Part II: The Twentieth Century

Reconnaissance, topographic, and cadastral cartography played a key role in the discovery, surveying, and settlement of the American West during the nineteenth century. Beginning with Alexander von Humboldt’s largely compiled map of New Spain, first published in 1811, cartographers refined survey methods to more accurately measure the land they covered and developed techniques to more accurately represent it on maps. Two such techniques to represent terrain — hachures and contours — became a staple of American topographic mapping, following the examples set by European cartographers.

The “Great Surveys” of the intermontane West during the 1860s and 1870s culminated in 1879 with the founding of the U.S. Geological Survey (USGS), which consolidated federal surveying and mapping efforts into one agency and eventually led to the use of contours as the preferred official method of relief representation. The federal surveys also inspired a number of related official and unofficial landform mapping projects that would influence American geography in the twentieth century and beyond.

One of the most revolutionary developments in the history of cartography — photography — emerged during the second half of the nineteenth century both as a method of gathering data and as a technique for reproducing maps. However, despite the presence of photographers and artists on many of the official and unofficial surveys of the time, as well as the use of anchored observation balloons during the American Civil War, the potential cartographic applications of photography went substantially unrealized until after World War I. The engraved topographical map based on instrumental field surveys continued to hold its own as the dominant method of representing terrain.

In 1858 Gaspard-Félix Tournachon, a Frenchman who preferred the name Nadar, took the first aerial photograph, from a tethered balloon. Two years later American photographer Samuel A. King, assisted by James Wallace Black, ascended to 1,200 feet to take a picture of Boston. At roughly the same time improvements were being made in optical equipment, especially in Germany, including the binocular stereoscope. The development of a more controlled means of flight, made possible in the first decade of the twentieth century by heavier-than-air craft (the airplane), allowed cartographers to more effectively utilize the medium, and shortly after World War I cameras mounted on aircraft were being used to take overlapping vertical photographs at regular intervals.

Over time the use of aerial photography gave rise to photogrammetry, the science of obtaining reliable measurements by means of photography, and, by extension, to mapping from photographs. The preferred source materials for air surveys are vertical photographs with a 60 percent overlap along the line of flight of the aircraft taking pictures (the endlap) and a 25 percent overlap with adjacent flight lines (the sidelap). The endlap and the sidelap ensure that only the most accurate part of any particular photograph — the center — need be used and, more significant, make stereoscopic analysis possible. By using the stereoscope and much more elaborate and refined optical instruments (such as the multiplex), photogrammetrists can create a miniature three-dimensional model of a given area that facilitates the production of contours and in important respects is generally superior to other methods of delineating terrain. It is only necessary to compare topographic quadrangles surveyed on the ground with maps of the same area generated by aerial methods to appreciate the difference. The latter representations also are easier and less costly to produce, can cover areas difficult to reach on the ground, and are more easily updated than topographic maps derived from conventional surveys. More recent innovations in terrain representation utilizing rectified aerial photographs as a base include the USGS’s orthophoto map and the National Imagery and Mapping Agency’s similar, false-colored pictomap. Both are particularly good for showing the texture of areas of low relief, including wetlands.

Given the benefits of photogrammetry, it might properly be asked why vertical aerial photographs have not replaced topographic maps altogether. The primary answer is simply that even though distortions can be removed to make them more or less correct in scale, such photographs contain too much information to be useful on a map. The need for a combination of both types of maps is illustrated by the fact that the U.S. Geological Survey website offers a modern orthophoto of the same area along with the topographic map.
Top: U.S. Geological Survey map of Yosemite Valley, California, with contours, shaded relief, and hypsometric tints.

Bottom: Detail from a Goode atlas map (circa 1925) depicting a section of the western United States.

much information; ideally, a map represents a judicious selection of data for a specific purpose. As a result, although most topographic surveys are now made photogrammetrically, modern topographic maps continue to feature conventional symbols, including contour lines, which allow mensuration. The typical contour interval (the vertical distance between successive contours) on modern official USGS topographic maps of the scale of 1:24,000 is twenty feet, or about six meters. Lesser contour intervals are sometimes used in very flat areas, with greater intervals in areas of considerable slope. So-called hachures are used only to indicate the direction of ground slope or for features too small to contour: banks, escarpments, and piles of waste materials. At their best, such maps, sometimes with the contours enhanced by shaded relief, are excellent for their designed purpose — to give a detailed, measurable representation of small areas.

