GEOLOGICAL SURVEY CIRCULAR 218

REVISED 1958

DEPARTMENT OF THE INTERIOR

March 3, 1849

DEVELOPMENT OF PHOTOGRAMMETRY IN THE U. S. GEOLOGICAL SURVEY

By Morris M. Thompson

UNITED STATES DEPARTMENT OF THE INTERIOR
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Washington, D. C., 1952

Free on application to the Geological Survey, Washington 25, D. C.

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INTRODUCTION

Photogrammetry, the science or art of obtaining reliable measurements by means of photography, is now used extensively in topographic mapping. Precise photogrammetric plotting instruments now enable the map maker to extract from aerial photographs much of the detailed information required for drawing the map that formerly was acquired by laborious ground surveys. Photography and photogrammetry have thus become essential components of all large mapping operations.

The Geological Survey has played a leading role in the development of photogrammetric methods of mapping over a period of half a century. This role has been well documented in numerous articles appearing in technical publications during this time. It is the purpose of this circular to present, in brief form, the highlights of Geological Survey activities and developments in the field of photogrammetry, from pioneer efforts to present-day practice.

HISTORICAL OUTLINE

The Geological Survey has employed photogrammetric methods since 1904, when two of its staff members, C. W. Wright and his brother F. E. Wright, first used a panoramic camera for topographic surveys in Alaska. The first cameras used by the Wrights were improvised from commercial instruments by the addition of level bubbles and internal scales. In 1907, C. W. Wright had a camera constructed specifically for the purpose of surveying. Another member of the Geological Survey staff, J. W. Bagley, redesigned and improved this type of camera for use in reconnaissance mapping in Alaska. Bagley also designed a photoalidade to facilitate the use of the panoramic pictures in map making.

In 1916-17, Bagley developed a tri-lens camera for aerial photography, and his colleague, F. H. Moffit, designed a transforming camera for tri-lens camera negatives. The following year, the Geological Survey participated with the Corps of Engineers and the Air Service in a program of photographing, with the tri-lens camera, several strips of country between aviation fields for the purpose of making aeronautical charts. In 1918, the Survey cooperated with the Air Service in experiments with a gyroscopically controlled camera; the resulting equipment achieved control of the camera axis within 2°.

In the spring of 1920, the Geological Survey used the tri-lens camera for a systematic aerial survey of parts of Santo Domingo and Haiti. In the same year, the Schoolcraft, Michigan quadrangle was successfully mapped with the aid of single-lens aerial photographs supplied by the Army Air Service. The photographs were used for the delineation of planimetry on the field sheets; the contours were then added by topographers on the ground. Following the success of this project, the method was applied to an increasing number of other quadrangles.

In 1921, the Section of Photographic Mapping was established in the Topographic Branch of the Geological Survey. In addition to the production of planimetric base maps, this Section soon turned part of its efforts to stereotopography. A semiautomatic stereoscopic plotting instrument, the stereoautograph, was received from Germany in 1921 and tested by the Geological Survey. This instrument employed terrestrial photographs only, and while workable, did not prove to be economical. A second instrument, the Hugershoff Aerocartograph, was imported from Germany in 1927; this was the first automatic stereoscopic plotting instrument utilizing aerial photography to be owned by the U. S. Government. Following a number of experimental projects, the Aerocartograph was assigned to a definite program of complete map construction in 1930, and several good maps were produced by means of this instrument (Birdseye, 1940).[1]

By this time, the growing importance of photogrammetric methods had been recognized with the inclusion of a 40-page chapter on "Map Compilation from Aerial Photographs," by T. P. Pendleton, in the Topographic Instructions of the United States Geological Survey (Birdseye, 1928). The Geological Survey also published, in 1929, a report on the Alaskan Aerial Survey Expedition of 1926, in which it participated with other Federal agencies (Sargent and Moffit, 1929).

When the Tennessee Valley Authority was established in 1933, one of the immediate necessities was map coverage of the entire valley. In cooperation with the TVA, the Geological Survey undertook the preparation of planimetric maps of this area, using five-lens aerial photographs and radial line plotting methods. The planimetric maps filled the immediate need, but there was still a long range need for complete topographic maps.

Although the Aerocartograph produced satisfactory contour maps, its initial cost was high and it was mechanically complex. The multiplex aeroprojector effectively overcame these disadvantages, and in 1935 the Geological Survey purchased its first multiplex equipment. After some experimentation, the value of these instruments was satisfactorily demonstrated, and in 1936 a fully equipped multiplex mapping office was established in Chattanooga, with a program of topographic mapping of the entire Tennessee River Valley, in cooperation with the Tennessee Valley Authority (Pendleton, 1939). Beginning in 1940, improved multiplex equipment was installed in a newly established office in Arlington, Va., and a revolutionary swing from field methods to photogrammetric methods as the basic map-making procedure gained full impetus. During the war years of 1941-45, the Geological Survey performed formidable strategic mapping assignments of the highest importance, using its well-established photogrammetric plant and personnel. Many members of its staff, called into service, played important roles in military mapping, notably Gerald FitzGerald, whose leadership in the development of trimetrogon mapping procedures was a contribution of the first rank (Arnold and FitzGerald, 1944).

Following the war, the development of photogrammetric practices by the Geological Survey has continued at an ever-increasing pace. Each of the regional headquarters offices of the Topographic Division is now fully equipped so that photogrammetry plays a major part in practically all mapping projects. In addition to enlarged facilities for multiplex mapping, the capacity and versatility of the plant have been augumented by the acquisition of several universal plotters, such as the Zeiss Stereoplanigraph and Wild Autograph A-5, A-6, and A-8, as well as a considerable number of Kelsh plotters (developed by Harry T. Kelsh while he was member of the Geological Survey staff). A new instrument, the twinplex, recently developed under the supervision of another member of the Geological Survey staff, Russell K. Bean, has promising potentialities. A new type of photogrammetric projector, the ER-55, also developed under the direction of R. K. Bean, is rapidly supplementing the multiplex as a basic mapping instrument.

