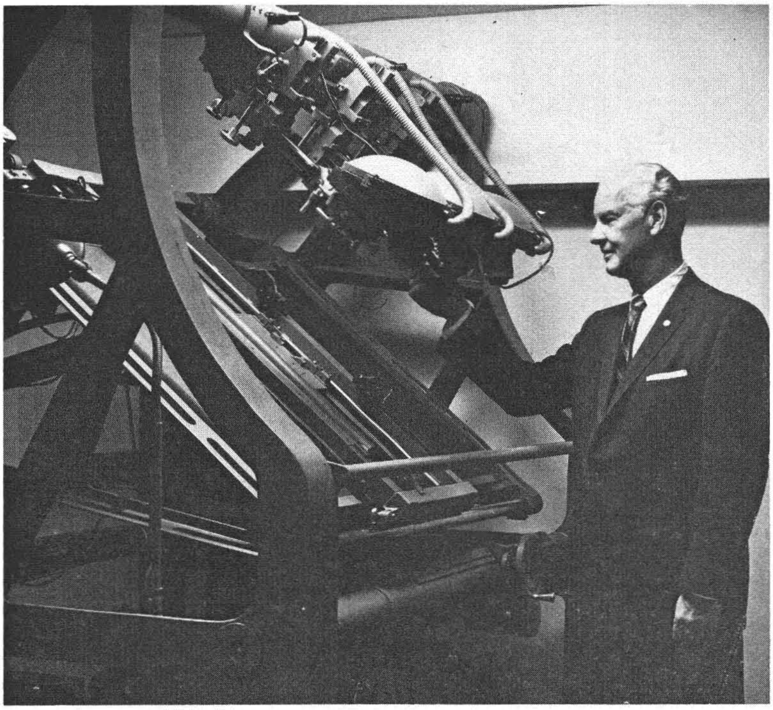

The Model T-64 Orthophotoscope and its inventor, Mr. Russell K. Bean.

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Photomaps for Urban Planning

Reliable distances and directions can be measured directly on orthophotographs.

INTRODUCTION

ESSENTIALLY ALL phases of modern urban planning can be done better and more efficiently through the use of photographs, photomosaics, and photomaps. Although no photogrammetric method can be considered the answer to all mapping problems, or a complete substitute for standard ground-surveying techniques, photographic maps must be recognized as a basic and efficient tool to supplement other standard methods (American Society of Planning Officials, 1951).

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A study of surveying and mapping requirements for urban planning, based on the planning programs and mapping procedures of a number of large cities, has been made by the Committee on City Surveys of the Surveying and Mapping Division of the American Society of Civil Engineers (Blessing, 1952; American Society of Civil Engineers, 1963). The study showed that a comprehensive

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planning program for a large urban area requires map information in 14 principal categories: geographic setting, economic base, population, land use, transportation, recreation, schools, public buildings, public utilities, local area studies, property valuation, comprehensive plan, official street map, and zoning map. It is interesting to note that the requirements in about 30 of a total of 73 different types of detailed studies cited could be met through the direct use of aerial photographs. Thus, photographs, mosaics, and photomaps appear to offer potential as a means of satisfying a large variety of map needs for urban area studies.

ABSTRACT: *The development in the United States and abroad of photomaps, combining some of the best features of an aerial photograph with the advantages of accurate planimetric maps, is a matter of interest to the engineer and planner engaged in the development of urban areas. The value of uniform-scale photographs which can be used for accurate measurement of distance, direction, area, and horizontal position while retaining the essential advantages of the literal detail of aerial photographs has long been appreciated by the engineer engaged in resources surveys. Several remarkable stereoscopic profiling machines are being developed for restituting the perspective view and the equipment is being automated. Unlike photomosaics, which are generally limited to nearly flat terrain, orthophotomaps can be made where the terrain has considerable relief. Hence, their value to the urban planner who is concerned with the terrain relief of suburban hilly areas exceeds that of individual photographs and mosaics.*

Rectified single photographs and controlled mosaics give excellent results when there is low relief in the area of interest. Where the range of relief does not exceed about 50 feet for 1:24,000-scale 6-inch photography (approximately 0.02 inch of image displacement), the controlled mosaic may still be the undisputed leader in this field from the point of view of quality and cost (Bean and Thompson, 1957). However, in hilly and mountainous terrain, the orthophotomosaic must be considered to be almost the sole answer to the need for true-scale, restituted photoimagery of map-sized areas.

