capable of maximum ocean depths of around 11,000 meters, as in the Challenger and Vityaz-1 Deeps in the Mariana Trench. It should be noted that most of the wide continental margins are at depths less than 200 meters, with the photic zone ending at around 100 meters. Approximately 64 percent of the ocean is deeper than 200 meters.

Effective remote sensing of the earth's oceans began in 1978 with the launch of the short-lived Seasat, the first satellite to use active and passive microwave sensors for all-weather capability and the first with synthetic aperture radar (SAR). In a brief forty-two-hour span of real time measurements it successfully collected data on sea surface winds and temperatures; atmospheric water content; sea ice coverage; internal waves and wave heights; and, for mapping purposes, ocean topography. Later satellites with microwave altimeters could measure their height above the sea surface to an accuracy of around six centimeters, while traveling at seven kilometers per second. As satellite orbit determinations improved, the short-period altimetric perturbations that were originally used to measure oceanographic and meteorological effects proved useful in determining the local gravity by measuring the sea surface slopes. As noted below, this produced one of the major breakthroughs in the gross description of world ocean bathymetry. The year 1978 also saw the launch of the Nimbus 7 carrying the Coastal Zone Color Scanner (CZCS), the first six-channel radiometric color scan of solar reflection off the sea surface. This technology, later very important to understanding the carbon cycle, mapped chlorophyll concentration in the water, suspended sediment distribution, salinity, and the temperature of coastal waters and ocean currents.

## Continental Drift, Seafloor Spreading, and Global Tectonics

The 1912 theory of Alfred Wegener and evidence in the 1920s from Alexander Du Toit suggested that continental drift was responsible for the parallelism of Atlantic shorelines, as well as the fitting together of rock sequences, mountain ranges, glacial evidence, and fossil assemblages in Pangaea, a proto-continent. As noted above, the 1925–27 *Meteor* expedition had shown the existence, symmetry, and continuity of the midocean ridge in the South Atlantic. Following World War II, three developments formed the basis of the proof of continental drift and provided the explanation of the mechanism. All three were related to research mandated by the needs of the Cold War. One was the study of the magnetic field over the oceans, and especially paleomagnetism, which permitted measurement of magnetic latitude as well as field polarity. The second was the worldwide establishment of instrumented seismographs, funded largely because of the need to detect underground nuclear explosions, which began to show the earth's seismicity in greater detail. And the third was the continuous recording of echo soundings by research vessels as well as extensive surveys undertaken by the U.S. Navy's Project Seascan, which began in 1960. This was an open scientific program for studying ocean depths, seawater temperature profiles, wave heights, and water chemistry. The needs of the American military for seagoing geophysical and oceanographic personnel were met in large part by marine research institutions and universities with ocean science programs.

Among these, Columbia University's Lamont Geological Observatory, established in 1949, was an active participant with its research vessel *Vema*, which made annual circuits of the world. Beginning in 1948, marine geologist Bruce C. Heezen and oceanographic cartographer Marie Tharp drew up global maps with the results. By 1957 they showed a continuous ridge running down the middle of the oceans. Associated with this system were ridge offsets along long and steep arcuate scarps, deep trenches, island arcs, and seamounts. Plots of the earthquake epicenters determined by Lamont's seismologists lay along the ridge crests, and defined dipping Benioff planes as seafloor was subducted via the trenches often producing island arcs. These epicenters also later served to define the mobile crustal plates of plate tectonics.

The new seafloor maps created a great stir. The first was a physiographic map of the Northern Atlantic Ocean published in 1957 by the Geological Society of America. The submarine morphology was shown in three-dimensional oblique perspective using an artist's sketch technique. The land background was yellow and the ocean a light green. Subsequent maps described the South Atlantic in 1961, the Indian Ocean in 1964, and the Western Pacific in 1971. In 1976 the American Geographical Society produced a composite of the major oceans painted in hypsometric colors by the French artist Tanguy de Rémur, which was followed in 1977 by a giant map painted by Heinrich C. Berann at a scale of 1:46,460,600 and funded by the U.S. Office of Naval Research (see fig. 888). Berann also painted maps published in *National Geographic Magazine*. These included the Indian Ocean floor in the October 1967 issue (see fig. 611), the Atlantic Ocean floor in June 1968, the Pacific Ocean floor in October 1969, and the Arctic Ocean floor in October 1971. (This last map portrayed the results of John K. Hall's doctoral studies. Heezen, his dissertation supervisor, was most impressed by the fact that the seventeen million copies printed represented a roll of paper 7,941 km long, extending from Florida to Washington State and back.)

In 1963, seafloor spreading passed its first test as credible theory when Lawrence W. Morley, F. J. Vine, and Drummond H. Matthews identified symmetric patterns of magnetization in the mid-Atlantic ridges caused by reversal of polarization of the earth's magnetic field imbedded in the cooling basalt produced along the axes (Morley-Vine-Matthews hypothesis). Somewhat later the dating of these reversals as seen in successive dated lava flows provided a way of dating the seafloor from the magnetic pattern. Further evidence emerged when the Deep Sea Drilling Project, initiated by the United States in 1968 (later the international Ocean Drilling Program), made samples of the basaltic seafloor available for age dating. These studies indicated that most seafloor was less than 200 million years in age, thus re-

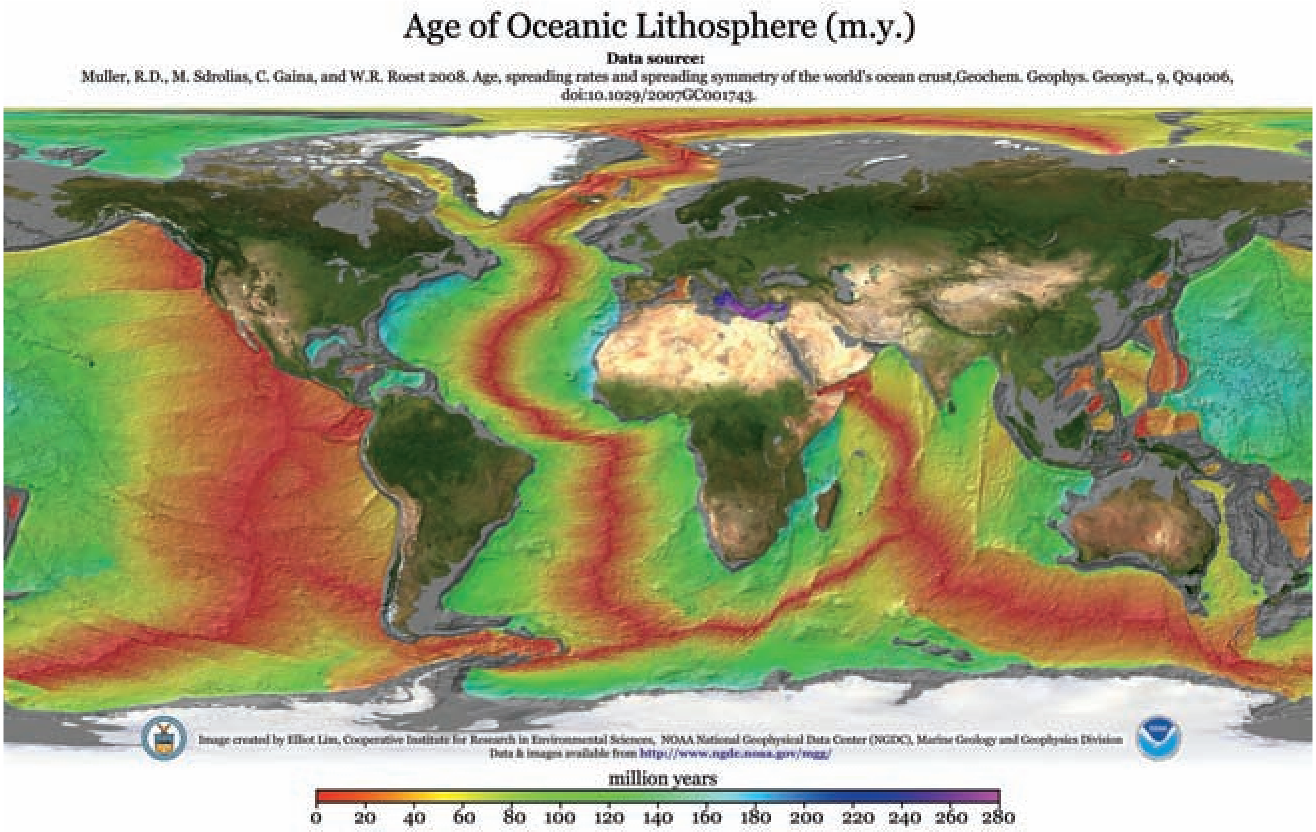



FIG. 632. *AGE OF OCEANIC LITHOSPHERE* PLOTTED ON A WORLD MAP AT SIMPLE GEOGRAPHIC PROJECTION. The ages are determined from the magnetic anomaly polarization patterns and samples from boreholes made by the Deep Sea Drilling Project. The oldest seafloor appears to lie in the eastern Mediterranean, where up to fourteen kilometers of sediments are found. Maximum ages may be even more. Description of the sources of the data are in Muller et al. (1997, 2008).
Image courtesy of Mr. Elliot Lim, CIRES & NOAA/NGDC.

inforcing the idea that the seafloor was continuously being recycled via subduction below the trenches (fig. 632).

As the amount of bathymetry captured by moving vessels slowly increased, satellite altimetry provided a synoptic picture of the oceans. Since the continuously manufactured crust was dense basaltic material, its various landforms and cavities, significantly larger than those on dry land, produced significant changes in the gravitational pull on the water, causing hills and valleys. William F. Haxby and his group at the Lamont-Doherty Geological Observatory pioneered the use of satellite altimetry, producing in 1985 a world map of predicted bathymetry, *Gravity Field Map of the World's Oceans*. The crustal mechanics of triple junctions, poles of rotation, fracture zones, and ridge offsets via transforms was gradually understood, as was the relationship between ocean depth and age (Sclater and Detrick 1973) (fig. 633).

By 1997 Walter H. F. Smith and David T. Sandwell (1994, 1997) had used additional satellite data to refine the raster map to a grid of cells with sides encompassing two minutes of arc. The results were spectacular and most reliable over the ocean ridges, which were mostly devoid of lighter sediment. At the equator the satellite tracks were generally about three kilometers apart, and converging to both the north and south, so that the coverage there was especially revealing. By contrast, altimetry was poorer on the broad ridge flanks, where the abyssal hills—the most dominant landform on earth—are blanketed by light marine sediments, which subdue the topography. The altimetry was useful for identifying the largest seamounts, estimated to number some 10,000. Seamounts, which are primarily volcanic, are defined as rising at least a kilometer above the seafloor, with some sufficiently tall to imperil deep-draft vessels in midocean. It was estimated that their number could exceed 100,000.