The Geological Survey and members of its staff have always taken a leading part in the development of photogrammetry in the United States. A continuing research program (Davey, 1949), integrated with production needs, has resulted in many improvements in equipment and procedures. Numerous articles by staff members on various phases of photogrammetry have appeared in leading technical journals and in a well-known surveying textbook (Whitmore, 1949). The Geological Survey has contributed to the American Society of Photogrammetry four presidents (C. H. Birdseye, T. P. Pendleton, Gerald FitzGerald, and G. D. Whitmore), three secretaries (E. J. Schlatter, H. M. Townsend, and M. K. Linck), four winners of the Fairchild Award for outstanding contributions to photogrammetry (Gerald FitzGerald, H. T. Kelsh, R. K. Bean, and M. B. Scher), two winners of the Talbert Abrams Award for outstanding technical articles (W. E. Harman, Jr. and M. M. Thompson),

[1] See page 27 for list of literature cited.

two honorary members (G. D. Whitmore and Gerald FitzGerald), and an editor of Photogrammetric Engineering (J. I. Davidson), in addition to numerous directors and committee members.

The Geological Survey is currently engaged in the preparation of new Topographic Instructions, including a comprehensive treatment of photogrammetric procedures. Some chapters of these instructions are already available.

The Geological Survey looks forward to continuing its contributions to the science of photogrammetry through independent research, through continued cooperation with other governmental agencies and with private photogrammetric organizations, and through the free exchange of information with its colleagues abroad by way of such media as the International Society of Photogrammetry.

PHOTOGRAMMETRIC INSTRUMENTS AND PROCEDURES DEVELOPED BY THE GEOLOGICAL SURVEY

Panoramic camera

The first panoramic camera used by the Geological Survey was constructed by C. W. Wright in 1904 and improved in 1907 (Wright, 1908, and Bagley, 1917). The improved model was a box type in which the lens was revolved about a vertical axis by a spring, the rate of revolution and, in part, the exposure being regulated by detachable fans connected by gearing with the lens shaft. Roll film in 5- or 6-in. cartridges with several exposures each was placed on a circular film guide, so adjusted that, when the film was in position for exposure, all elements of the cylindrical surface of the film were perpendicular to the level plane and parallel to the lens shaft. The top of the camera, being the reference plane for leveling, was fitted with leveling-bubble slots at right angles to each other. Three leveling screws of the common type were used in connection with an adapter plate that fitted a plane-table tripod, thus avoiding the necessity of transporting two tripods. The horizontal field of view was 126° for each exposure, and the vertical range was from 18° to 22° above the horizon and from 26° to 30° below the horizon, depending on the width of film used. The film was usually developed in the field to check the quality of exposure and the coverage of the area to be mapped.

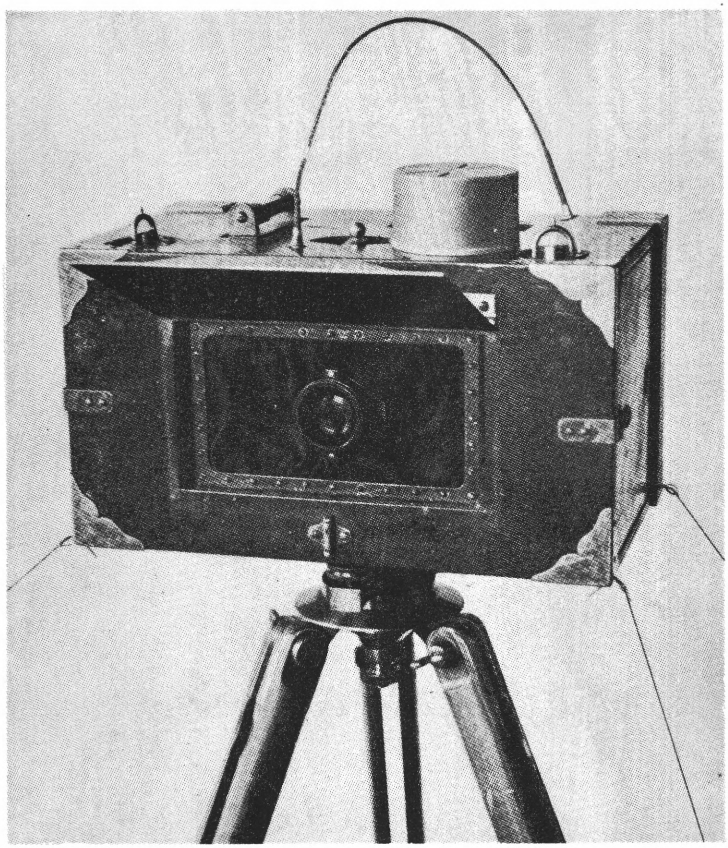

Figure 1. --Panoramic camera.

In some instances, the panoramic camera was used aboard ship for the topographic mapping of the terrain adjacent to the shore. One such application was in the 1916 survey of Prince William Sound, Alaska, where the mountains rise abruptly from the water's edge. Photographs were made from a 40-ft launch cruising on the sound; two panoramic cameras were mounted on a stand with gimbal rings in the bow of the vessel. Prior to each exposure, the engine was shut off and the cameras leveled as nearly as possible. Exposures were then made at the instant the boat seemed in least motion.

Panoramic photoalidade

The panoramic photoalidade (Bagley, 1917) was developed between 1910 and 1916 for use with panoramic photographs taken by Bagley's parties in Alaska. Its purpose was to transfer to the map the information obtained from the photographs. It was so designed that the operator could sight any image point in the photograph and determine the horizontal direction from the station point to the image point, in the same manner in which the topographer operates the telescopic alidade on a plane table in the field. A reading glass with a vertical hair, used with a sighting vane, could be said to represent the lens system in a field instrument. A radial arm represented the plotting base on an alidade, and directional lines were plotted along this arm on the map sheet. The reading glass, sighting vane, and radial arm were controlled by a mechanism of the rack-and-pinion type revolving around a point representing both the optical center of the lens and the camera station.