Direct Use of Aerial Photographs and Enlargements

Contact prints and enlargements of aerial photographs are among the first tools needed and demanded by the urban planner. Most of the aerial photography being used for this purpose is taken with a camera having a focal length of 6 inches and a format of 9 by 9 inches. For planning purposes, this photography is obtained at various scales from 1 inch equals 50 feet up to approximately 1 inch equals 1 mile, and sometimes even smaller. The scale of the photography to be selected for an urban-area study depends on the purpose for which the photography is to be used, the development or land use of the area, and the physical size of the project. Smaller scales are used for reconnaissance and preliminary studies whereas larger scales are used for detailed studies of site and route selection. Chapter 12 of the MANUAL OF PHOTOGRAPHIC INTERPRETATION (American Society of Photogrammetry, 1960) describes a number of uses of aerial photographs in studying the basic properties of an area, the preparation and annotation of aerial photographs and mosaics, the type of information to be collected in an urban-area analysis, and the manner of presenting the data relative to land use.

Higher-altitude, smaller-scale photographs often provide important economies in mapping, provided that precision-type high-quality cameras are used. The larger area covered by such photographs enables the urban planner to obtain a comprehensive view of the "setting" of an area. He can tie together many different details of geography, geology, vegetation, drainage, communication, and other factors in a single view. Enlargements made from single aerial photographs also provide an inexpensive method for a town or community to obtain low-cost planimetric-type maps. As an example, a single 6-inch photograph flown at 30,000 feet above ground will cover an area of about 72 square miles; this is an area greater than an entire 7½-minute, standard quadrangle.

Photomosaics in Urban Planning

When aerial perspective photographs can be mosaicked together in a geometrically correct and rigidly controlled manner, the photograph mosaic is one of the most rapid and economical methods of mapping. When the displacements due to tilt have been removed by rectification of the original perspective photographs, and the displacements due to relief are held to a minimum, the method can be an extremely accurate one.

Mosaics, in general, may be classified as controlled or uncontrolled. If the aerial photographs have been properly rectified and brought to a common scale, the photographs can be assembled with reference to control established by ground surveys and/or aerophotogrammetric triangulation. An uncontrolled mosaic is one that is constructed with little or no reference to ground survey control. The photographs will probably be nonuniform in scale and may contain small amounts of tilt. These factors make it impossible for the uncontrolled mosaic to become an accurate planimetric-type map.

The principal advantages of the photomosaic are its low cost relative to other methods, its relative simplicity, and the speed with which it can be constructed. It provides to the trained eye of the photointerpreter a wealth of detail not found on a conventional line map. While mosaics are accurate enough for many purposes of city planning, they do