An unanticipated long-term drawback of the publication of these physiographic maps was the wide perception—at the time when less than 5 percent of the oceans had been mapped—that the oceans were properly covered. Thus funding of outer space exploration rapidly

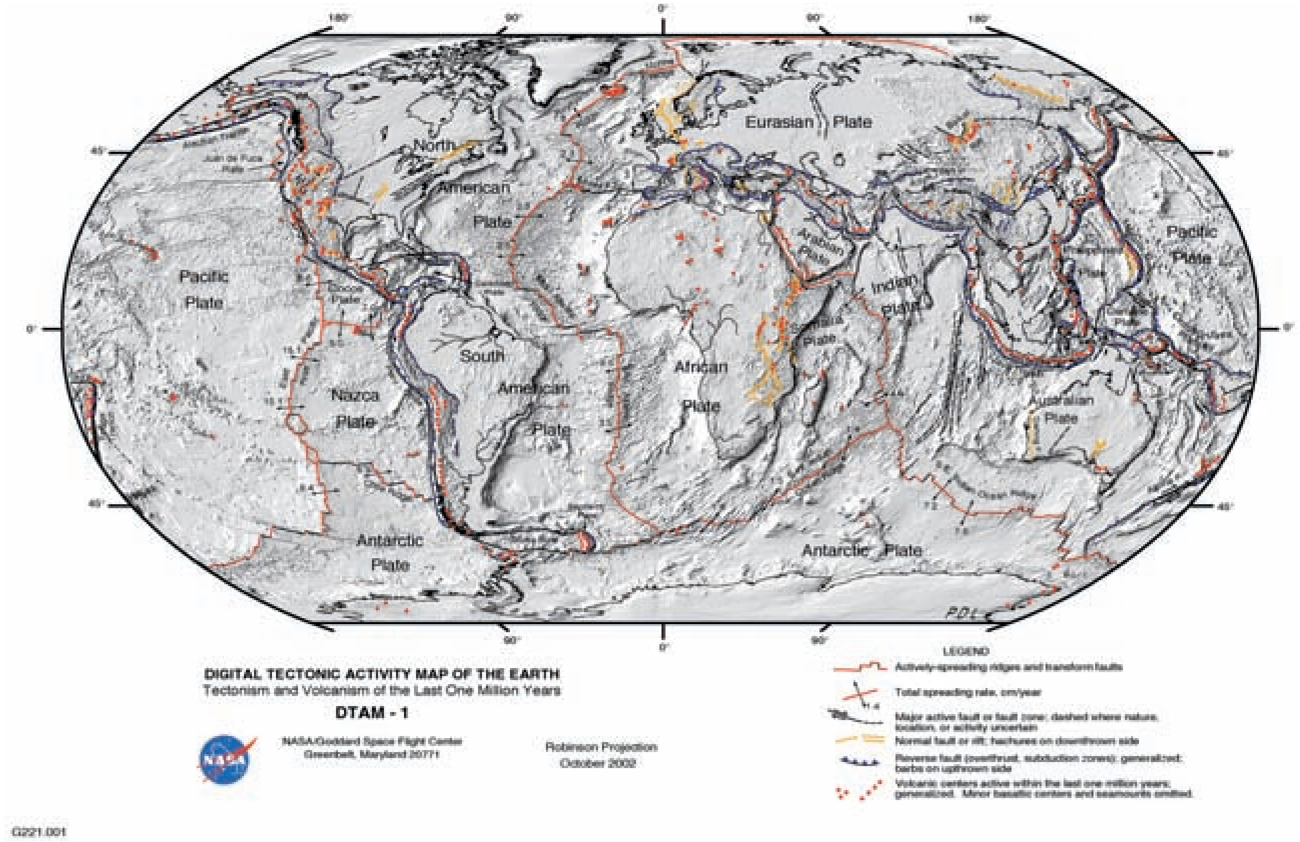



FIG. 633. *DIGITAL TECTONIC ACTIVITY MAP OF THE EARTH*, 2002. This map uses the nonpolar bathymetry and topography as a backdrop to the boundaries of the tectonic plates, the motion vectors and spreading rates at the plate margins over the past one million years, as well as rifts, major normal and reverse faults, and volcanoes. The 70,000- to 80,000-kilometer-long midocean ridges and the transform faults at right angles are clearly discernible in the shaded relief even though the grayscale is largely subdued.
Image courtesy of NASA Goddard Space Flight Center, Greenbelt.

outstripped that of inner space (Macnab 2007). At the end of the century, when nearly 10 percent of the seabed had been mapped, the backside of the moon and the surfaces of Mars and Venus, the latter shrouded in a hot acid atmosphere, were better mapped than 60 percent of earth.

## Compilational Efforts: GEBCO, the IBCs, and SRTM30-Plus

The first bathymetric compilation began in 1903 with the General Bathymetric Chart of the Oceans (GEBCO) project. Begun by Prince Albert I of Monaco, GEBCO periodically issued new editions, with the accumulating soundings contoured at intervals of 500 meters. Unfortunately, as a primarily hydrographic undertaking, GEBCO did not have continuous profiles of the topography that would portray geological information on the origin of features.

Beginning in the 1970s, the Intergovernmental Oceanographic Commission (IOC) and International Hydrographic Organization (IHO) also initiated what later amounted to eight regional International Bathymetric Chart (IBC) compilation projects. The first was the International Bathymetric Chart of the Mediterranean (IBCM) covering the Mediterranean and Black Seas at a scale of 1:1,000,000, which also included geological/geophysical overlay sheets of Bouguer gravity, magnetics, seismicity, Plio-Quaternary sediments, and bottom sediments. The other projects gradually compiled more detailed sheets for the eastern and western African margins, the Caribbean, the Southern Ocean, the western and southeastern parts of the Pacific Ocean. The *International Bathymetric Chart of the Arctic Ocean* (IBCAO) went directly to a digital grid in 2000.

The last printed edition of GEBCO was the fifth, published by the Canadian Hydrographic Service between 1975 and 1982. Eventually the GEBCO members with hydrographic roots gave way to marine geophysicists who were using geological principles, digital methodology, and new software to interpolate grids. In parallel since 1988, GEBCO-SCGN (Sub-Committee on Geographical Names and Nomenclature of Ocean Bottom Features), later SCUFN (Sub-Committee on Undersea Feature Names), maintained the online IHO-IOC gazetteer of undersea feature names, vetted for their scientific and historical suitability. The first worldwide grid, the Digital Bathymetric Data Base with node spacing of five arc minutes (DBDB-5) produced by Frank Marchant at the U.S. Naval Oceanographic Office, appeared in the early 1980s. It was based on digitization of contours from all available mapping but with an assumed sound speed of 1,500 meters per second.

The end of the century and the following decade saw the release at the GEBCO Centennial in 2003 of a one–arc minute grid from all sources, followed in 2004 by J. J. Becker and Sandwell's SRTM30-Plus (thirty arc seconds between nodes) with sequential upgrades, and a new GEBCO thirty–arc second edition, available online and used in Google Ocean (fig. 634). Unsurprisingly, the land mapping, with spacings of 5′ (ETOPO5), 2′ (ETOPO2), 1′ (GLOBE), and then in 2000 the Shuttle Radar Topography Mission, whose synthetic aperture radar coverage produced ten- to thirty-meter grids worldwide (60°N to 56°S). These were released publicly on the Internet at 3″ (roughly 90 m) in 2003. In 2009, Japan's Ministry of Economy, Trade and Industry (METI) and NASA collaborated to produce the ASTER-GDEM (global digital elevation model), a thirty-meter grid between 83°N and 83°S, based upon computerized stereo correlation of 1.3 million 60 × 60 kilometer optical images in the ASTER VNIR (visible near infrared) archive.

The development of computers made much of post-1970 seafloor mapping possible. This evolved into digitizing records at slope changes, and plotting contour crossings. Digitized soundings from survey fairsheets and transit tracks began to be gridded and raster representations replaced vectorized contours. Gridding the data led to the first plots of analytic hill shading and finally to the hypsometrically colored shaded relief, which typified most bathymetric maps at century's end. And in the 1980s the gridding moved aboard ships as the mapping was done by multibeam sonars that could map swaths with widths over seven times the water depth.

In 2001 Peter R. Vogt at the U.S. Naval Research Laboratory and others proposed proactively mapping the world's ocean deeper than 500 meters using multibeam sonar (Vogt, Jung, and Nagel 2000; Carron, Vogt, and Jung 2001). The intended grid would be 0.1′, and the roughly 225 ship years was estimated to cost \$8–\$16 billion. Some twenty to thirty years might be required, with part of the work carried out to provide the mapping for Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS) concerning the continental shelf, which allowed nations to accrue additional offshore areas.

## Use and Impact

The existing knowledge of the oceans at any time set the cartographic standard for maps of marine areas, as distinct from traditional navigational charts. By 1900 the world's shorelines were generally well known, despite the use of some 700 different geodetic datums to define their positions. Thus, maps with shorelines were available for plotting feature names, ships' tracks and soundings, current vectors, depth contours, surface temperatures, salinities, and other marine phenomena. As oceanographers began to make ocean transits with bathymetry and many hydrographic stations with Nansen bottles to measure salinity and temperature, and therefore density, profiles were shown with the spiky seafloor topography and then with contours of temperature, salinity, and density, and identification of the various water masses. Representative of that earlier time were the myriad illustrations in the book *The Oceans* (Sverdrup, Johnson, and Fleming 1942).

