PHOTOGRAMMETRY APPLIED TO EARTH SCIENCE IN THE U.S. GEOLOGICAL SURVEY

GEOLOGISTS AND HYDROGEOLOGISTS have traditionally prepared their maps by field-surveying techniques, either by sketching pertinent information directly on topographic or planimetric base maps or by annotating data directly on aerial photographs or on transparent overlays. Geologic mapping with only a topographic map as a base is still common, but when aerial photographs became widely available in the 1940's their use superseded much direct plotting on base maps. Nowadays in the Geological Survey, photogrammetric techniques are commonly used both for geologic mapping and for compiling data from aerial photographs.

Geologists who map on aerial photographs take advantage of the three-dimensional quality of the stereoscopic model and the wealth of its inherent image detail for interpreting and accurately delineating geologic features. Details that can be seen and mapped on the photographs, however, must be transferred to a base map for compilation and publication, and much of the accuracy gained by careful annotation can be lost by inaccurate transfer. Excessive radial displacements caused by high topographic relief, and distortions caused by tip or tilt of the aerial camera, must be corrected in the transfer process. These corrections can be made visually by careful and skillful terrain interpretation and freehand sketching, or instrumentally by the use of photogrammetric techniques. For areas of low relief, where radial distortions are small, details mapped on aerial photographs can be adequately transferred to a base map by tracing or by using a simple optical projector to make adjustments for scale differences; if tip or tilt cause distortions, a tilt-correcting device, such as a sketchmaster, can be used to correct them. Many mapping projects, however, are in rugged areas of high relief where radial distortions must be corrected photogrammetrically for accurate compilation.

HISTORY AND DEVELOPMENT

During the 1940's and early 1950's, the use of aerial photographs for geologic interpretation and mapping increased rapidly, and new instruments and techniques were devised. Though limited in capability, radial planimetric plotters were used for constructing planimetric base maps and transferring geologic annotations from the paper prints onto the base map. Higher order projection-type photogrammetric plotters such as the ER-55 and Kelsh were used routinely for topographic contouring and base-map control. These plotters were first used in 1954 by Survey geologists who soon afterward began teaching other geologists to set up and orient the stereomodels. The Survey's Kelsh and ER-55 plotters were widely used for geologic mapping during the 1960's and the early 1970's.

The PG-2 plotter replaced the projection plotters, because it combines high plotting accuracy with an excellent viewing system for stereoscopic inspection. It also is the only instrument that (1) with equal ease uses black-and-white or colored paper prints and film or glass transparencies, (2) has a high-quality viewing system incorporating a readily changed, variable magnification, (3) has an illuminated floating mark that can be easily seen in dark parts of the image, and (4) has an ease of operation that enables geologists with little use experience to operate the machine as soon as the stereomodel has been oriented. Though designed for topographic mapping, the PG-2 plotter is particularly well suited for geologic studies because the paper prints used by the geologist in the field can be placed directly in the plotter so that field annotations, together with additional data observed in the stereoscopic model, can be plotted directly and accurately onto a topographic base map. This plotter also enables the operator to sit comfortably in a well-lit room while viewing the model and at the same time referring back to field notes and photographs. The projection-type plotters required subdued room lighting and, therefore, were inconvenient for studying map annotations and field notes simultaneously.

Once the photographs are properly placed in the machine and parallax is cleared from the stereoscopic model, the PG-2 plotter is simple to operate. However, certain procedures must be followed to clear the parallax and level and scale the model to a base map. At the Geologic Division Plotter Laboratory in Denver, a photogrammetric technician orients the model for geologists who prefer not to do so themselves. Features seen in the model can then be plotted by tracing their images, just as with other stereoplotters. Many geologists use the machines only to trace lines already mapped on the photographs, simply compiling previously mapped geology (thus the needed capacity of the plotter to accommodate paper prints). Other geologists, using field stations or measurements mainly as guides to mapping, prefer to map directly from the stereomodel, followed by field checking—a combined procedure that is highly effective for mapping areas of good exposure and little vegetation, such as deserts, high mountains, and polar regions.