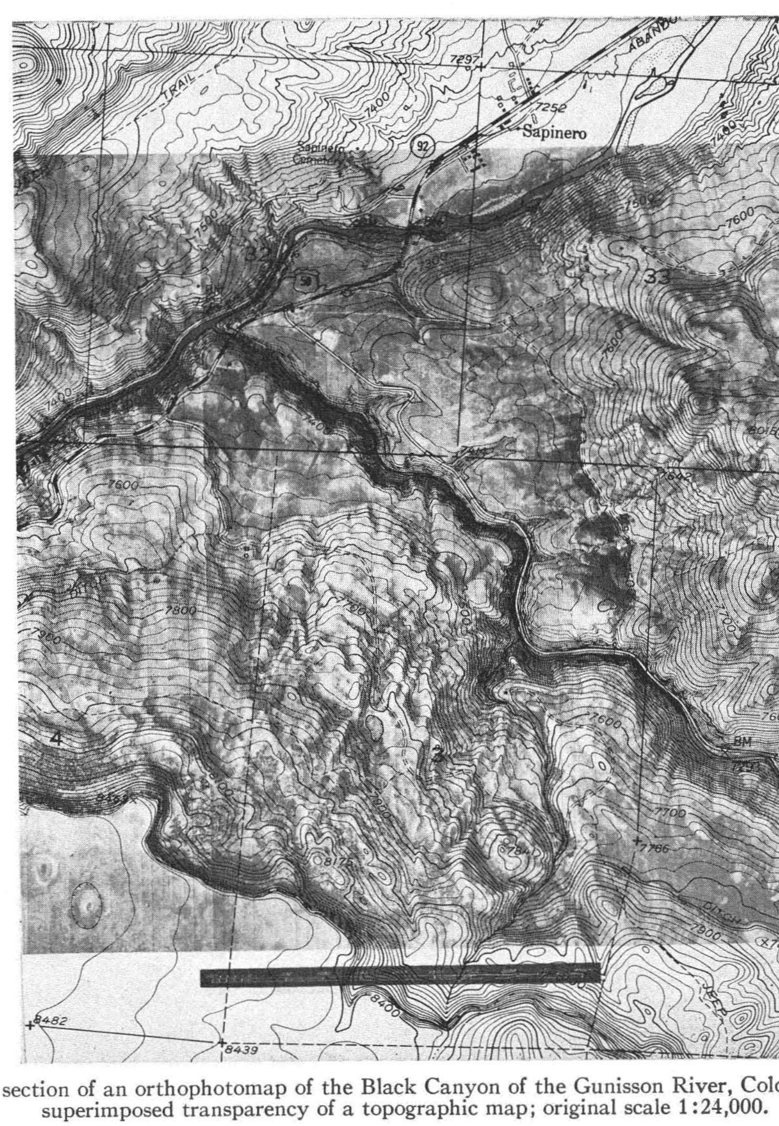

FIG. 1. A section of an orthophotomap of the Black Canyon of the Gunisson River, Colorado, with a superimposed transparency of a topographic map; original scale 1:24,000.

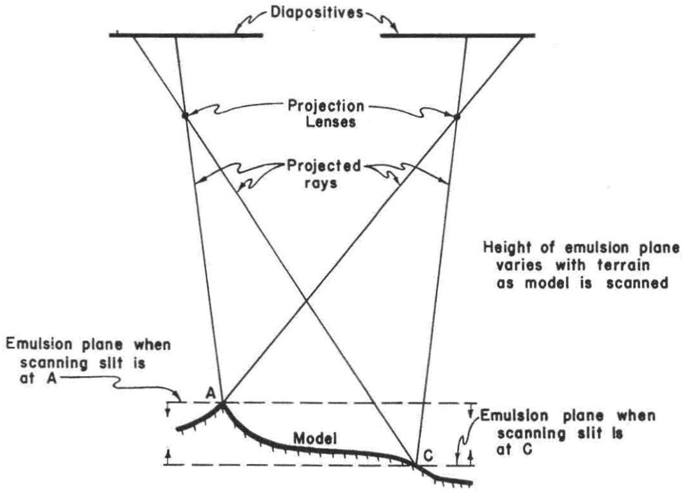

FIG. 2. Principle of the orthophotoscope.

not usually include contours or elevations. The principal disadvantages of mosaics is that they fail to meet National Map Accuracy Standards in hilly or mountainous terrain. Under these conditions, the matching of photographic images between adjacent photographs becomes extremely difficult or impossible. Detailed descriptions for the preparation of photographic mosaics are given in Chapter 10 of the MANUAL OF PHOTOGRAMMETRY (American Society of Photogrammetry, 1952).