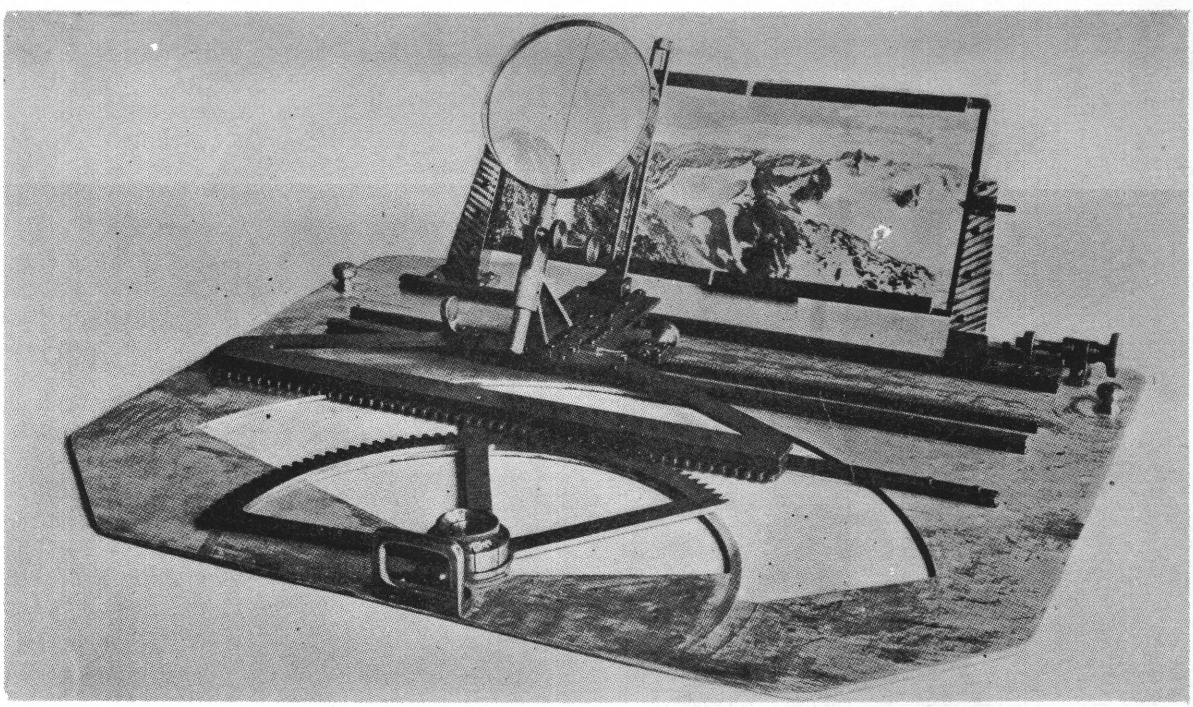

Figure 2.--Panoramic photoalidade.

In order to obtain differences of elevation for contour sketching, vertical distances of points above or below the horizon line, which appeared as shadowgraphs on the print, were measured. A simple formula that used these measured vertical distances with the corresponding map distance and the principal distance of the photograph gave the difference of elevation. A separate office instrument, known as a rotary scale, was constructed to expedite the measurement of the vertical distance.

Tri-lens camera

The tri-lens camera (Anonymous, 1921) was designed in 1916-17 by J. W. Bagley, with the assistance of J. B. Mertie, and F. H. Moffitt, and developed by the Corps of Engineers. It consisted of a base with three compartments and a magazine capable of carrying a roll of film 400 ft long. The central compartment was equipped with an f/6.3 lens of about 6 in. focal length whose axis pointed directly downward. The side compartments were equipped with f/6.3 lenses of about 7 in. focal length; their optical axes were inclined at 35° to the optical axis of the center lens, in opposite directions. The original camera was operated entirely by hand, the only automatic features being the between-the-lens shutters, a pencil which marked the film at the point midway between exposures, and a dial which