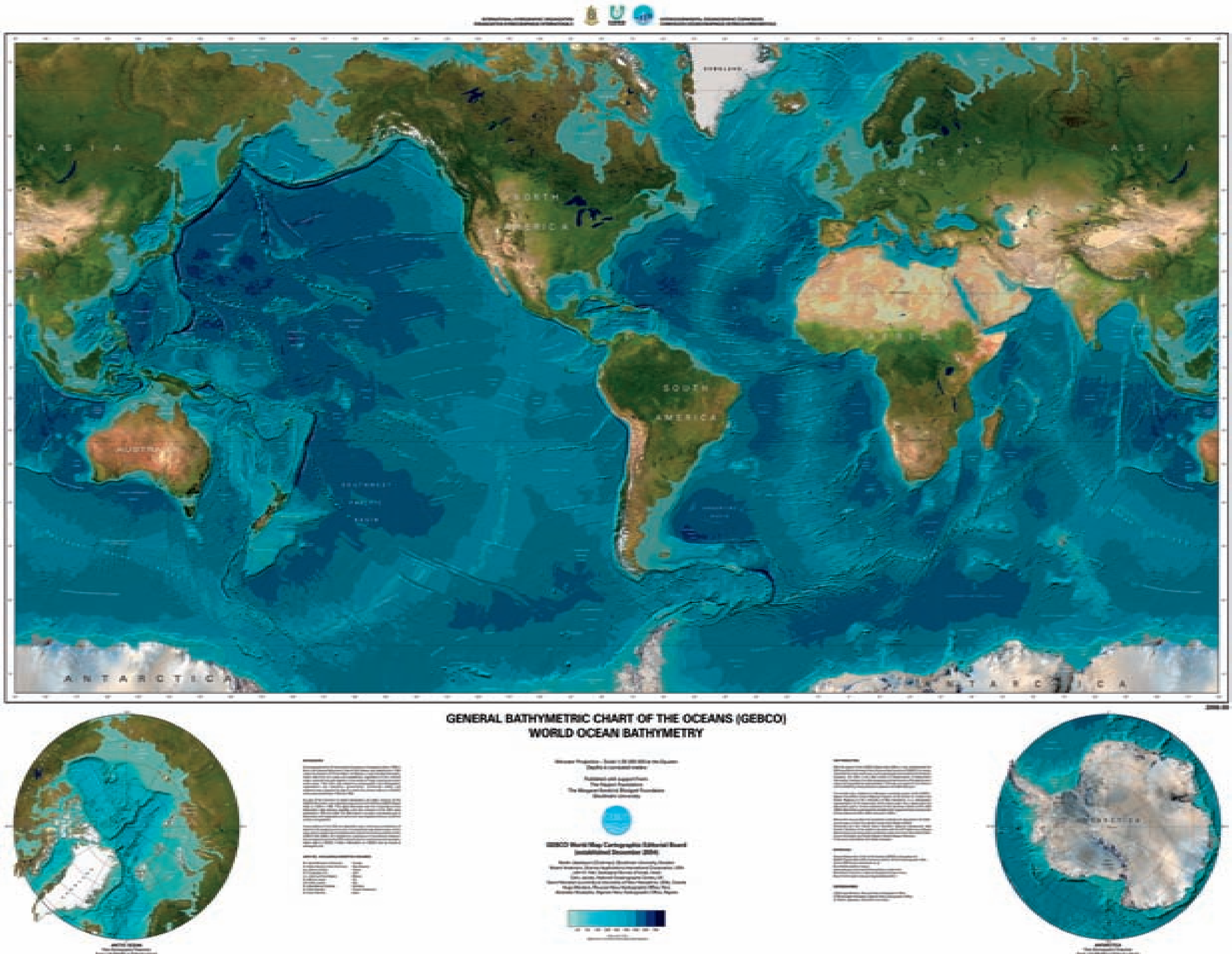
As the gridded maps became available in the 1980s, algorithms for digital hill shading were developed, and by the 1990s even personal computers could produce useful shaded relief in grayscale or even with hypsometric tints according to height or depth. In 1993, for instance, a grayscale shaded relief representation of the twenty-five-meter grid made for Israel, based on over 107 million elevations, required eighty hours on a state-of-the-art personal computer (Hall 1996). In 2010, by contrast, relatively inexpensive software like Global Mapper could create a color map of equivalent data in seconds.

Despite the fact that little more than 10 percent of the oceans had been accurately mapped, at the scales that the oceans were usually represented graphically, the raster data sets available in the early twenty-first century offered the full spectrum of cartographic presentations. Steadily improving digital grids promised all manner of numerical manipulations.

JOHN K. HALL

(*Facing page*)

FIG. 634. *GENERAL BATHYMETRIC CHART OF THE OCEANS (GEBCO): WORLD OCEAN BATHYMETRY*, 1:35,000,000, 2006. This poster was printed by Professor Martin Jakobsson, Marine Geology and Geophysics Department of Geological Sciences at the University of Stockholm, assisted by John K. Hall and alumni of the GEBCO/NIPPON Ocean Mapping program at the University of New Hampshire's Center for Coastal and Ocean Mapping.
Size of the original: 97.8 × 127 cm.


ASIA
NORTH AMERICA
SOUTH AMERICA
AUSTRALIA
ANTARCTICA
GENERAL BATHYMETRIC CHART OF THE OCEANS (GEBCO)
WORLD OCEAN BATHYMETRY

SEE ALSO: General Bathymetric Chart of the Oceans (GEBCO); Geophysics and Cartography; Hydrographic Techniques; Scientific Discovery and Cartography; Tharp, Marie

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***Office fédéral de topographie (Switzerland).*** See Bundesamt für Landestopographie

***Office of Strategic Services (U.S.).*** Created during World War II, the Office of Strategic Services (OSS) was the first United States central agency for procuring, analyzing, evaluating, and disseminating foreign military intelligence. While supporting the Allied war effort 1941–45, the OSS also became a crucible that reshaped geographic and cartographic methodology with lasting postwar impact.

The founder of the OSS, William J. Donovan, was a World War I army hero turned New York lawyer who cleverly exploited the visual display of information when defending mid-1930s corporate antitrust cases (Katz 1996, 5). Concerned about impending war, Donovan began gathering military intelligence and suggested America needed a Coordinator of Information (COI). Appointed in June 1942, he reported to President Franklin D. Roosevelt until January 1943, when the renamed OSS was reassigned to the Joint Chiefs of Staff (JCS).

Initially advised by Hollywood film consultants, Donovan envisioned a White House briefing room equipped with futuristic technology, including a huge illuminated globe upon which strategic map information could be projected. In 1942 the JCS canceled that costly plan, and the OSS was restructured to increase output of intelligence reports and maps (Katz 1996, 5–7).

Although OSS cartographic activities occurred in all theaters of war, Washington, D.C., was the hub (Wilson 1949, 302–7). Arthur H. Robinson, an Ohio State University geography graduate student, was recruited in October 1941 to oversee COI mapmaking (Sterling 1998, 223–24). Striving to meet the growing demand for maps by using inadequate map sources, inexperienced compilers and draftsmen, and antiquated production techniques, he and a nucleus of experts ramped up the OSS Map Division, expanded in 1942 to four sections. Because borrowing maps had proved ineffective, the Map Information Section collected and cataloged systematically about 500,000 maps (Wilson 1949, 303), as well as supplying copies (110,000 copies of 20,000 different maps in a typical month of 1944). The Cartography Section progressed from illustrating reports with simple location maps to preparing substantive strategic planning maps. Robinson's systematization of design principles, specifications writing, and production techniques enabled workers with minimal training to produce accurate, communicative maps quickly—8,200 of them between 1941 and 1945 (fig. 635). Against that solid achievement, the special project instigated by Donovan in September 1942—to create three fifty-inch globes as Christmas gifts for Roosevelt (see fig. 21), British Prime Minister Winston Churchill, and U.S. Army Chief of Staff General George C. Marshall—stands out as a showman's flourish (Robinson 1997, 146–47). In the Topographic Model Section new techniques, such

(*Facing page*)

FIG. 635. OSS, *RUSSIAN SUMMER OFFENSIVE JULY 12–OCTOBER 15, 1943*. Summing up the military situation at the Russian Front as of 15 October 1943 and efficiently drafted for multicolor photolithographic reproduction just nine days later, this OSS map illustrates the effective use of visual contrast and other design principles to convey its message (24 October 1943, Provisional edition).

Size of the original: ca. 40.6 × 30.5 cm. Image courtesy of the U.S. National Archives, Washington, D.C. (RG 226: OSS #2759).


PROVISIONAL EDITION
RESTRICTED
RUSSIAN SUMMER OFFENSIVE
JULY 12 - OCTOBER 15, 1943
Extreme German Penetration 1941-1942
Beginning of Summer Offensive
Line of August 10
Russian Advances to October 15
SINGLE TRACK RAILROAD
DOUBLE TRACK RAILROAD
Gulf of Finland
L. LADOGA
WHITE LAKE
LENINGRAD
L. PEIPSI
Vologda
Novgorod
VOLKHOV
Kirov
L. ILMEN
Pskov
STARAYA RUSSA
Demyansk
Yaroslavl
LOVAT
Kholm
KALININ
VELIKIE LUKI
Nevel
Rzhev
GORKI
KAZAN
W. Dvina R.
Vitebsk
Gzhatsk
MOSCOW
Vyazma
Mozhaisk
SMOLENSK
Orsha
Mogilev
OTULA
Roslavl
KUIBYSHEV
Bolkhov
PENZA
Bryansk
Mtsensk
Gomel
OREL
Tambov
Sevsk
KURSK
SARATOV
Konotop
VORONEZH
Chernobyl
Novy Oskol
KIYEV
Sumy
Belgorod
VOLGA R.
KHARKOV
Chuguyev
DNEPR R.
Cherkassy
Poltava
Barvenkovo
Kremenchug
Krasnograd
Slavyansk
Lisichansk
Voroshilovgrad
STALINGRAD
Pavlograd
Kramatorsk
Millerovo
DON R.
Dnepropetrovsk
DONETS R.
STALINO
Zaporozhye
Shakhty
Taganrog
Kotelnikovski
Nikolayev
Melitopol
ROSTOV
Kherson
Astrakhan
Armyansk
ODESSA
Yeisk
Elista
Sea of Azov
Dzhankoi
Tikhoretsk
Taman
KUBAN
CASPIAN SEA
Krasnodar
Armavir
SEVASTOPOL
Yalta
Peninsula
Maikop
Novorossiisk
Cherkessk
BLACK SEA
Tuapse
Mozdok
MILES
0 50 100 150 200
Nalchik
Terek
GROZNY
Makhach-Kala
Alagir
Ordzhonikidze
Sukhumi
MAP NO. 2759
24, OCTOBER 1943
Declassified by
date
COMPILED AND DRAWN IN THE BRANCH OF RESEARCH AND ANALYSIS, O.S.S.
LITHOGRAPHED IN THE REPRODUCTION BRANCH, OSS

as painting on shadows to accent minor relief features, speeded production. The Special Photography Section photographed topographic models for use as shaded-relief base maps.

Although the OSS was disbanded in 1945, the Central Intelligence Agency (CIA), founded in 1946, has carried on its work in intelligence mapping. Meanwhile the OSS's research staff of young social scientists took the rigorous approach to information learned there back to academe. Many built upon it to become leading innovators in their fields, as Robinson did in cartography. American cartography had entered World War II still mainly an art and craft but emerged on the way to becoming an academic scientific discipline (Harris 1997, 251–52). The OSS experience played no small part in that transformation.