THE U. S. GEOLOGICAL SURVEY ORTHOPHOTOMAP

Photomosaics of superior quality are now being made from new high-altitude perspective photography. However, even the best of the controlled mosaics too commonly exceed the limitations of acceptable accuracy because of relief displacement. A series of orthophotographs can be assembled to form a rigorously controlled photomosaic. Figure 1 is a section of such a photographic map. A difference of elevation of over 1,000 feet occurs between the mesa in the foreground and the canyon bottom. A transparent overlay carrying 20-foot contour data and planimetric features, superimposed upon the mosaic, fits nearly perfectly despite the considerable relief. Thus, the two forms of map data—the orthophotograph and the topographic map—can be used either independently or combined as a photo-contour map in a geometrically-correct relationship.

An orthophotomap is an orthophotomosaic which has been prepared from individual orthophotographs and positioned to control plotted upon a standard quadrangle projection, generally at 1:24,000-scale. A limited number of cartographic symbols and names, and marginal information are generally added, and the map may be printed in several colors.

The orthophotomap carries in its margins latitude and longitude tick marks. It may also carry a rectangular grid system.

Because the orthophotomap is practically free of errors caused by tilt and relief displacements, any distance or azimuth or direction between two points can be measured directly. Areas may also be measured directly, and any image point such as an identifiable property marker may be directly related to any other image. Property lines, and even small parcels of land, have a correct geometric relationship to those on other precision maps. This should be a very useful tool to the city planner, as all of the photointerpretative data as well as all the engineering data are interrelated.

In the Geological Survey, orthophotographs are prepared with the Orthophotoscope. This is a photographic rectification instrument which employs the principle of bit-by-bit, differential rectification of a stereoscopic model formed by a double-projection instrument such as the Kelsh or ER-55 plotter. Figure 2 illustrates how (1) all common photographic images are located in plan position by the intersection of two homologous rays, and (2) all such images are restituted to a common scale by magnifying the diapositive images inversely as their scale. In the latest machine, the T-64 Orthophotoscope (Frontispiece), the support-

FIG. 3. Section of the Roanoke, Virginia, orthophotomap, original scale 1 inch equals 1,000 feet.

ing platform has been tilted forward toward the operator for greater convenience in viewing.

The first application of orthophotography in city planning was the Roanoke project, completed in 1963. This was an investigation to determine, first, the possible uses of orthophotography in the National Topographic Mapping Program, and, second, the means of using orthophotography itself as a map product. An experimental map publication, a six-color orthophotomap of the Roanoke, SW, Virginia, 7½-minute quadrangle was also completed in 1963. Reproduction of the map from pressplates prepared from photo-negatives processed by image-enhancement techniques permitted essentially grainless reproduction without halftone screening. A new reproduction technique developed by the Army Map Service (Pumpelly, 1964), called the photoline-phototone process, was used; in this method, the edges of the images are enhanced to produce a form of line drawing in the reproduced image. The resulting publication is pleasing as a cartographic product and complies with National Map Accuracy Standards (Scher, 1964; Bureau of the Budget, 1947).

Figure 3 shows a portion of the Roanoke orthophotomap, compiled at the scale of 1:12,000, or 1 inch = 1,000 feet. The relief in this area ranges from about 900 feet along the Roanoke River to over 1,700 feet on Mill Mountain, near the bottom of the figure.

The use of high-altitude photographs in the making of orthophotomaps sometimes offers a means for obtaining map data at low cost. Figure 4 shows a portion of an orthophotograph of the Chain Bridge area on the Potomac River, made from a 6-inch-focal-length aerial photograph flown at 30,000 feet. The orthophotograph shown in the figure is at the stereomodel scale of 1:24,000, or 1 inch = 2,000 feet. The useful area of each model contains approximately 25 square miles; hence, an entire 7½-minute quadrangle can be processed from the equivalent of approximately three stereoscopic models.