Concurrent with developments in official large-scale topographic mapping efforts in the United States (and elsewhere), a number of unofficial cartographers working independently or allied
with commercial establishments and educational institutions were making relief maps of much smaller scales. Using data provided by the new surveys in the West, these cartographers compiled generalized hypsometric maps, typically printed privately. Such maps appeared in an atlas prepared by J. Paul Goode, of the University of Chicago. Goode’s *World Atlas*, as it eventually became known, was first published by Rand McNally and Company in 1925 and soon became the standard U.S. college atlas. However, the earlier editions did not adequately account for the fact that with plains up to 1,500 meters in elevation, there is not necessarily a positive correlation between height (altitude) and ruggedness. Some elevated areas, such as eastern Colorado, are quite flat. By contrast, mountains of considerable elevation, such as the 2,800-meter peaks of the Wasatch Range in Utah, were lost between the atlas’s standard hypsometric interval of 1,500 meters to 3,000 meters. The addition of shaded relief supplementing less generalized contour lines has corrected the problem in recent editions.

Another reaction to hypsometric maps whose generalized “contour” lines of elevation above sea level may have no topographical significance was the development of small-scale landform mapping. This particular application had its origins at the end of the nineteenth century in the block diagrams of geomorphologists Grove Karl Gilbert, who served on both the Wheeler and the Powell surveys, and William Morris Davis. Davis’s 1898 block diagram of the Black Hills of South Dakota, pictured in Part I of this article, illustrated the relationship of surface forms to subsurface geology.

Davis taught at Harvard University in the early years of the twentieth century, where he was followed by the Hungarian-born cartographer Erwin J. Raisz. Beginning in the 1930s, Raisz took block-diagram surface forms and put them on a map base to produce what he called landform maps. These representations became popular with educators and as book illustrations. Other geographers, including Armin Lobeck, who taught at Columbia University and made similar delineations at the same time, refused to use the term “map” for these “physiographic diagrams,” as he described them, because of the incompatibility between the oblique-viewed surface forms and the plan view of the map, a distortion that only increases as the scale of the map increases. Nevertheless, at small scales landform maps or physiographic diagrams are extremely graphic and valuable pedagogic aids.

*Anticipating images from space, Richard Edes Harrison drew small-scale perspective representations on orthographic projections that were very popular during World War II. Harrison also combined hypsometric tints with shading on more conventional small-scale terrain maps. At the time cartographers wrestled with the issue of a universal system of conventional colors to use as hypsometric tints between selected contour levels. Using green for lowlands, yellow for intermediate heights,
an area with nearly 3,500 meters of relief, shows lowland grasslands in yellow, chaparral-covered hills in light green, coniferous-forested uplands in dark green, and snow-covered peaks in white, combined with shaded relief. This method has found great favor with airlines, which provide their passengers with maps using “natural” colors, enabling passengers to more easily recognize the landscapes they are flying over.

In the 1950s Arthur Robinson and I experimented with extensions of the “inclined contour line” method of terrain representation invented by Kitirō Tanaka of Japan. Our research was prompted by the difficulties U.S. Army personnel were experiencing in learning how to “read” contours. Tanaka used his lines in a series, inclined at 45 degrees to produce the effect of relief. However, as he acknowledged, his relief maps appeared too flat, produced a pseudo-scopic (inverted image) effect, and were too dark to allow for the overprinting of other information. Robinson and I used traces of parallel, inclined planes (as we called them) of less than 45 degrees and found that this enhanced the effect of relief while preserving correct planimetry. Our 1955 map of part of the Colorado Rockies, for example, illustrates the correct planimetry characteristic of this method of relief representation. The method is not quantitative in the same sense as a contour map, allowing slope to be measured and showing elevation above a datum (mean sea level), but it gives a picture of the landforms at topographic scale. Of course, the contours on which this method is based could be added, but this leads to such a confusion of lines that the “physiographic” quality of the presentation is diminished.

The mapping of extraterrestrial relief, using methods developed for depicting landforms on the earth, truly represents the next frontier of topographic mapping. Although it would take a separate work to chronicle the advances made over just the last several decades, it is worth calling attention to a lunar chart from the topographic section of the U.S. Defense Mapping Agency (now the National Imagery and Mapping Agency) delineating the crater Copernicus and other selenographic features. This map was made before, and to assist in, the lunar landing by the United States on 20 July 1969. It should be pointed out that images from space of the earth and other bodies, though often beautiful and impressive, unless annotated with quantitative symbols (including isolines), do not take the place of contour maps of these bodies.

A more recent example, which illustrates the development of computer-generated terrain representation, is a map of a small part of the area of the 1994 Northridge earthquake in California, using both raster (line) and pixel (area) symbols. It was
produced only days after the January 17 quake by the Environmental Systems Research Institute (ESRI) of Redlands, California, with the help of the California Institute of Technology and the Thomas Brothers Map Company, and greatly assisted in solving problems caused by the earthquake in a timely manner.

As with cartography itself, terrain representation brings together art, science, and technology in a remarkable way, as illustrated by the evolving methods of representing the form of the land in the United States over the past two centuries.

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Illustrations courtesy of Norman J.W. Throver

Further Reading
Lobeck, Armin K. Block Diagrams and Other Graphic Methods Used in Geology and Geography. Amherst: Emerson Trussell, 1958.