KAREN SEVERUD COOK

SEE ALSO: U.S. Intelligency Community, Mapping by the; Robinson, Arthur H(oward); World War II

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***Ordnance Survey** (U.K.).* In common with all European national mapping agencies of the time, the Ordnance Survey (OS) was still a military organization at the start of the twentieth century. The director general and all the senior personnel were serving officers in the Royal Engineers, and many of the workforce were soldiers, although the organization was under civil control and the budget for the survey's work came through the Board of Agriculture. The army had a small mapping capability within the War Office, but any major projects needed to draw on the resources of the OS. This arrangement was to continue in peacetime until World War II, when the establishment of the Directorate of Military Surveys led to the development of an independent military mapping capability. In both world wars the OS provided a reservoir of resources and trained personnel for military mapping at the expense of its own mapping programs.

The range of maps provided by the OS, from large-scale plans at 1:2,500 to small-scale mapping at 1:1,000,000 (not introduced until 1905), was greater than that provided by any other national mapping agency, but attention had focused on the need to maintain that coverage to the exclusion of any real scientific work. Geographer, surveyor, and director of the OS Charles Frederick Close (1925) argued that the OS had not carried out any real scientific work since the middle of the nineteenth century and compared it unfavorably with the work of the Survey of India. The need to maintain the large-scale coverage—1:2,500 for lowland Britain and 1:10,560 for mountain and moorland—was the most important function of the OS and dictated its approach to any new developments in survey and mapping. If the development did not directly improve the ability of the OS to maintain the large-scale coverage, either through cost savings or greater productivity, it was unlikely to be adopted.

In 1892 the Dorington Committee, chaired by Sir John Edward Dorington, had carried out a review of the OS and made recommendations about its future work (Seymour 1980, 185–94). In the same year, another committee carried out a review of the requirements for a military map of Great Britain for use by the British Army. While the Dorington Committee's report had a profound influence on large-scale mapping by the OS—at least until 1936, when the Davidson Committee, as it came to be called, chaired by Sir John Colin Campbell Davidson, made many recommendations for changes—it was the report on the military map that was to influence the look and content of OS, colonial, and commonwealth mapping for the whole of the twentieth century. The idea of publishing a colored map at 1 inch to 1 mile (1:63,360) had been rejected by the British treasury in 1892 on the grounds of cost. When the decision was made in 1898 to approve a trial printing of a colored map, the model immediately at hand was the new military map. The decision was therefore made to put the military maps on sale to the public as the Third Series OS maps (Seymour 1980, 201). The simplified style, without the heavy hachuring that characterized much European mapping, became the model for most British Empire mapping and subsequent commonwealth mapping (fig. 636).

The OS had made changes in its medium-scale mapping, but its large-scale mapping had changed little since the middle of the nineteenth century. Each county, or small group of counties, had its own central meridian and projection. This caused problems as the growing industrial cities of Britain increasingly spread across county boundaries, and map users had problems joining the maps of adjacent counties. In 1912 Close started to recast the mapping on a smaller number of projections, but the outbreak of World War I stopped progress (Seymour 1980, 215). One of the few changes that Close was able to implement during the war was the introduction


FIG. 636. DETAIL OF AN ORDNANCE SURVEY THIRD SERIES MAP SHEET (*FALMOUTH*), 1900. Sheets 352, 359 at a scale of 1:63,360. The map shows the combination of hachures, contours, and spot heights used to depict relief. The use of symbols for churches, windmills, and other prominent features and a road classification scheme were other innovations of the Third Series derived from the original design for the military map.
Size of the entire original: 71.5 × 48.8 cm; size of detail: 9.9 × 17.3 cm. Image courtesy of Peter Collier.

of a new one-inch series, the Popular Edition (fig. 637). This was a much cleaner version of the Third Series, with no hachures, and was introduced to serve the rising number of automobile owners. It was the first OS series to be issued with a decorative, rather than purely functional, covers.

During World War I much of the OS's regular work was curtailed, leading the mapping to be increasingly out-of-date. This would not have mattered if, after the war, the OS had been able to catch up with the program. But postwar cutbacks in government spending meant that the wartime shortfalls were not made good and even the planned program of revision could not be maintained. World War I also drew attention to problems with OS working methods. Almost alone among national mapping agencies, the OS had relied upon chain survey techniques to carry out detailed survey for its mapping. OS surveyors quickly found that the technique was completely unsuited to mapping on the Western Front, where plane table work became the norm followed rapidly by air survey for carrying out map revision of areas behind enemy lines.

Following the war, the OS staff complement was cut from 2,007 personnel to 1,462, and numbers did not start to rise again until the growing threat of another war in the mid-1930s. Not only were there cutbacks in staff, but it also became increasingly difficult to negotiate any additional funding from the Treasury for research and development in emerging areas such as air survey. Despite these limitations, there were a number of attempts to use the new technology. In 1919 the OS produced an experimental air map of the city of Salisbury (Collier and Inkpen 2003). The high cost of the map, however, may have deterred purchasers, and sales were poor. The OS carried out experiments to produce more conventional mapping, but the combination of a parsimonious treasury, a lack of cooperation by the Royal Air Force, a conservative approach by the OS, and bad weather conditions led to all the experiments being either less accurate than existing methods or more expensive. This situation persisted until the appointment of Malcolm MacLeod as the director general in the mid-1930s.

While the cutbacks in staffing inhibited many new developments, they also encouraged the abandonment of some of the older techniques. In the early 1920s the decision was finally taken to abolish copperplate engraving.


FIG. 637. DETAIL OF AN ORDNANCE SURVEY POPULAR SERIES MAP SHEET (*LAND'S END & LIZARD*), 1928. Sheet 146 at a scale of 1:63,360. The Popular Edition used only contours and spot heights for relief depiction and included a new road classification scheme.

Size of the entire original: 67.9 × 86.9 cm; size of detail: 9.9 × 17.3 cm. Image courtesy of Peter Collier.

The technique had been in decline for many years, and the decision, when taken, simply recognized that heliozincography had become the preferred method for map reproduction (Seymour 1980, 242–43). One important innovation in OS mapping was the introduction of reference grids on the Fifth Series of the one-inch maps, a direct consequence of experiences in World War I.

By the mid-1930s OS mapping had become so out-of-date that local governments were finding it difficult to meet central government requirements in matters such as slum clearance and town and country planning. The government's own land registry could not carry out registrations of title in suburban areas, where subdivision for housing developments had not been recorded on OS mapping. At the 1934 rate of large-scale plan publication, the revision cycle had become 100 years rather than 20 years, as originally intended. The minister of Agriculture and Fisheries decided to establish a Department Committee on the Ordnance Survey under Davidson, who was charged with making recommendations on the future role and products of the OS. The Davidson Committee took oral and written evidence from nearly 100 interested parties, but the decisive influence on the outcome was MacLeod, who, through a network of contacts, was able to get his views presented to the committee as if from independent parties (Collier and Inkpen 2003, 235–39). The recommendations of the Davidson Committee were to shape the OS for the rest of the twentieth century.

One of the most important recommendations of the Davidson Committee was that all large-scale mapping (1:2,500 and 1:10,560) should be rearranged as a single continuous series on a single projection and a single metric grid (the so-called National Grid) to replace the individual Cassini projections and 5,000-yard grids previously in use. The National Grid was an important innovation in allowing the coordinates of any point in the country to be given in a single system. One reason MacLeod wanted a single coordinate system was to avoid the difficulties that had arisen during World War I from having different parts of the front on different grids. MacLeod also wanted to change all OS scales to metric equivalents, but in this he was unsuccessful as resistance was too strong. In evidence to the committee, the argument had been made that if the OS introduced metric scales, the British Empire would have to follow, and that the cost to countries such as India would be too great. MacLeod was, however, able to secure the introduction of two new metric scales, 1:1,250 for urban areas and 1:25,000 for the whole county. The latter scale was the one favored by the War Office for its purposes, and MacLeod had long advocated its introduction. Another major recommendation of the Davidson Committee was that the OS should move to a system of continuous revision, whereby small survey sections would be established around the country to survey any new changes as they occurred.

The Davidson Committee also recognized the potential of air survey and recommended that the OS have its own air survey unit, again in line with MacLeod's wishes. Not only was MacLeod able to form an air survey unit within the OS, he was also able to acquire the research officer and equipment previously based in the War Office (Collier and Inkpen 2003, 235–39).

The outbreak of World War II put all changes within the OS on hold as the organization lost many of its survey staff to Royal Engineer survey companies supporting army operations. The OS attempted to meet its civil mapping responsibilities, but these were severely restricted by the loss of its survey staff and the demands of the war effort. To make matters worse, German bombing raids on the nights of 30 November and 1 December 1940 resulted in major damage to OS offices in Southampton and the loss of equipment. The OS spent the rest of the war dispersed in various locations, but mainly in southwest London and Chessington, Surrey, where it was to remain until a new headquarters was built in Southampton in the 1960s. The enforced dispersal of the various functions of the OS had major implications for the efficiency of its operations.

In addition to the disruption caused by the war to the OS program of map revision and resurvey, the extensive damage to British cities as well as infrastructure development during the war meant that much of the existing mapping was obsolete. The need for new mapping was especially acute in the cities, leading the OS to adopt photomapping as an interim solution. Air photos were rectified and enlarged to an approximate scale of 1:1,250. Lettering, such as street names, and a grid were added, and the resulting image was printed with the appropriate marginal information for the scale. The success of the photomaps led to the extension of this approach to nonurban areas at a scale of 1:2,500. The photomaps were always regarded as an interim solution, however, and were replaced by conventional line maps as soon as these were available.

The new 1:1,250 plans of urban areas were based on new survey. The revision of the 1:2,500 series involved the replotting of the old county maps on the new projection and National Grid and graphic revision from rectified air photos. This practice resulted in maps of variable accuracy, which was to create problems later, when the OS started to create its seamless digital database of the large-scale mapping.

As part of the postwar revision of mapping, it was decided to replace the existing contouring at 1:10,560. MacLeod had been aware of the inadequacy of the nineteenth-century contouring, for which interpolation had been extensively used, especially in upland areas (Collier 1972; Seymour 1980, 172). Photogrammetric techniques were used to carry out the recontouring, with contours captured at imperial intervals (intervals of twenty-five feet rather than in meters). It was recognized that the Davidson Committee's decision to retain imperial units would be overturned in the near future, and the argument was made that a metric set of contours should also be collected in anticipation of the move to metric mapping. Financial constraints meant that only imperial contours were collected, leading to the OS having to contour again, when metrication took place in the 1970s.

Though the OS recognized the benefits of newly emerging computer automation in the 1960s, there was initial concern that investment in such new technologies would conflict with existing work programs and the demands for greater cost-effectiveness. Indeed, the digital mapping program began while the OS was preoccupied with the revision and overhaul of its entire topographic map series.