An example of the use of orthophotography in highway planning is shown in Figure 5. This is a controlled orthophotomosaic, pre-

FIG. 4. Section of an orthophotomap of the Chain Bridge area on the Potomac River, original scale 1 inch equals 2,000 feet. The original was flown at 30,000 feet with a camera having a focal length of 6 inches.

pared from low-altitude photography, at a scale of 1 inch = 100 feet. Rectangular, 500-foot grid lines based on the Virginia State Plane Coordinate Grid serve as a map projection for the six stereomodels. The photomap was used for the planning and design of a highway interchange.

THE PHOTO CONTOUR MAP

For a perspective aerial photograph to serve as a planimetric-type map, two conditions must be present—the ground must be relatively flat and the aerial camera free of tilt. Such a dual condition is obviously not often encountered, but methods have been developed which systematically restitute the photograph images by zones, correcting for displacement due to relief and tilt.

The Photo Contour Map, based on the method of zones, was developed by Robert Mahan and R. M. Towill of the R. M. Towill Corp. of Honolulu, Hawaii (Mahan, 1958). A licensee of the method is the Aero Service Corp. of Philadelphia. The Photo Contour Map shows both contour lines and photographic details. The map is considered to be particularly well suited for highway planning, drainage studies, agricultural planning, and the planning of large housing projects. Figure 6 shows a portion of a Photo Contour Map made for a highway planning project in Northern California. The scale is 1 inch = 200 feet and the contour interval is 10 feet. The final product is a photograph with all its images in plan position. Contours may be shown as black or white lines, depending on the background. Contour numbers and spot elevations may be added photographically.

The Stereomat Orthophotomap

Automatic stereoplotting instruments basically embody a system of electronics and electro-mechanics in combination with a conventional plotting instrument to perform, first, the relative orientation of the plate-pairs and, subsequently, the production of an orthophotograph and the drawing of contours or profiles. An important achievement in this field is a development begun in Canada in 1967 by Gilbert L. Hobrough (Hobrough, 1959) of the Photographic Survey Corp., Ltd., of Toronto. This was called the Automatic Scanning Correlator, or Auscor. Another series of this instrument was called by the tradename Stereomat. Stereomat IV, the latest instrument in the series, incorporates the Stereomat principle with a modified Wild B-8 stereoplotter, a well known conventional mapping instrument made by the Wild Company of Switzerland.

The B-8 Stereomat, as it is more commonly called, is equipped to produce orthophotographs. The rectified image is painted by means of an electron beam upon the face of a cathode-ray tube where the scanned lines are then photographed and converted into an orthophotograph. Figure 7 shows an example of orthophotography that has been produced automatically with the Wild B-8 Stereomat. The scanning strips are 1.5 mm. wide. The scale is approximately 1:3,000. The instrument also draws contours automatically—that is, without an operator—by sensing the stereoscopic images for shades of gray contrast, and determining their elevations by means of correlation techniques (Esten, 1964).

The Gigas-Zeiss Orthoprojector and Orthophotomap

As early as 1935, Gallus-Ferber (Talley,

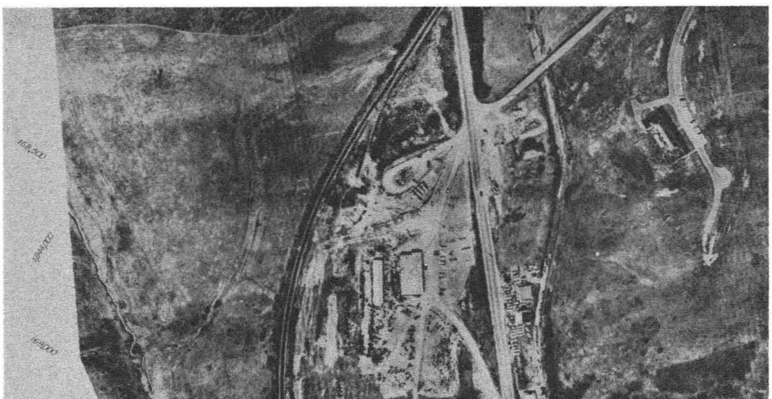

Fig. 5. Orthophotography for highway planning. (Virginia Department of Highways photo.)