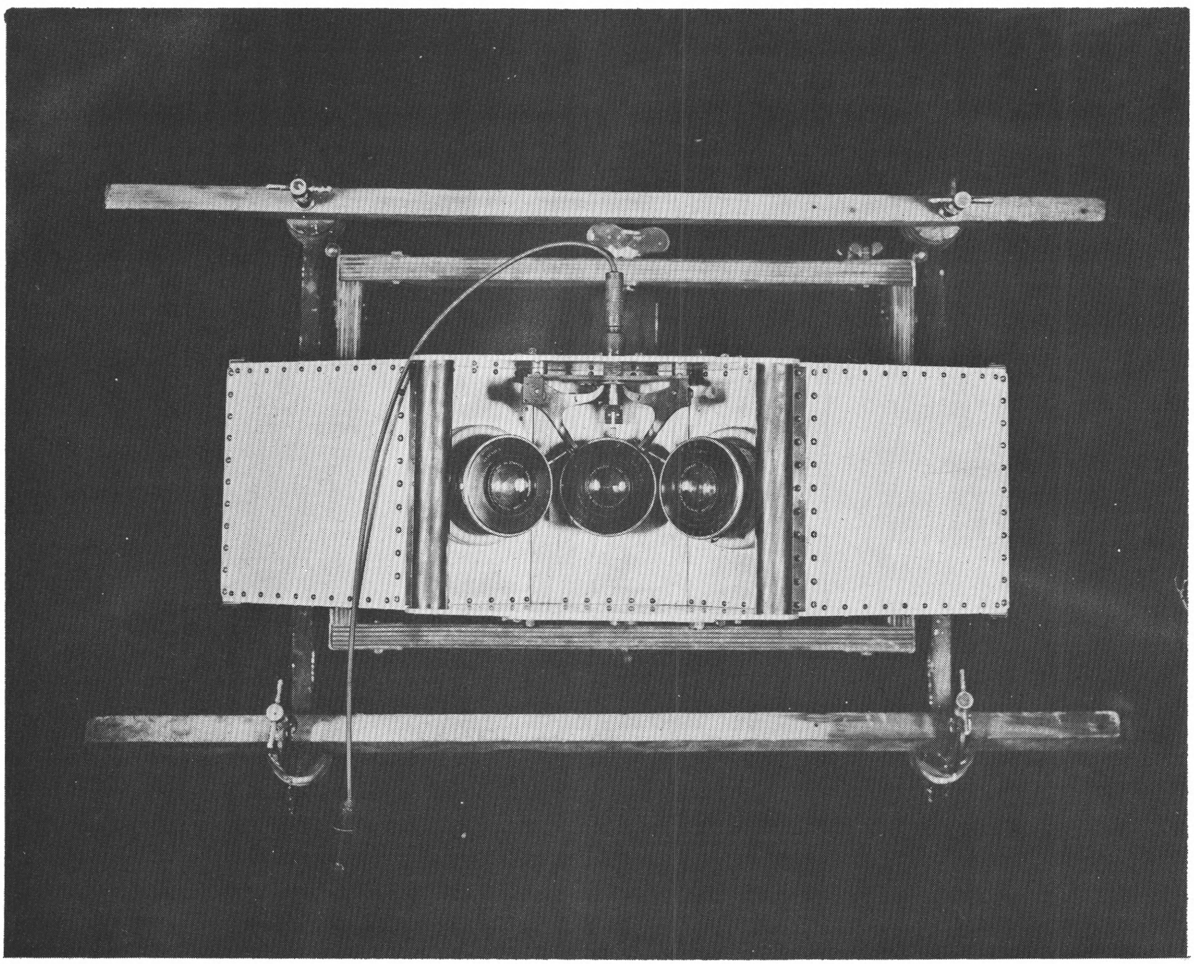

Figure 3.--Tri-lens camera in adjustable mount, bottom view.

indicated the amount of winding necessary to advance the film. The field of the camera was roughly three times the flight altitude. Later, cameras of this general design were built with 4- and 5-lens combinations.

A transforming camera, designed by F. H. Moffitt in 1916-17, was used to project the side negatives through the angles necessary to bring the photographs to the same plane as the center photograph.

Wilson photoalidade

This instrument, designed by R. M. Wilson in 1932 (Wilson, 1937), and subsequently modified and improved, makes it possible to conduct in the office most of the operations that would be possible with an ordinary plane table and telescopic alidade in the field. It can be used with oblique aerial photographs, or with photographs taken with the panoramic camera. The instrument consists of an adjustable print holder, a telescope for reading horizontal and vertical angles, a centering microscope used to place the station point on the map sheet exactly in the vertical axis of the viewing telescope, and a straightedge connected with the vertical axis of the telescope so that directions from the station point can be plotted on the map sheet. Topographic features may be located and their altitude determined, provided oblique photographs of the same terrain have been taken from two or more different points of view. Thus, the sketching of contours may be controlled, just as is done by using the intersection method with a plane table. This instrument was an important factor in the success of the trimetrogon method of mapping.

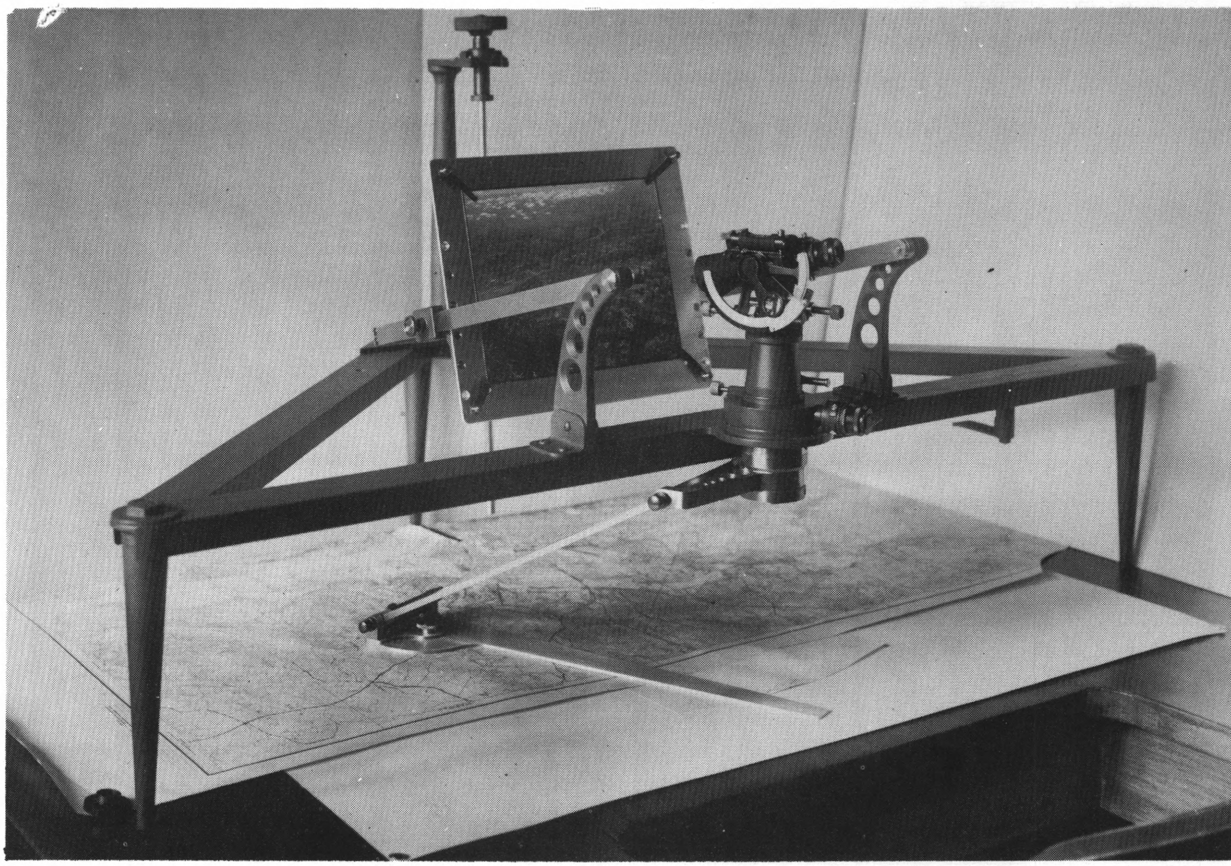

Figure 4.--Wilson photoalidade, original model.

ketchmaster, vertical, oblique, and universal

This portable instrument, based on the camera lucida principle, was designed by J. L. Buckmaster in 1931 (Buckmaster, 1946). The vertical sketchmaster permits the transfer of detail from he vertical photograph to the plotting sheet, while the oblique sketchmaster is used for the same purpose with oblique photographs. The universal sketchmaster can be used with either vertical or oblique photographs. By means of a mirror arrangement, the sketchmaster permits the photograph and the plotting sheet to be viewed simultaneously. Its adjustments are arranged to take care of scale changes and approximate tilt correction.