The task of digitizing all of the basic OS mapping of Great Britain was enormous. The OS maintained 229,351 basic-scale (the scale at which the data were originally captured) maps, of which 54,574 covered urban areas at 1:1,250, 164,597 covered agricultural areas at 1:2,500, and the remainder were at 1:10,000 (Smith 1987). A well-organized and very efficient method of graphical survey had been developed in which the surveyor added a high proportion of detail directly to a master survey drawing (MSD). The MSD could be the result of a high-order control survey with detail usually added either by photogrammetric survey or from a copy of the previously published map on a stable plastic base. The mapping was maintained by a system of continuous revision, the survey archive being on MSDs in the field surveyor's office and not at headquarters in Southampton. The basic maps at 1:1,250 and 1:2,500 were generalized and redrawn to produce 1:10,000 derived maps, which in turn were photographically reduced to produce the 1:25,000-scale mapping.

According to Michael Sowton (1991, 24), who directed a major study of OS operations and was appointed head of research and development in the OS in 1983, the commencement of the digital mapping program "was entirely due to the far-sighted decisions of the then Director General, Major General B St G Irwin." It was Irwin who initiated an evaluation of computerization as a means of providing a cost-effective way to support the existing mapping program. Progress continued under the direction of Colonel R. C. Gardiner-Hill, who as deputy director of the Development Branch made it quite clear that high-quality printed maps, and not the provision of digital data, remained the priority of the OS (Gardiner-Hill 1972). The digital map should emulate the cartographic excellence of predigital production, and noncartographic uses of the data were secondary. Saving production costs was of paramount importance: the falling cost of automation would counter the rising cost of skilled labor, thereby reducing the cost of map drawing. The cost of revision would fall if expensive manual redrawing was avoided, and in the longer term accuracy would be more easily maintained by eliminating errors during redrawing for new editions.

The OS purchased its first digitizing table in April 1970 and added more digitizing tables and a drum plotter to begin experimental digitizing of 1:1,250 maps of urban areas of Hampshire and 1:2,500 maps of Herefordshire. Software was developed in-house to support digitizing and transforming the machine coordinates in millimeters to the system of the National Grid (Gardiner-Hill 1972; Williams 1973). By April 1975 there were seventy draftsmen and fourteen digitizing tables employed in the digitizing and editing section, and about 500 1:1,250 maps and 900 1:2,500 maps had been digitized.

Initial interest in the application of digital techniques focused on deriving medium- and small-scale mapping from large-scale digital data (Gardiner-Hill 1971). The OS felt that computer-assisted map production would be cost-effective if it were capable of deriving 1:10,000 and 1:25,000 mapping from larger-scale digital data. The OS joined forces with the Experimental Cartographic Unit of the Royal College of Art, London, headed by David P. Bickmore (Bickmore 1971), one of the champions of the new technology. Unfortunately, experiments demonstrated that the costs outweighed the technical desirability of deriving maps this way (Gardiner-Hill 1971; Sowton 1991) even though Bickmore viewed these initial experiments as a test of feasibility rather than cost-effectiveness (fig. 638). While costs were approximately equal, the main advantage was the flexibility of automated cartography. Nevertheless, the OS persisted with the automation of derived mapping and in 1975 began to investigate the production of derived maps from basic-scales data (Bell 1978; Atkey and Gibson 1979). Maps at 1:10,000 were produced successfully from 1:2,500-scale digital files, though with a modified drawing specification that eliminated most of the generalization that had previously taken place at that scale. Despite saving 50 percent of the conventional drawing costs by automatically deriving 1:10,000 mapping from 1:2,500-scale data, photographic reduction of the 1:10,000 maps to 1:25,000 was no longer possible because of particularly severe congestion in urban areas mapped originally at 1:1,250. Thus the 1:25,000 maps had to be produced independently, and the generalization consequently shifted from one scale to another. Taking the two derived scales

FIG. 638. DETAIL FROM AN EXPERIMENTAL TOPOGRAPHICAL MAP OF THE BIDEFORD AREA AT A SCALE OF 1:25,000. The map (sheet SS42) was produced by the Experimental Cartographic Unit of the Ordnance Survey using experimental generalization techniques. Though technically impressive for its date, the OS abandoned the automatic generalization of large-scale data to produce derived scales on the grounds of cost.
Size of the entire original: 49.4 × 46.5 cm; size of detail: 15.6 × 8.4 cm. Image courtesy of Alastair W. Pearson. © Crown Copyright. Reproduced by permission of the Ordnance Survey.

together, digital production proved to be more expensive than its conventional counterpart because the increased production cost of the 1:25,000 map swallowed up the savings achieved for the 1:10,000. Derived mapping using automated techniques was therefore shelved until improvements were made in the automation process.

Failure of the automation of the generalization process removed one of the anticipated benefits of digital mapping for the OS. As a result, research concentrated on the use of digital data to support the production of paper maps within a computer-assisted environment rather than on a fully automated map production process (fig. 639). Early methods involved using cumbersome "blind" digitizing techniques, off-line editing, and subsequent redigitizing (Sowton 1991; Coles 1974). By 1980 the production line had matured to incorporate more advanced technology and a rigorous method of editing (fig. 640).

The OS experimented with automatic line-following devices and scanning methods to speed up digitizing. Semiautomatic methods using a line-following laser scanner were evaluated. This approach was most efficient for digitizing contours and other closed boundary data, but it rapidly became inefficient as the number of junctions increased and the operator had to intervene. Though digital linework and text came up to the exacting standards of the specification, the addition of symbols and other ornamentation remained a conventional cartographic process.

The creation of digital data as a by-product of its production flow line provided the OS with an opportunity to market these data. During the early 1970s, however, the market was in its infancy and organizations were reluctant to invest in this emerging technology. Because the order of individual sheet digitizing was designed to follow the need for map revision, the digitizing of con-

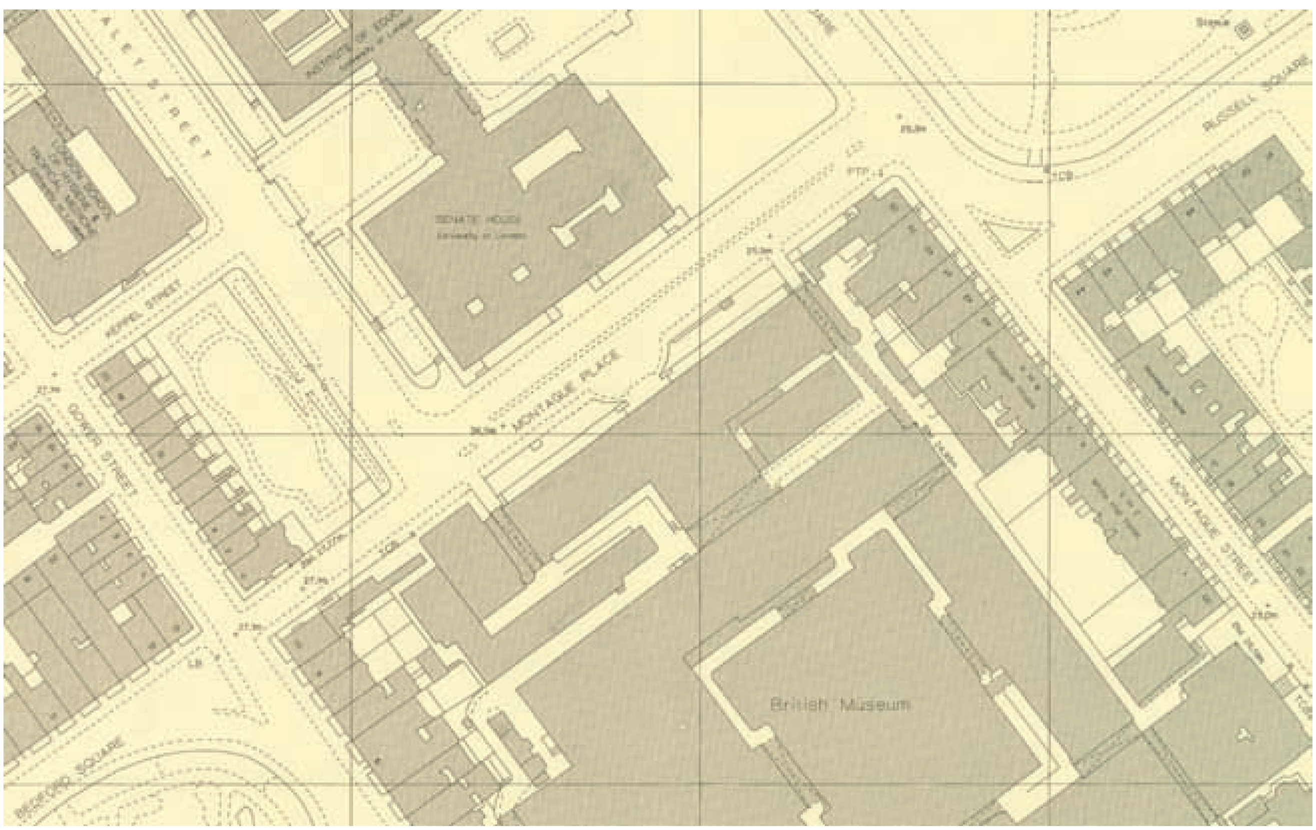


FIG. 639. DETAIL FROM AN EARLY 1:1,250 MAP PRODUCED DIGITALLY BY THE ORDNANCE SURVEY, 1972. The map showing the British Museum, London, was digitized using a Ferranti Freescan Digitizer, processed using Ordnance Survey software, and plotted by an EP 138 Automatic Light Spot Projector on a Ferranti master plotter. The plotter took two hours and forty-five minutes to complete the job. The Ordnance Survey was keen to demonstrate the flexibility of digital techniques. Although most sheets would follow the normal sheet lines for the foreseeable future, this sheet of part TQ2981 NE and TQ3081 NW demonstrated how a map could be produced independent of the original sheet lines using digital techniques.

Size of the entire original: 56 × 48 cm; size of detail: 18.7 × 29.9 cm. Image courtesy of Alastair W. Pearson. © Crown Copyright. Reproduced by permission of the Ordnance Survey.

