FOREST SERVICE PLANIMETRIC MAPS*

E. S. Massie, Jr.
U. S. Forest Service

For the information of many it may be well to preface the reading of this paper with a few remarks. The Forest Service, charged as it is with the protection, administration and utilization of the National Forests, necessarily falls into the category of a map-user—not a map-maker. For many purposes other than map-making, however, aerial pictures are desirable and the advantages offered to the Forest Service have been so great that a real need exists whether or not maps were compiled. To discharge its duties, maps are a necessity and lacking suitable maps, the Bureau is forced to make them.

THE Forest Service has for many years been interested in the use of photographs as a means of gathering data for its use in the administration and protection of the National Forests.

At the time when aerial photography was still in its infancy and little or no use was being made of aerial pictures by the Government, the Service had taken pictures with a panoramic camera from the top of fire lookout towers as a means of recording for future use and study the extent of the terrain that could be viewed from the exposure stations. Three such pictures taken from the same station covered an angle of view of 360° with sufficient overlap between adjacent exposures to allow matching of photographic images. Such pictures taken from prominent peaks or high points in the forest afforded one means of determining the extent of visible and invisible areas as viewed from the points from which the photographs were taken. A study and correlation of such panoramic views could be used advantageously in extending the net of fire control lookout towers.

The advantages afforded by the use of such pictures led the foresters and engineers to believe that pictures taken from the air should prove to be of even greater advantage than panoramic pictures. Consequently in 1926, the Regional Office at Missoula, Montana, realizing the possibilities afforded by aerial photographs for its work, undertook the photography of a small area with a single lens camera. The use of aerial pictures by the Service dates from this time and has continued until now they are employed in practically all the varied activities of the Bureau. Most of these activities require that a planimetric map be compiled upon which to record the data secured from the pictures.

In 1926, the Alaskan Branch of the U. S. Geological Survey, in co-operation with the Navy Department, had photographed approximately 10,000 square miles in southeastern Alaska. This work was so successful and of such value that the Forest Service joined the Alaskan Branch of the Geological Survey in urging the Navy Department to send another expedition into southeastern Alaska to extend the work into areas that had not been photographed. The Navy Department, recognizing the merits of the request as well as the training such a project would afford its personnel, consented to co-operate with the two bureaus in this venture. During the 1929 photographic season, approximately 13,000 square miles of the southeastern portion of Alaska were photographed with a three-lens camera. The Forest Service contributed supplies, quarters and personnel to the expedition and assisted in the photographic laboratory in the transformation of these photographs. The Alaskan Branch of the Geological Survey performed the compilation of the maps.

In 1930, the Regional Office at Denver was in need of a more accurate and detailed map covering approximately 900 square miles in the Gunnison, Holy Cross and Grand Mesa National Forests. These forests embraced possibly as

* Presented at the Annual Meeting, 1940.

high a mountainous area as exists in the United States, many peaks averaging over 12,000 feet and several close to 14,000 feet in elevation. It was decided that the map of this area should be compiled from aerial photographs. Lack of qualified personnel in the compilation of planimetric maps from aerial photographs made it advisable to let to contract the mapping of this area. The contract, awarded to Curtiss-Wright Flying Service, called for the delivery of a map on a scale of 1 inch equals 1 mile. All prominent cultural and topographical features were to be plotted to within 1/16 inch of their true position on this scale. Considering that many individual photographs showed a difference of elevation of 5,000 feet, such specifications were considered to be very rigid. The map was compiled at the average scale of the pictures which was approximately 2 inches equal 1 mile. While the compilation was in progress by the contractor, the Forest Service, unknown to the contractor, placed surveyors in the field to establish an intensive control net by plane table methods of the area for the purpose of checking the completed map prior to acceptance. A vellum overlay was prepared on the same projection and scale as called for in the contract. On this overlay were plotted all positions established by ground survey methods. When the completed map was delivered by the contractor, this overlay was placed over the map, the latitude and longitude lines matched and the detail shown on the map checked against the plotted positions. The accuracy of the map was well within specifications. This was sufficient evidence of the results that could be obtained through the use of aerial photographs to convince the Forest Service that future work should be undertaken along these lines.