1938) provided an example of bit-by-bit or differential rectification with the aid of stereoscopic plotting instruments. Ferber, in scanning the stereomodel, stored the profile data in graphic form and later repeated the profiling, using a single projector to expose the image, while varying the projection distance according to the scale on the vertical profile (Ferber, 1936).

One of the advantages of using this method is that projection equipment having a very large depth of field can be employed. Today, modern data-storage techniques using punched-tape storage may be used. The stereoplotting itself can be made simple and more flexible; the operator, for example, can start and stop his stereoplotting at any time. The punched-tape storage record of profiling in the C8 Stereoplanigraph is used later in the Orthoprojector (Figure 8) as stepping orders for x, y, and z movements in the projector.

The Gigas-Zeiss Orthoprojector (Ahrend, 1965) is an orthophotoscope-type instrument for strip-by-strip rectification of the aerial photograph. It employs a photocarrier shown in Figure 9 which is very similar to the photocarrier used in the C8 Stereoplanigraph. The Orthoprojector, controlled by the punched tape, is articulated as an optical and mechanical analogue of the original profile data, thus permitting the transfer of images at optimum image quality. Photomaps of rolling and mountainous terrain can be prepared, reproducing the full details of the original photograph. The Orthoprojector can also be

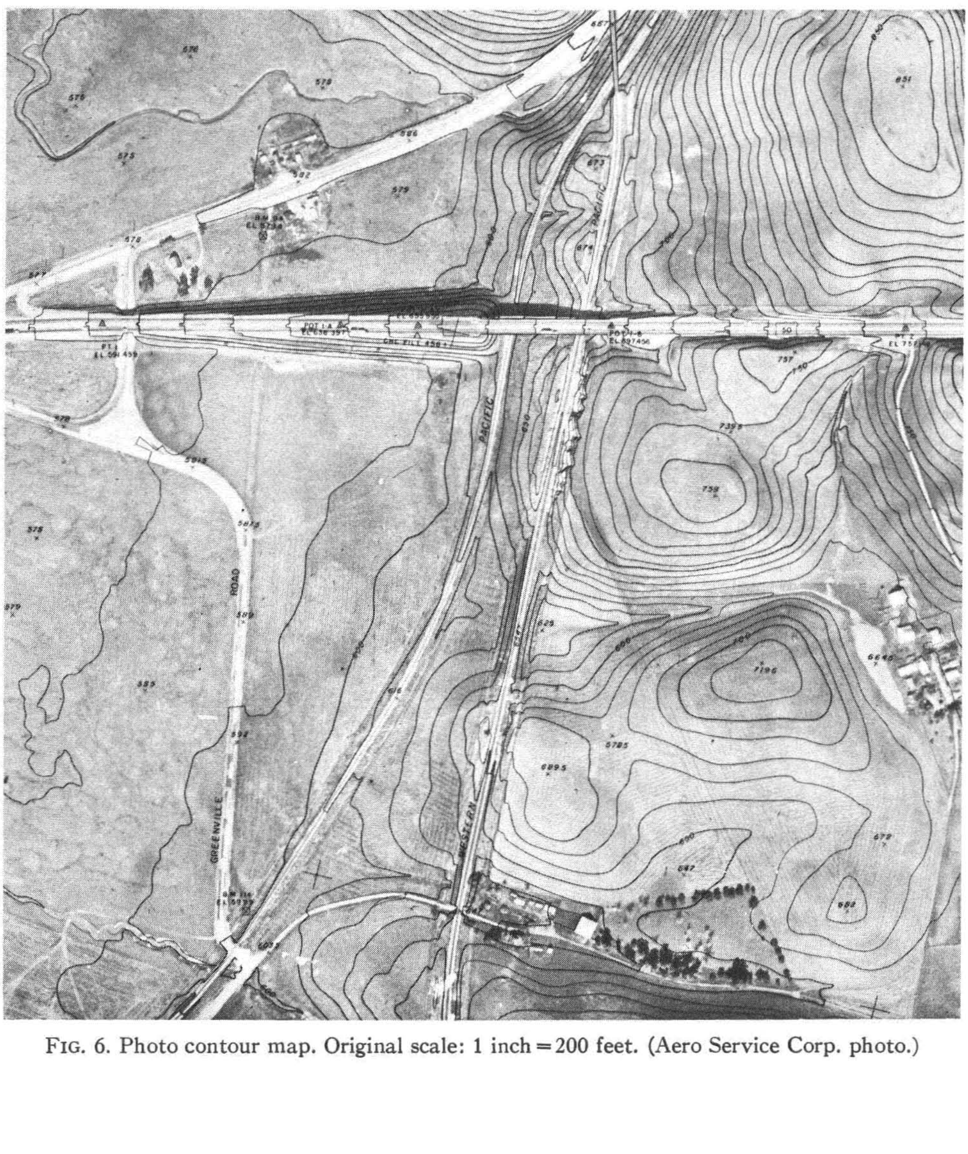

FIG. 6. Photo contour map. Original scale: 1 inch = 200 feet. (Aero Service Corp. photo.)

FIG. 7. An orthophotograph produced automatically with the Wild B-8 Stereomat. The original scale was 1:3,000. (Courtesy of Autometric Operation, Raytheon Co.)

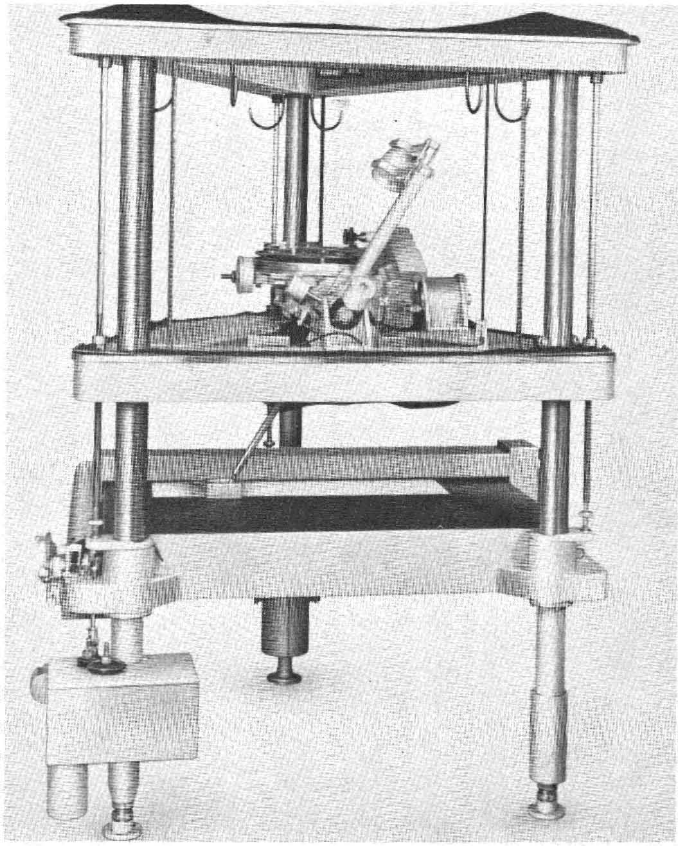

FIG. 8. The Gigas-Zeiss Orthoprojector. (Zeiss-Aerotopograph photo.)

coupled directly to the C8 Stereoplanigraph.

As by-products of the profiling operation, line-drop contour charts are obtained simultaneously with the orthophotomaps. The dropped lines may be converted later into contours which fit the orthophotomap details.