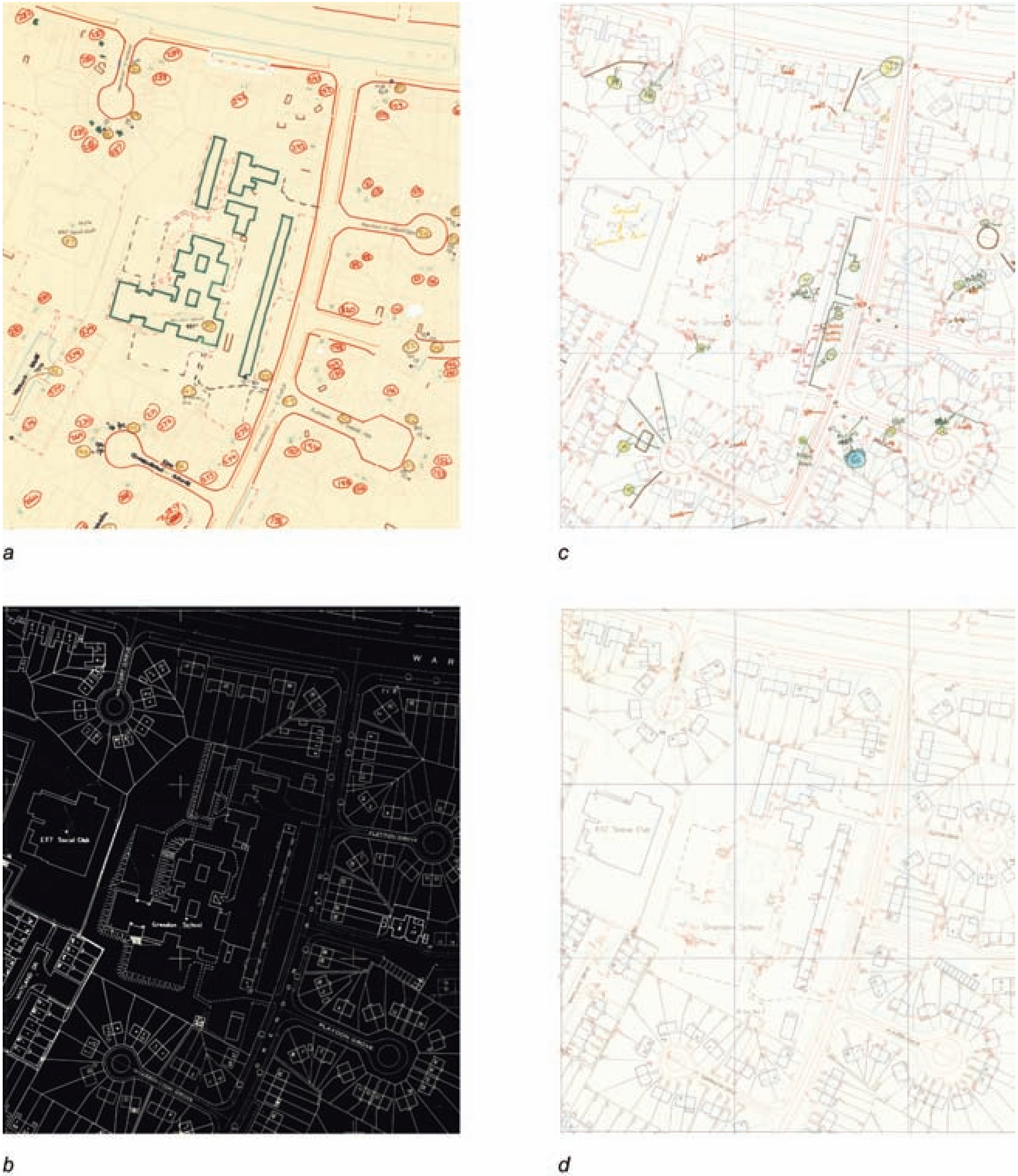


FIG. 640. THE DIGITAL PRODUCTION FLOW LINE, CA. 1980. A series of details from the same Ordnance Survey 1:1,250 series sheet. A pre-edit diazo copy of the original field document (*a*) would be marked up with changes that would be incorporated during the initial digitizing of a film negative (*b*). Errors would then be marked on the initial digitizing plot (*c*) and checked once again on the first correction plot prior to plotting of the final correction plot (*d*). All this work was conducted at the enlarged scale of 1:750.

Size of the entire original: 81 × 75 cm; size of detail: ca. 40.5 × 35.1 cm. Images courtesy of Alastair W. Pearson. © Crown Copyright. Reproduced by permission of the Ordnance Survey.

solidated blocks of sheets made little progress. The OS did attempt to prioritize repetitive areas where there was a firm commitment from users. However, digital map coverage was patchy. Early interest in purchasing digital map data had been further limited by the structure of these early data. The production process relied on data of a very low level of cartographic feature coding consisting of independent vector strings, often referred to as "spaghetti." In 1974 a feasibility study commissioned by the Department of the Environment for Great Britain evaluated the benefits of restructuring the data to a topological structure for use in an information system. The study also assessed the needs of potential users of large-scale digital map data in local governments, utility organizations, and the central government. Several useful possibilities were identified, including the need for land and property gazetteers and databases of properties, roads, and highways. Public utilities, such as gas, electric, and water, were identified as major users for large-scale digital data.

The methodologies developed during this phase were then applied to the metropolitan borough of Dudley, a few miles to the west of Birmingham, and the restructured data and land parcels were used successfully in a GIS (geographic information system) trial. A trial block of topologically structured data provided to utility services successfully demonstrated the benefits of using structured data in an information exchange system based on a single central processor to which various utilities were linked (Mahoney 1991).

While the OS clearly recognized the growing demand for digital data, the digital mapping program was estimated to be about 30 percent more expensive and no quicker than conventional methods (Great Britain, Ordnance Survey Review Committee 1979, 73–75). Government policy required the OS to stress cost recovery, but the demand from utilities for digital versions of base maps was increasing. Furthermore, the accuracy levels required by utilities were substantially below those of the OS, and the private sector could produce digital data to utilities' specifications substantially quicker and at lower cost than the OS. The OS's monopoly and copyright were therefore under pressure from the private sector.

The OS Review (or Serpell) Committee, under the chairmanship of Sir David Serpell, supported the OS strategy to continue developing its digital map production system before accelerating its existing program (Great Britain, Ordnance Survey Review Committee 1979). The report recommended completion of a digital topographic database of Great Britain by 1993 once the OS evaluated users' requirements and their level of commitment, reduced substantially the cost of digitizing, and confirmed the suitability of the data format. The proposed long-term objective was a single repository of data meeting the needs of both large and small scales. In 1983 the House of Lords' Select Committee on Science and Technology added its support to the acceleration of the digitizing program, which was not making sufficient progress. Together with a specially commissioned review of digital mapping at the OS by geographer David Rhind and Central Computer and Telecommunications Agency (CCTA) consultant R. A. S. Whitfield in 1983 ("A Review of the OS Proposals for Digitising the Large Scale Maps of Great Britain"), these reviews gave the OS a strong case for additional government funding, which was granted in 1984. These reviews also encouraged the OS to seek joint agreements with the private sector to relieve the growing pressure. As a result, the OS began a program of external contracts for digital data.

Despite these clear indications of progress, there was still concern that the OS would not complete its digitizing program in time to satisfy user demand. At the recommendation of the House of Lords Select Committee on Science and Technology, the government established a Committee of Enquiry, under the chairmanship of Lord Chorley, into the handling of geographic information (Rhind and Mounsey 1989; Chorley and Buxton 1991). Its recommendations underscored the need for the OS to collaborate with its major customers, the utilities, to produce digital data faster (Great Britain, Committee of Enquiry 1987). The OS agreed that its customers could let their own contracts for areas not yet digitized. Clear standards were created and a new specification was devised that reduced the number of feature codes from over 160 to just 35. These measures speeded up the digitizing program significantly. Though digitizing agreements with utilities accelerated production of consolidated blocks by the end of 1989, only seven counties were approaching full digital coverage. Nevertheless, the OS completed the digitizing of its basic scales by 1995, making Britain the first country in the world to convert its mapping to a digital format.

Cartography was traditionally viewed as a craft industry requiring a high degree of manual and artistic skill. Although digital mapping removed the need for these skills, greater responsibility fell on the management and staff in other ways, such as the need to manage much greater investments in capital equipment (Smith 1987). The support of systems that are more complex to maintain and more critical to the running of the organization became central to many staff roles, as did the availability of programmers and analysts rather than direct production staff. The OS underwent major changes in its corporate objectives. By the end of the century, the OS had begun to present itself as a supplier of information as well as a supplier of high-quality mapping—in essence a data warehouse.

The digital mapping program was dogged by uncertainty about whether the data were appropriate to the needs of an emerging market. The government-imposed increase in cost recovery during the program put pressure on the OS to define a pricing policy for which there was no precedent. The inherent flexibility and ease of transfer of digital data made it very difficult to define a satisfactory pricing policy. Reaching licensing agreements with the major utilities and government at all levels was therefore of critical importance to guarantee its long-term future.

Controversy surrounded OS digital mapping work, both in terms of its lack of progress and in the way it developed (Rhind 1990). Application development moved significantly faster than data creation. Defenders of the OS were quick to point out that its role as a government department was to provide a service to the nation as a whole and that it had to avoid serving the needs of one sector of the market at the expense of others (Sowton 1991).

The beginnings of digital mapping were dogged by the absence of a clearly defined purpose. Indeed, from the earliest days of digital mapping at the OS a dichotomy had existed between digital mapping as an internal production technique and digital mapping to support the wider applications of digital data. Progress was hampered because the OS was forced to serve both goals (Whitfield 1981). This can be seen at the more technical level. The OS had been such an early investor in automation that it was bound to reflect old ideas and technology concerning hardware, communications, software design, and data handling concepts. Furthermore, the OS digital mapping program had suffered due to a lack of an integrated design incorporating the needs of map production, field survey, and data storage. Map production could (and perhaps should) have been just one of the applications of a more flexible design. Instead, its design was based upon the automation of a traditional map production process, which was organized for a particular product. Nevertheless, by the end of the century the OS could reflect with some pride on its role as a pioneer of the digital age.

PETER COLLIER AND ALASTAIR W. PEARSON

SEE ALSO: Close (Arden-Close), Charles Frederick; Geodetic Surveying: Europe; Intellectual Property; International Map of the World; Property Mapping: Europe; Remote Sensing: Satellite Imagery and Map Revision; Report of the Committee of Enquiry into the Handling of Geographic Information (1987); Topographic Mapping: Western Europe

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***Orell Füssli Kartographie AG (Switzerland).*** The beginnings of this publishing house date from 1519, when the Zurich council granted Bavarian-born Christoph Froschauer citizenship and gave him printing jobs, thereby according him a status similar to that of government printer. In 1515 Froschauer had come to Zurich and apprenticed in the printshop of Hans Rüegger; after his master died two years later, Froschauer married his widow. The business grew to encompass wood engraving, typesetting, papermaking, printing, and bookbinding, and its reputation spread far beyond Switzerland's borders. In addition to publishing important books with map illustrations, Froschauer and his nephew, also named Christoph Froschauer and who succeeded him, published some separate sheet maps. Although the company's ownership and name changed throughout the following centuries, it always remained in the hands of prominent Zurich families. By the nineteenth century, it was operating under the name Orell Füssli & Co. (1798–1890), and from 1890 to 1993, for most of the twentieth century, it was known as Art. Institut Orell Füssli. The company has conducted a diverse range of activities throughout its existence, including map publishing.