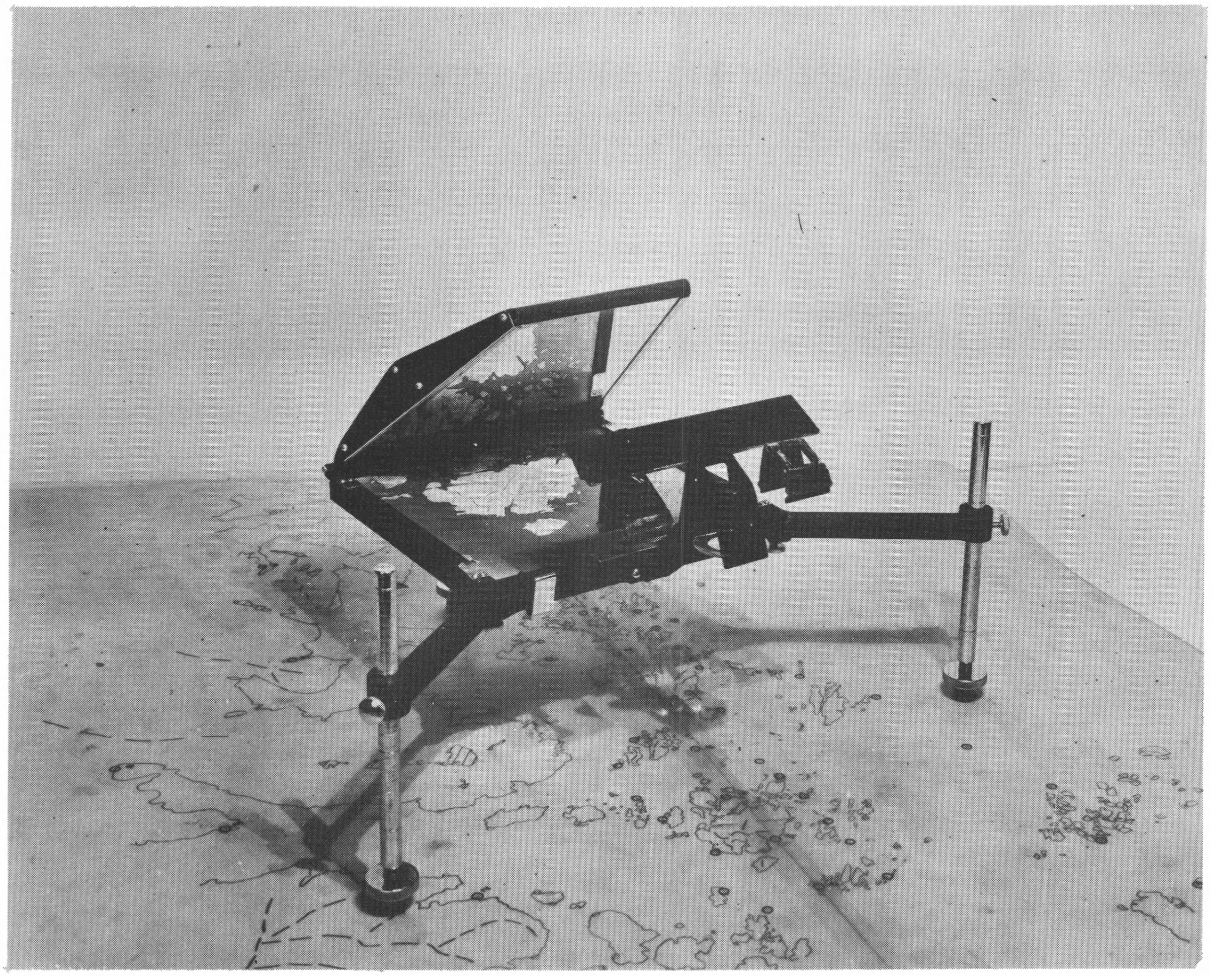

Figure 5.--Vertical sketchmaster, 1942 model.

Floore radial intersectors

In 1938, S. P. Floore developed a method of compiling a radial triangulation net in which the underlying map base was not covered and in which bulky or expensive templet cutters were not needed. In this method (Davidson and Buckmaster, 1942), slotted intersector arms made of metal are used instead of slotted templets. Each arm represents a radial; the radials emanating from a given point are bolted together to form an intersector unit. The intersector units are then assembled in a manner similar to conventional slotted templets.