The mapping activities of the Service are the responsibility of the ten regions. Occasionally, at the request of a region, the Washington office will undertake the compilation of a map from other sources or will undertake the final drafting of a map compiled in one of the regions, but the actual compilation from aerial pictures is accomplished in the field office. Consequently, the method best suited to the type of area and conditions in each region determines the method to be used for each project rather than endeavoring to adopt one method as standard for all work. However, the methods used in the compilation of planimetric maps have more or less followed the advances made in aerial photography, the section line method first being used, then the strip method and finally the templet method. A region may find one method more advantageous for one particular area than another, in which case, that method will be used. A combination of methods will be employed if by so doing the desired results can be obtained more expeditiously and economically.

The Federal Board of Surveys and Maps was established in December 1919, to co-ordinate the mapping program of the Federal Government and to avoid duplication of effort on the part of the several bureaus of the Government. The Forest Service is represented on this Board and annually requests the mapping of those areas highest in priority for Forest Service administration. These requests are forwarded to the U. S. Geological Survey which considers the requests of not only the Forest Service but other bureaus of the Government. In this way, the areas for which there exists the most need can be included in the program of the Geological Survey, and the Forest Service makes no attempt to compile maps of any area included in the program of that agency.

Some areas highest in priority so far as the Forest Service is concerned are not included in the Geological Survey program and it becomes necessary for the Forest Service to undertake the mapping of such areas. Such maps are compiled to an accuracy which will allow their being used for incorporation into the general map of the United States.

Ground control established by the U. S. Coast and Geodetic Survey and the

U. S. Geological Survey is used as the basis for Forest Service planimetric maps. Lacking sufficient amount of first and second order control on which to base such surveys, the co-operation of the U. S. Coast and Geodetic Survey and the U. S. Geological Survey is sought. Third or fourth order control established by the Forest Service and used in the compilation of planimetric maps is tied into control of higher order of accuracy.

Planimetric maps are required for acquisition surveys of areas to be purchased for addition to the National Forests and also for administrative maps of the forests. The base compiled for acquisition purposes can be used at a later date as a base for the preparation of an administrative map of the same area.

Prior to 1934, acquisition surveys had been made entirely by ground survey methods. In that year, funds were made available for the purchase of large areas in the eastern portions of the United States. To undertake surveys for such an extensive program entirely by ground methods would have been a very costly and time-consuming job. It was decided that aerial photographs would be used in the program as a means of decreasing the cost of the work and the time required for completing the program. As the result of this decision, an aerial program, at that time unprecedented for size, was initiated. Very few basic changes have been made in the method then employed for this type of work although refinements of detail have since been effected, and where the addition to existing forests or newly established purchase units embrace several hundred square miles, the aerial survey method is used.

The purposes of an acquisition survey are: (1) to locate and define the boundaries of ownership within the area; (2) to determine the acreage of individual tracts; (3) to establish a system of monuments; (4) to locate counterclaims and evidence of adverse possession; (5) to prepare a map showing boundaries, drainage and culture; (6) to furnish descriptions and maps on which to base conveyance or condemnation; and (7) to mark the boundaries between Federal and private lands. The procedure does not require the actual running of all tract boundary lines. These should be determined by the most economical methods; the objective being to locate all lines and corners on the maps as accurately as possible. Within the allowable limits of accuracy, boundaries may be plotted from record descriptions, when possible; from identifiable points on aerial photographs; from ties made to corners of boundaries from transit or compass traverse, or by actual compass or transit traverse of the boundary.

No endeavor will be made to describe in detail the process followed in making such surveys but sufficient data are given to show the advantage of the preparation of the planimetric map to be used in the accomplishment of acquisition surveys by the aerial method.

In the ground survey method, a system of secondary control lines are run by transit and tape so as to form a network of lines at the rate of approximately 1 mile per 500 acres, or, expressing it differently, a little more than 1 mile of control per square mile of area. These lines are run in the most convenient manner following roads, ridges or clearings except that along exterior boundaries or along agricultural or permanent eliminations, the lines are run along the boundaries of lands to be purchased. Ties are made along these secondary control lines to lines and corners of tract boundaries and these lines located so as to secure sufficient ties to adequately control subsequent work.

From such ties the field surveyor runs sufficient additional survey lines to prepare a map of the area showing thereon drainage and cultural features and tract boundaries.