The date when Orell Füssli (also known by its acronym, OF) printed its first maps is not certain. In 1924, Orell Füssli acquired the Winterthur-based company Kartographia Winterthur, a move that enabled the firm to begin continuous map production. Kartographia Winterthur was already the publisher of important maps (fig. 641) and atlases, such as the Swiss middle-school atlases.

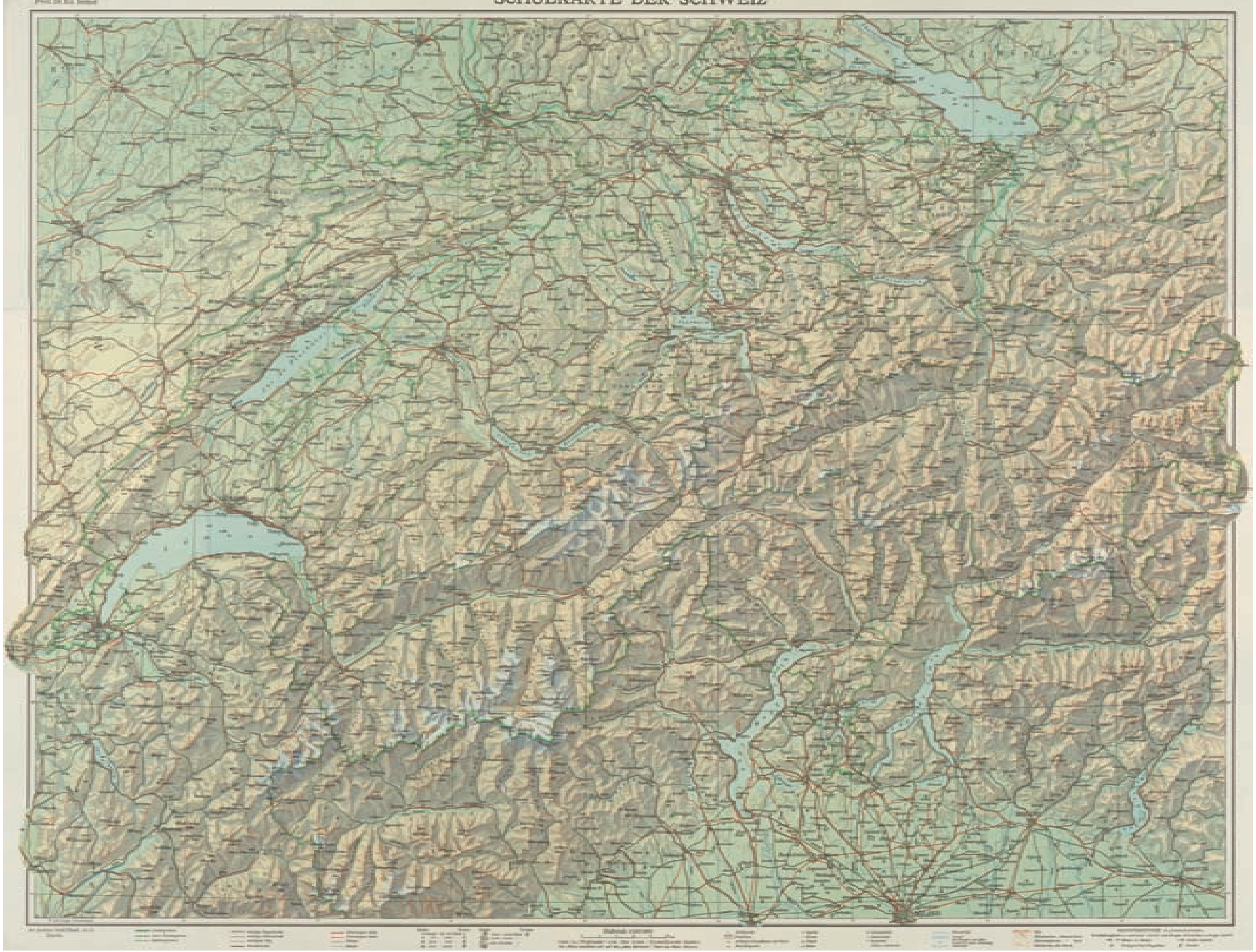
Dissatisfied with foreign-produced atlases, which did not provide enough detail about Switzerland, the Swiss cantons decided about 1898 to print their own official teaching materials. The federated school system of Switzerland posed a difficult task, preparing an atlas for middle schools in German-, French-, and Italian-language versions, as well as another version for secondary schools. After many delays, the Konferenz der kantonalen Erziehungsdirektoren published the *Atlas für schweizerische Mittelschulen* in 1910, followed by a French edition, *Atlas scolaire suisse pour l'enseignement secondaire*, in 1911, and an Italian edition, *Atlante per le scuole medie svizzere*, in 1915. Under the direction successively of August Aeppli from 1898, Eduard Imhof from 1927, and Ernst Spiess from 1976, the production of middle-school atlases in the three official languages of Switzerland continued without interruption for a century. The publication of the atlases passed to Orell Füssli in 1924. Continuous revisions occupied the editors, both of the Swiss middle-school atlas (first revised edition published in 1932, with further redesigns in 1948 and 1962, and totaling twelve editions, each in German, French, and Italian, published by 1972) and also of the Swiss secondary-school atlas (first published in 1934, appearing in twelve editions until 1975). Imhof, for example, was involved for over four decades, as he worked on revisions for more than 1,000 atlas maps (fig. 642).


FIG. 641. COVER OF *POLITISCHE SCHULKARTE DER SCHWEIZ* (ZURICH: ART. INSTITUT ORELL FÜSSLI, 1928). Scale 1:600,000. The cover of this political school map of Switzerland indicates that it was printed by Kartographia Winterthur AG after it had been acquired by Art. Institut Orell Füssli in 1924, and the cover design is characteristic of the period before 1940.
Size of the original: 25 × 12.7 cm. Private collection.

In addition, Orell Füssli gained a reputation for the production of thematic maps. Some were of the company's design while others were commissioned from map authors or educational publishers. Orell Füssli donated most of the archive of its map products to the Zentralbibliothek in Zurich in 2010.

In 1992, the entire company was restructured. All

# SCHULKARTE DER SCHWEIZ



printing operations were moved to the facilities of Zürichsee-Druckerei AG in Stäfa, near Zurich. Within the holding company, cartographic activities became independent after a management buyout. Today, the company mainly produces road maps, city maps, hiking maps, language atlases, geological and hydrogeological maps, soil maps, school maps, and atlas maps. From 1993 until the end of 2003, Photoglob AG, a subsidiary of Orell Füssli Holding AG, was in charge of map publishing. Since 2004, Orell Füssli Kartographie AG has been responsible for map production and publishing, while Photoglob is in charge of sales. In 2007, Orell Füssli acquired Edition MPA, part of MPA GéoDistribution SA based in Chavannes-près-Renens, thereby strengthening Orell Füssli's map publishing capabilities in the French-speaking part of Switzerland.

Today, Orell Füssli is an international industrial trading group with its headquarters in Zurich, and the Orell Füssli Holding AG is listed on the Swiss stock exchange. It focuses on printing legal tender and securities, industrial systems for individualizing securities and brand products, and the book trade. The publishing house remains the traditional base of the company. Due to massive technological changes in cartography, Orell Füssli Kartographie AG has become a general contractor and provider of geographic information systems (GIS) services and digital cartographic products. As such, it also offers all printing services: multicolor offset printing, equipment, packaging, and shipping.

HANS-ULI FELDMANN

SEE ALSO: Marketing of Maps, Mass; Road Mapping: Road Mapping in Europe; Wayfinding and Travel Maps: (1) Indexed Street Map, (2) Road Atlas

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***Orienteering Map.*** Orienteering as a sport started as a military navigation test/training in the second half of the nineteenth century, mostly in Norway and Sweden. In 1886 the word "orienteering" was used for the first time to mean crossing unknown territory with the aid of a map and compass. The main reason for the term's Scandinavian origin is probably due to the very complicated terrain there compared to continental or Mediterranean areas, but the long tradition of using topographic maps (available for civilian use) must have played a decisive role too.

The first civil orienteering competition was held in Norway in 1897. The birth of orienteering is generally dated to this event, although the use of maps and compass was not compulsory. Modern orienteering racing did not begin until the end of World War I. Ernst Victor Killander, president of Stockholm's Idrottsförbund (sports federation), established the rules of a cross-country event where competitors not only ran a course but had to select their routes using a compass and a map (Berglia 1987).

By 1930, orienteering had become firmly established in Finland, Norway, and Sweden with meetings and cooperation between these three countries a regular feature. At the end of the 1920s, there were about 5,000 active orienteers in Sweden. The first nighttime orienteering event was held near Stockholm in 1922, and the first event for women was also held in Sweden in 1925 (Myrvold 2004–8). The first independent national orienteering federations were formed around 1937–38 in Norway and Sweden. In 1946, a Nordic body for cooperation (NORD, Nordisk Orienteringsrat) was founded (Nüscheler 2005–9).

During the early period of orienteering, large-scale civil topographic or tourist maps were commonly used. In most countries there were no suitable maps available for public use. According to running speed and course length, the scale of the maps needed to be from 1:20,000 to 1:40,000 (1:50,000 to 1:100,000 in the early years). In some Eastern European countries, topographic maps were classified, in other areas the largest available scale of topographic maps was only 1:50,000. Using tourist maps was a logical alternative, but in Eastern Europe the accuracy of publicly available tourist maps was not suitable for these events. Therefore, these countries tried to find more accurate tourist maps published before the Communist era.

There was also a problem of copying. Offset printing (especially color) was too expensive and technically very difficult even for keen organizers. For the sport to reach a higher level it needed to increase the number of participants in the events, create international relationships, and form regional and continental organizations. The first orienteering map, specially drawn and based on specific fieldwork for an orienteering event, was created in Norway in 1941. The first color orienteering map was published in Norway in 1950 (fig. 643).

(*Facing page*)

FIG. 642. EDUARD IMHOF, *SCHULKARTE DER SCHWEIZ* (ZURICH: ART. INSTITUT ORELL FÜSSLI, 1952). Scale 1:500,000. The terrain shading and coloring on this school map illustrate not only the mountainous topography of Switzerland but also the cartographic skill in relief representation for which Imhof was renowned. Size of the original: 55.8 × 72.8 cm. Image courtesy of the Zentralbibliothek, Zurich. Permission courtesy of Orell Füssli Verlag, Zurich.