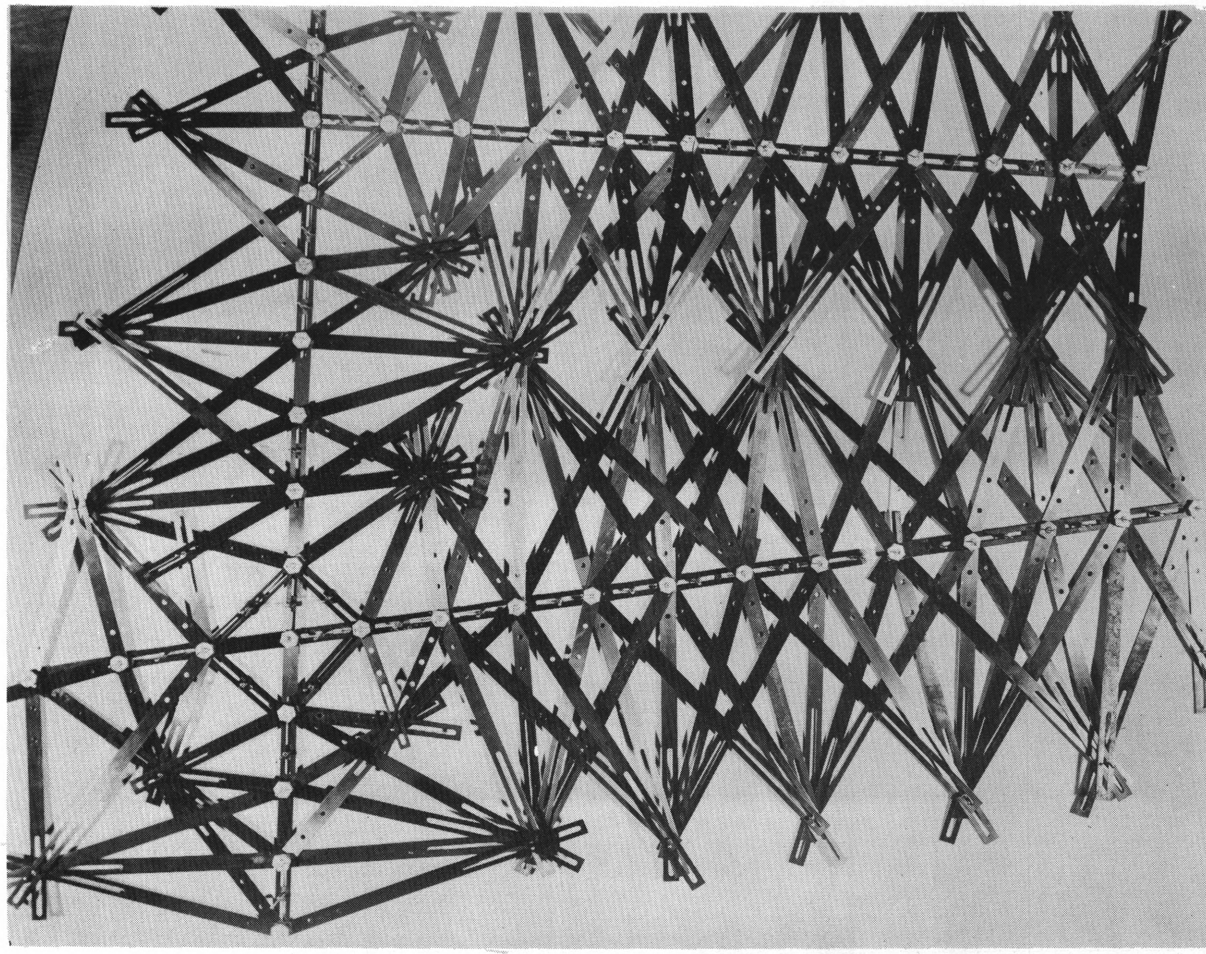

Figure 6.--Radial intersector assembly.

Rectoblique plotter

This instrument was developed by J. G. Lewis, during the war years, 1941-45 (Lewis, 1945). The purpose of the instrument is to obtain, by mechanical means, horizontal directions of rays drawn from the nadir point of a set of three trimetrogon photographs to image points on the oblique photographs. The rectoblique plotter consists of a tilted table upon which are mounted two arms of different lengths connected by a bar free to slide parallel to the horizon. The left, or photo arm, is made of transparent material and is pivoted on the table at its lower end at a point corresponding to the photo nadir point. The right arm is known as the templet arm and pivots about a point at its lower end which corresponds to the ground nadir point. The templet arm generates angles in a horizontal plane which correspond with angles described by the photo arm in the plane of the oblique exposure.

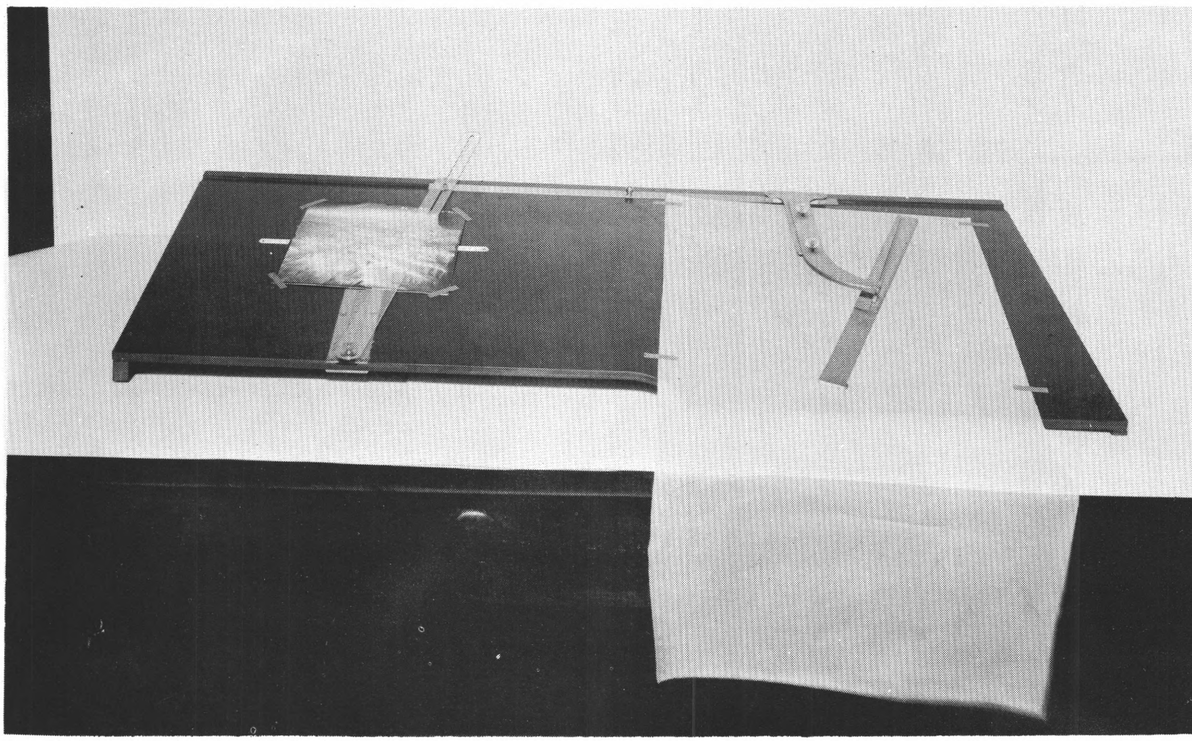

Figure 7.--Rectoblique plotter.