The Computer-Assisted Geologic Mapping System

In the 1980's the Survey devised a computer-assisted geologic mapping system that uses the PG-2 plotter to (1) enhance the capabilities of the plotter for geologic mapping, (2) provide a means for geologists to make geologic maps more efficiently, and (3) develop new ways to apply computer technology to geologic studies. The system is capable of producing geologic maps and geologic-map products such as structure-contour and isopach maps, overburden and interburden maps, and surface profiles for geologic cross sections—all from stored digital information generated by the plotter, supplemented by subsurface data entered from a two-axis digitizing table. In some projects, it will be possible to go directly from stored data from photographs to published maps without the necessity for drafting or scribing. In addition, a set of computer routines designed specifically to aid in geologic studies has been developed jointly by the U.S. Geological Survey and the Geological Survey of Greenland in Copenhagen, Denmark. This routine, called Geoprogram, allows the geologist to integrate the visual stereoscopic model with the three-dimensional mathematical model of the geology. A rapid interchange of information between the computer and the operator is one of the most useful aspects of the system. As the tracing carriage is moved about the stereomodel, the Geoprogram provides the kinds of information the operator needs for making structural interpretations by the near-instant generation of mathematical planes representing geologic attributes. For example, dips and strikes of any planar surface can be computed automatically by simply tracing the floating mark along the outcrop of the surface or by occupying three or more points on the surface. Once a plane has been computed, the floating dot can be guided by the computer so that it remains on the plane throughout the model and thus allows comparisons of geologic surfaces, mapping of covered contacts, and precise measurements of inclined strata. The dot can also be controlled by a surface-model grid, which allows projection of curved geologic surfaces, rather than flat planes, throughout the model.

Analytical plotters, which are fully computer controlled, are not restricted by the limitations of the mechanical analog plotters. Computer-controlled systems offer the additional advantages of working with a wide array of photographic materials ranging from hand-held, 35-mm stereophotographs of any orientation to satellite imagery. All that is required to utilize the stereoimagery is control in the form of x-y-z coordinates for at least three points that appear on both images of the stereopair. Mappers should be familiar with these new instruments and techniques.

How to Get Aerial Photographs

The great increase in use of aerial photography in the United States in the past few decades has resulted in millions of photographs. These range from low-altitude photographs of small areas with great detail to high-altitude photographs that cover more than 100 square miles in one exposure and to photographs from space that cover vast regions of the planet.

The U.S. Geological Survey's Earth Science Information Center (ESIC) maintains records of aerial photographic coverage of the United States and its Territories, based on records from other Federal agencies, State governmental agencies, and commercial companies. From these records, called the Aerial Photography Summary Record System, ESIC can assist you in finding the photography to meet your needs. (Address is at the end of this section.) Records go back as early as the late 1930's for certain areas. Most early photographs were taken on black-and-white film. Color and color-infrared films were introduced later. Contact paper prints, film positives, or enlargements of these photographs can be ordered.

Contact paper prints 9×9 inches presently cost about two-thirds as much as film positives; film positives, however, produce the highest quality images for photointerpretation and mapping on the PG-2 plotters. For official use, the Geologic Division Plotter Laboratory in Denver can borrow available compilation photography or "quad-centered" high-altitude (1:80,000-scale) film positives and paper prints from National Mapping Division's photographic libraries. Quad-centered photographs are those taken at the centers and north-south borders of 7½′-quadrangles—each photograph portrays the area of more than one 7½′-quadrangle.

Before ordering aerial photographs, you must identify the area of needed coverage. Send ESIC the geographic coordinates (longitude and latitude) of your area of interest, and ESIC will promptly research your request. If the geographic coordinates are unknown, ESIC strongly recommends circling, pinpointing, or outlining the area on a USGS topographic map or a State or local highway map to indicate the desired area—the more specific, the better. Also state if stereoscopic coverage is required.

ESIC cooperates with the Earth Resources Observation System's (EROS) Data Center in Sioux Falls, South Dakota. Both ESIC and the EROS Data Center take orders for aerial and space photographs and space images. If the exact roll and frame numbers are known, ESIC and the EROS Data Center can provide addresses, prices, and order forms for ordering from many other Federal and State agencies and commercial companies. For information write or contact:

Earth Science Information Center
U.S. Geological Survey
507 National Center
Reston, VA 22092

or

User Services Section
EROS Data Center
U.S. Geological Survey
Sioux Falls, SD 57198

All ESIC and EROS photograph and image orders must include project accounting or prepayment by check or money order. Each print of a photograph is custom made, so all orders must contain the correct information.