In the aerial survey method, the surveyor establishes only sufficient ground control to permit the extension of a radial line templet triangulation net. All

property lines crossed by the traverse and all property corners along the control line are identified in the field on a set of prints of the area. Any additional property corners desired are also located on the prints by field identification.

The graphic triangulation net is extended by the radial line templet method on celluloid base sheets at a scale of 1:15,840. This control net is transferred to metal base sheets. Also transferred to this base are all property corners and points on property lines. The comparative ease with which an abundance of such corners and points on property lines or other points desired as control stations can be established permits the adoption of the lower order and less expensive compass and tape boundary surveys rather than use of the transit and tape method required by the ground method. On the metal base sheet are shown only a skeleton outline of cultural and drainage features and all tract boundaries. Graphically established tract lines and property corners are used as points to which can be referenced any additional information it is necessary to obtain by compass and tape surveys. Such a method precludes the possibility of accumulative errors by the compass and tape method.

The celluloid base sheets are still available on which to show the entire network of drainage, roads, fence lines, houses, power lines and similar man-made features which are to be shown on the administrative map of the area.

The compilation of forest administrative maps compiled by photogrammetric methods is generally accomplished at scales of 1:15,840, 1:20,000 and 1:31,680. Ground control of third and fourth order accuracy tied into control of higher order of accuracy is used to control the radial line net.

In general, there are two methods used in the compilation of these maps. In areas where recent General Land Office surveys exist, advantage is taken of such surveys. The General Land Office survey is tied into the third or fourth order control and the General Land Office net plotted on the master base sheet. Section corners, ridge lines, drains, roads, railroads and other features accurately located are traced on the master base as well as additional control points established by the Forest Service. The strip method is used, taking advantage of the additional data available from the General Land Office plats to correctly orient and adjust the individual strips.

Where sufficient Land Office information is not available, ground control is established and the radial line templet net is extended. Identified section corners are graphically located on the radial line base sheet in order to properly orient the General Land Office net.

All cultural and topographical data that can be obtained by a stereoscopic study of the photographs are delineated thereon for transfer to the base sheet.

The following features are shown on the map:

Projection lines, triangulation stations and important bench marks with elevations.

Civil boundaries including international, state, county, Indian reservations, fish and game reservations, primitive or natural areas, important land grants, military reservations, national parks, national monuments and national forest boundary lines.

Public land surveys including township exteriors and section lines together with the projection of unsurveyed township and section lines.

Cities, towns, villages, supervisors' headquarters, ranger stations and lookout towers.

Railroads, highways, secondary roads and trails.

Water bodies and streams, canals, canyons, arroyos.

Relief comprising merely the main peaks, mountains and salient points of important ranges are shown by hachures.

These maps are published on scales of $\frac{1}{4}$ inch, $\frac{1}{2}$ inch or 1 inch equals 1 mile, depending on the intensity of the detail to be shown. These administrative maps generally cover an entire forest. The base on a larger scale is available, however, for the preparation of ranger district maps, fire control maps or as a base on which to plot data obtained from timber or grazing surveys. With such a planimetric base available, the use of aerial photographs to obtain timber and grazing data is evident.

One has only to compare a map compiled today from aerial photographs with one compiled by ground methods to appreciate the additional information not only available from the photographs but the additional data now shown on Forest Service maps.

As to accuracy, one has only to compare the specifications used in the compilation of the planimetric map of the Gunnison, Holy Cross and Grand Mesa National Forests in 1930 with accuracy prescribed for maps now compiled. While the accuracy of maps compiled varies with the type of country and the purpose for which the map will be used, the following accuracy requirements specified in a recent application for a planimetric survey is given as an example of the accuracy of the planimetric maps now compiled by the Forest Service by photogrammetric methods:

Prominent cultural and drainage features in mountainous or heavily timbered country shall be plotted to within 100 feet of their true horizontal position and to within 60 feet of their true horizontal position in low and open areas.

The additional amount of detail now shown on Forest Service maps and the increase in accuracy at no extra cost are directly attributable to aerial photographs and compilation of maps by photogrammetric principles. Coupled with the fact that the pictures are also available for other forest activities, it can readily be seen why this method is employed almost exclusively in the preparation of Forest Service planimetric maps.