Figure 9 shows a section of an orthophotomap, at 1:5,000 scale, prepared with the Gigas-Zeiss Orthoprojector from photography at the scale of 1:12,000. The white lines shown represent cadastral and property information and were plotted directly on the orthophotomap with the C8 Stereoplanigraph. Cartographic symbols have been added.

CONCLUSIONS

The engineer and city planner will be interested in the development, within the last decade, of the orthophotograph, a photograph whose geometry resembles that of an engineer's plan, and of the orthophotomaps prepared from them. Man has been striving to achieve this goal for almost a hundred years—since the very beginning of photography (Landen, 1959).

It would be difficult to conceive of a wiser investment for municipalities than adequate photographs, mosaics, and orthophotomaps for the proper planning and use of urban space—now perhaps our most important economic and social resource.

A catalog of the many specific applications of orthophotographs in the different types of surveys and resource studies would be almost endless. Whenever there is an advantage in being able to use the literal detail of the aerial photograph as a measure of the positions of images, lengths and directions of lines, areas, and the physical outlines of the land, the orthophotograph offers the planner a valuable addition to his present tools.

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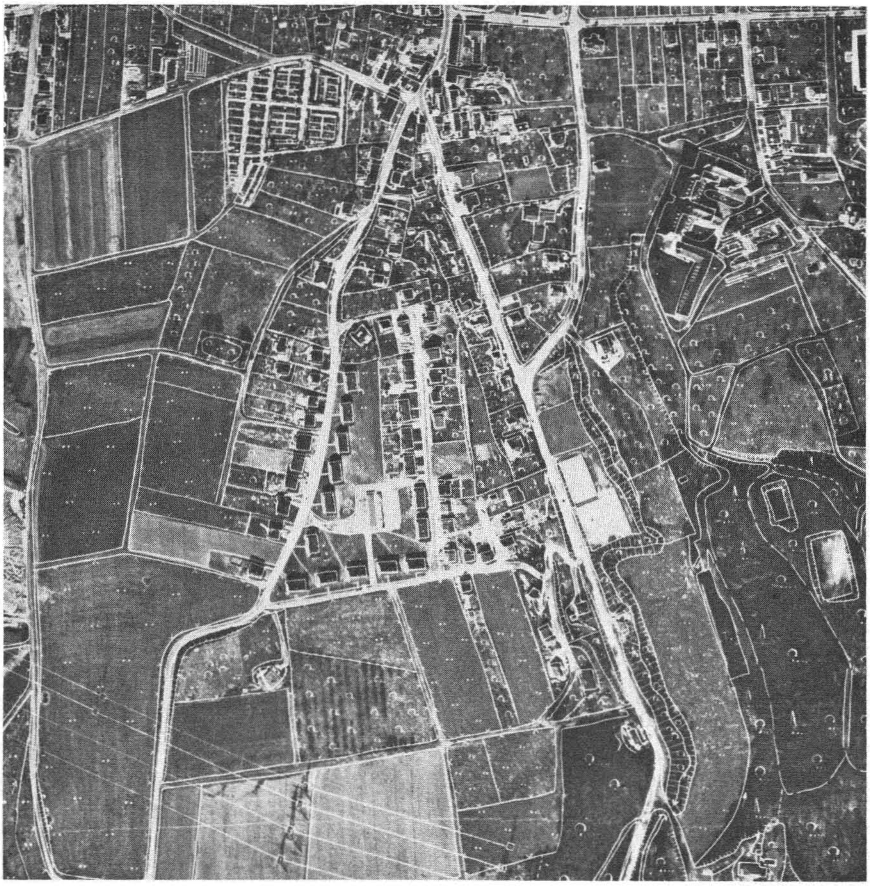

FIG. 9. Section of an orthophotomap made with the Gigas-Zeiss Orthoprojector. Orignal scale 1:5,000. (Zeiss-Aerotopograph photo.)

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