Photoangulator

The photoangulator was developed by J. G. Lewis (1945) as an improvement on the rectoblique plotter. The purposes of the two instruments are identical. The basic difference between them is that in the photoangulator the photo arm and templet arm operate from a common pivot, whereas in the rectoblique plotter the two arms operate from separate pivots.

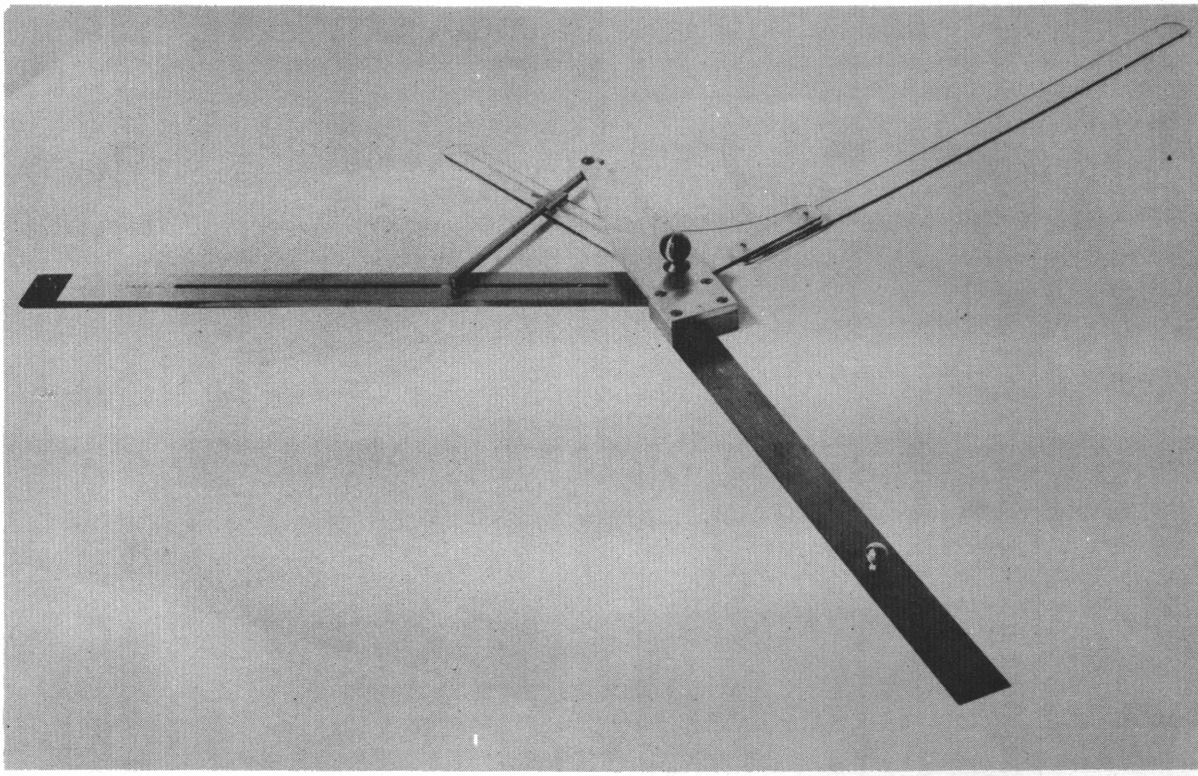

Figure 8. --Photoangulator.

Stereoblique plotter

The stereoblique plotter was developed by J. G. Lewis in 1944 (Lewis, 1945) to draw planimetry from overlapping oblique photographs in orthographic projection. The device is a stereoscopic plotting instrument containing two revolving index lines that combine in the stereoscopic model to form a vertical line piercing the ground at a definite point, the map position of which is determined by two revolving rods intersecting in a plotting pencil. The operator actuates the floating line by directly sketching with the pencil on the map.

This apparatus required special treatment of the viewing stereoscope in order to reduce eyestrain resulting from the difficult perspective conditions and to meet the definite orientation requirements imposed by the oblique photographs. These conditions were met by a stereoscope, developed by J. L. Buckmaster, which provided the necessary adjustments.