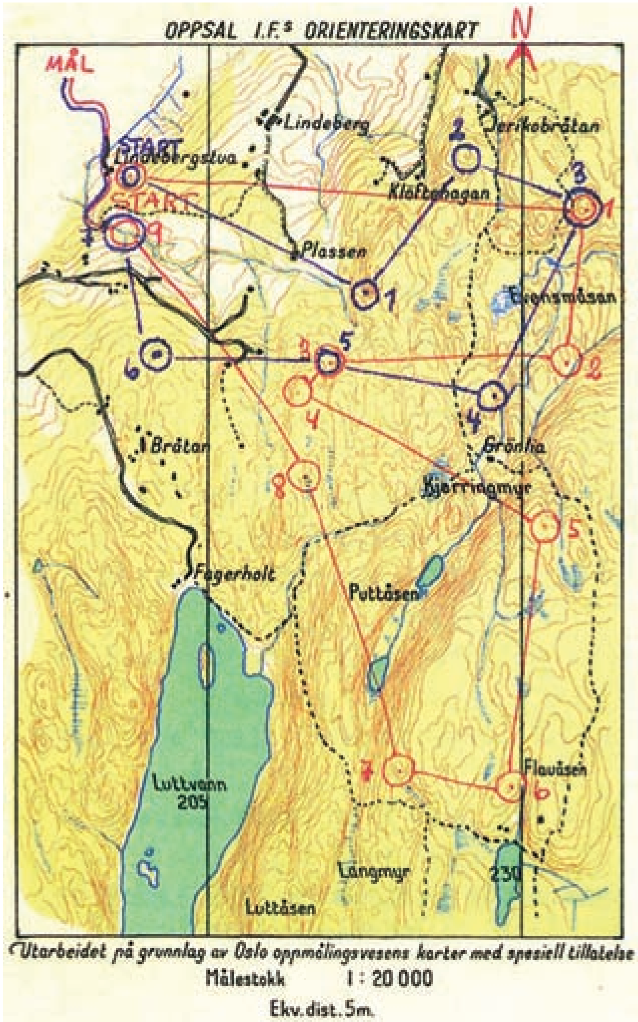


FIG. 643. FIRST COLOR ORIENTEERING MAP, OPPSAL, NORWAY, 1950. Competition courses are hand drawn in blue and red ink.
Size of the original: ca. 9.9 × 6.1 cm. Permission courtesy of the International Orienteering Federation, Helsinki.

The International Orienteering Federation (IOF) was founded in 1961 with ten members: Bulgaria, Czechoslovakia, Denmark, East Germany, Finland, Hungary, Norway, Sweden, Switzerland, and West Germany. The first European Orienteering Championships was organized in Norway in 1962 and the first World Orienteering Championships in Finland in 1966 (figs. 644 and 645). The earliest international discussions on orienteering maps drew heavily on the mapmaking experience of Scandinavians. At that time, the map specifications of different countries were based on their own topographic maps, which gave local competitors an unfair advantage in international events. In 1965, the Map Committee of the IOF was formed. The members were cartographers and orienteers: Jan Martin Larsen (Norway), Osmo Niemelä (Finland), Christer Palm (Sweden), Torkil Laursen (Denmark), and Ernst Spiess (Switzerland). The most important and urgent work of the committee was to develop the specifications for world championships maps: (1) they had to be based on new fieldwork; (2) they had to show every detail of the terrain that could affect the route choice of the competitor; (3) accuracy and legibility were most important; small and unimportant details had to be omitted; and (4) for international events the maps had to use the same specifications. The suggested scales were 1:25,000 or 1:20,000, the contour interval was 5 meters (10 m or 2.5 m were also allowed) (Palm 1972, 131; Spiess 1972; and see table 40).

The international specifications for foot orienteering are the basis for drawing specifications for maps to be used in the other three disciplines of orienteering—ski, mountain bike, and trail orienteering (foot orienteering includes sprint orienteering). Despite these common features, some special rules are needed for generalization along with extra symbols and comments for the different forms of orienteering (Zentai 2000; and see table 41).

Orienteering maps are one of the very few map types that have the same specifications worldwide. Theoretically, there should not be national deviations in orienteering maps. Although there can be some in practice, they are not important or the maps are used in local events only.

To make maps suitable for orienteering, mapmakers have to be familiar not only with the map specifications but also with the rules and traditions of the sport. Generally, makers of orienteering maps are not professional cartographers. Depending on the quality of the available base maps, the mapmakers regularly spend twenty to thirty hours on each square kilometer (for foot orienteering maps). State topographic maps can be used as base maps if the scale is appropriate, but as mentioned above, in many countries the largest available scale of state topographic maps is too small. In these cases the orienteers look for alternatives. Aerial photos, orthophotos, or laser scanning data are commonly accessible in these countries and special services are offered for making stereophotogrammetric plots with detailed contour lines (Zentai 2009).

Sprint orienteering uses mostly urban or park areas. The courses are very short (twelve to fifteen minutes), and the number of terrain features is much higher than in forested areas. To represent such complexity and make legible maps for very fast events, larger scales (1:5,000 or 1:4,000) and a different set of specifications with more symbols in plan shape and fewer point symbols are needed.

Since 1985, the Map Commission of the IOF regularly has held an international conference to improve the level of orienteering mapping and emphasize the im-


FIG. 644. MAP OF THE FIRST WORLD ORIENTEERING CHAMPIONSHIPS, FISKARS, FINLAND, 1966. See also figure 645. Size of the original: ca. 26.2 × 25 cm. Permission courtesy of the International Orienteering Federation, Helsinki.

portance of standardization. The IOF is responsible for the four official disciplines of orienteering. Other similar activities (like motorized navigation, GPS-based games, adventure races) are not regulated by the IOF.

The small number of symbols in orienteering maps made it relatively easy to replace the formerly hand-drawn orienteering maps with ones drawn by computer, but it was difficult for nonprofessionals to draw all the symbols of the orienteering map specification. Currently, nearly all orienteering maps are drawn with a Swiss OCAD software, first published in 1988–89. Around 10,000 different orienteering maps are published every


FIG. 645. DETAIL FROM THE FIRST WORLD ORIENTEERING CHAMPIONSHIPS MAP, 1966. The women's start is shown.
Size of this detail: ca. 8.2 × 4.9 cm. Permission courtesy of the International Orienteering Federation, Helsinki.

year worldwide, most of them using computer printers instead of offset printing.

LÁSZLÓ ZENTAI

SEE ALSO: Perception and Cognition of Maps: Map-Use Skills; Navigation; Recreational Map; Topographic Map

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***Ormeling, Ferdinand J(an).*** Ferdinand (Fer) Ormeling was a geographer of powerful intellect and great charisma who devoted his exceptional life to maps and mapping and became an international hero of twentieth-century cartography. Born in Amsterdam on 12 April 1912, he was educated at Gemeentelijk Gymnasium Hilversum and the University of Utrecht. His first employment, in teaching, was interrupted by World War II, when he went underground to avoid cooperation with occupying forces. In 1945 he was sent with an expeditionary force to deal with continuing strife in the Netherlands East Indies. Although a soldier, his contributions as a geographer and cartographer include an outstanding PhD study of Timor and the cofounding of the Geografisch Instituut van de Topografische Dienst

TABLE 40. Overview of the *International Specifications for Orienteering Maps* (*ISOM*)

| Year published | Number of symbols | Suggested scales | Other remarks |
|---|---|---|---|
| 1969 | 52 | 1:25,000, 1:20,000 | Four colors only. |
| 1975 | 100 | 1:20,000, 1:15,000 | Green color in three shades for the representation of restricted runnability. |
| 1982 | 98 | 1:15,000, 1:10,000 | Combination of green and yellow colors allowed. |
| 1990 | 105 | 1:15,000, 1:10,000 | From a guideline to a rule set by continuous improvement. |
| 2000 | 104 | 1:15,000, 1:10,000 | Includes the four official disciplines of orienteering (foot, ski, trail, and mountain bike) for the first time. |

TABLE 41. Disciplines of orienteering

| Disciplines/ competition formats | First world championship | Limitations in the map or in the event |
|---|---|---|
| Foot orienteering | 1966 | |
| Ski orienteering | 1975 | Reduced content of the map: runnability is omitted. The skiers have to ski on the tracks. |
| Trail orienteering | 1999 | Map must be viewable from a sitting position (for participants who use a wheelchair). |
| Sprint orienteering (part of foot orienteering) | 2001 | Suggested organizing in urban or park areas. |
| Mountain bike orienteering | 2002 | Reduced content of the map: runnability is omitted. The bikers use mainly roads. |

(in 1947) to which he was later appointed director by the new government of independent Indonesia. His ten years in Indonesia (1945–55) were most significant for Indonesia, his personal development, and wider recognition of his organizational and leadership skills.

Ormeling's next destination was Groningen, where he spent eight influential years editing and modernizing atlas production for J. B. Wolters. In 1964 he was made chair of Economic Geography at the University of Amsterdam, but it was his professorial appointment in 1971 at the International Institute for Aerial Survey and Earth Sciences (ITC), where he established and headed the Department of Cartography, that launched his truly international career (Ormeling 1974). The original mission of the ITC—to assist, through education and training, the mapping of developing countries—matched his own objectives, and by his retirement in 1982, over 450 international students from 140 countries had benefited from his personal encouragement and vivid, inspiring teaching (Hedbom and Böhme 1989).

From the 1960s his motivation and organizational skills were directed toward rationalizing and developing the geography and mapping communities in the Netherlands. He introduced a new Cartographic Section in the Koninklijk Nederlands Aardrijkskundig Genootschap, enlarged that society (and was its president, 1967–71), and in 1975 helped consolidate various mapping groups into the Nederlandse Vereniging voor Kartografie. Another passion, born of experience in Indonesia's multilingual environment and later at the ITC, was the standardization of geographic names. For over twenty years he was a worthy representative on the United Nations Group of Experts on Geographical Names (UNGEGN), his special contributions being in education and training (Ormeling 1984).

Ormeling's crowning achievements came from his involvement with the International Cartographic Association (ICA), whose international mission was closely in step with his own. An early and distinguished ICA supporter, he was elected secretary-treasurer in 1964 and served as president from 1976 to 1984. His valedictory, a personal record of the ICA, was presented in Morelia, in 1987, but his final greeting to ICA friends was sent (on video) to the ICA Conference in Beijing in 2001. Ormeling's years with the ICA brought many changes, including new activities, new commissions, and a huge expansion of membership (Ormeling [1986?]). It is no surprise that such a distinguished life attracted many honors, including Knight of the Order of the Netherlands Lion in 1978 and the ICA's own Mannerfelt Medal in 1987. Ormeling died in Enschede on 1 May 2002.

MICHAEL WOOD

SEE ALSO: International Cartographic Association; International Institute for Geo-Information Science and Earth Observation (ITC; Netherlands)

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