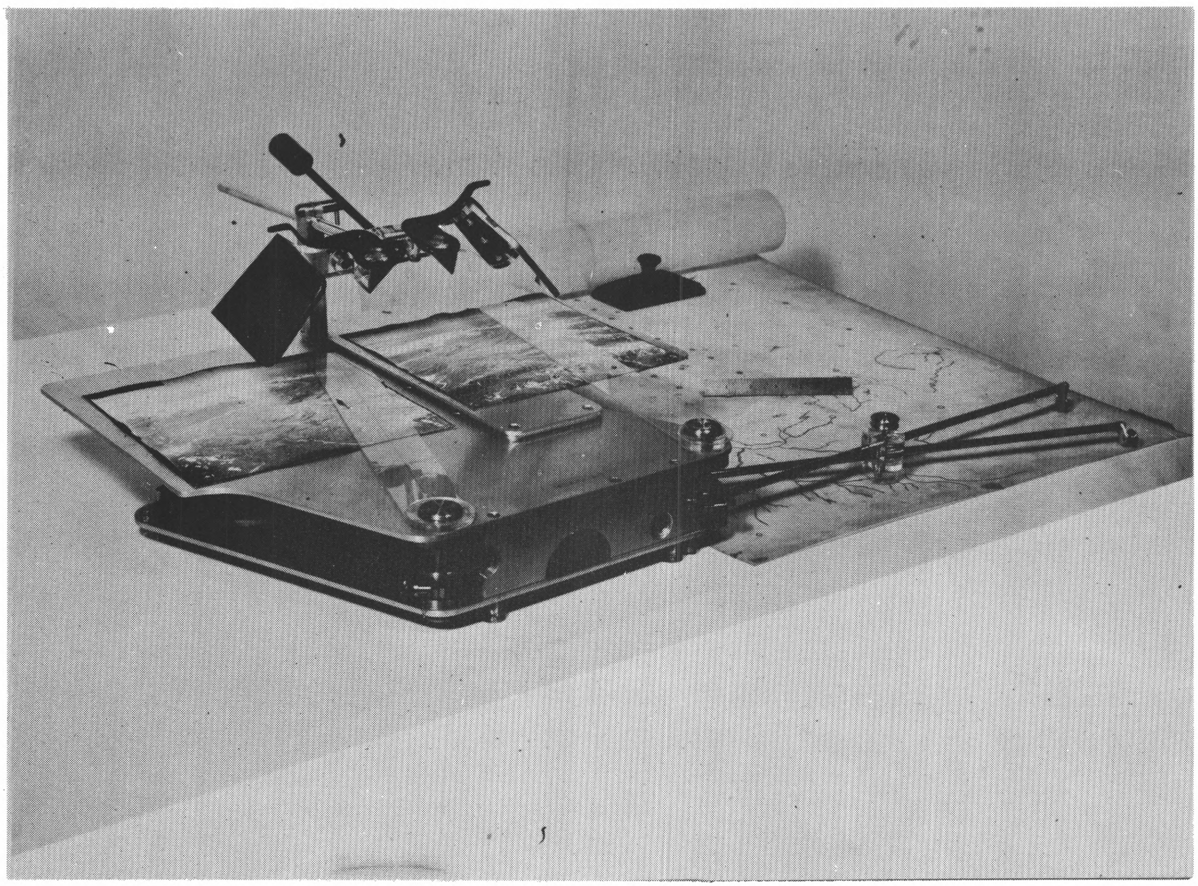

Figure 9.--Stereoblique plotter.

Topoangulator

The topoangulator is a mechanical device developed by David Landen in 1944 (Landen, 1945) for use with trimetrogon photography, which projects photographic detail into the principal plane for elevation determination. This is accomplished by means of a transparent plate called the projector that is etched with a hairline. The projector and hairline are actuated by means of a slide operating parallel to the principal plane of the photograph.

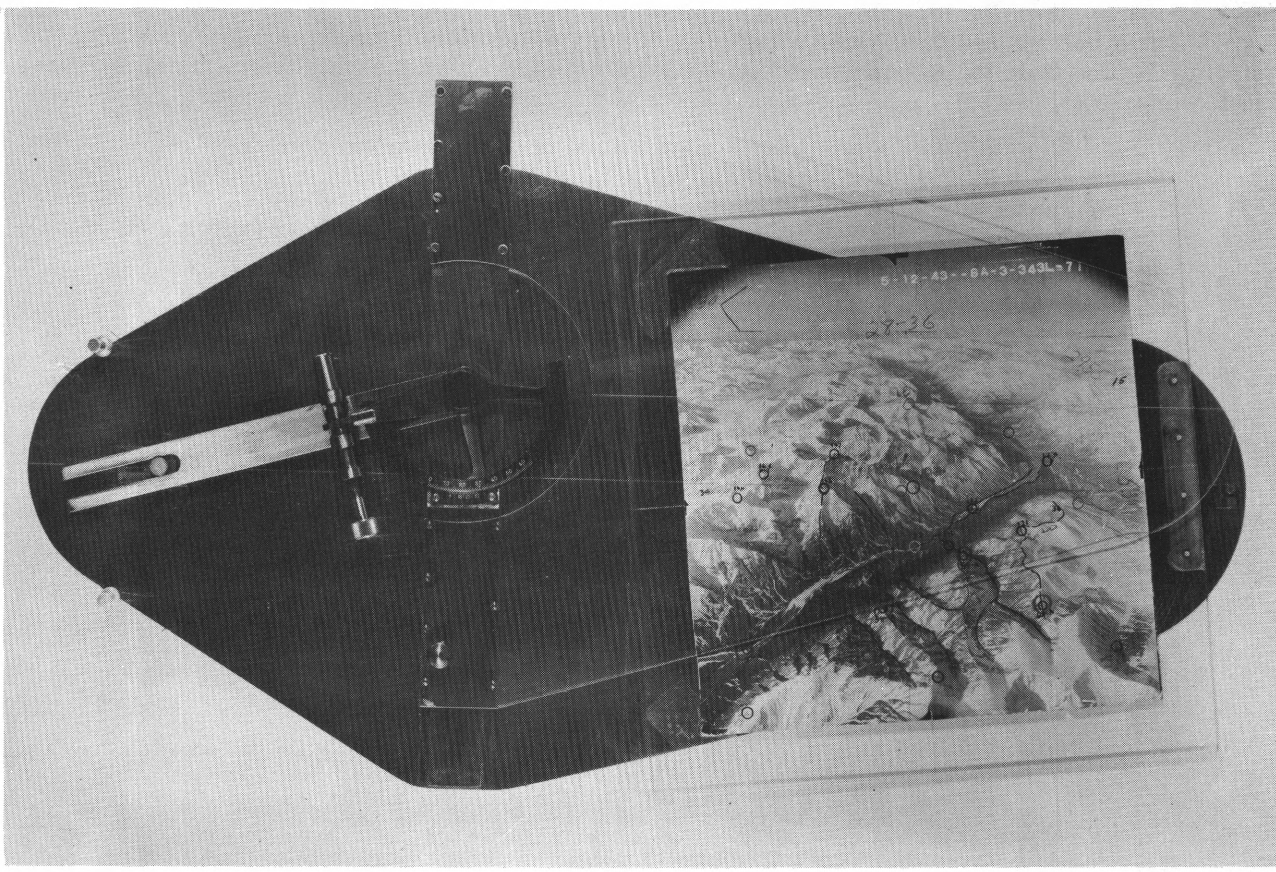

Figure 10. --Topoangulator.

Trimetrogon method of aerial photogrammetry

The trimetrogon method (FitzGerald, 1944) was developed jointly, in 1941 and 1942, by the Geological Survey and the Army Air Forces. Important contributions to this development were made by the following members of the Geological Survey group: Gerald FitzGerald (who directed the group), J. I. Davidson, J. L. Buckmaster, R. M. Wilson, David Landen, J. G. Lewis, T. W. Ranta, J. E. Mundine, and Irving Gessley. In the trimetrogon method, the photography is obtained with an assembly of three cameras equipped with wide angle "metrogon" lenses, in which one of the cameras is vertical and the other two are 60° obliques. The technique of mapping from this type of photography involves the use of instruments already described: the rectoblique plotter or photoangulator, radial intersectors, the stereoblique plotter, the topoangulator, and the photoalidade.

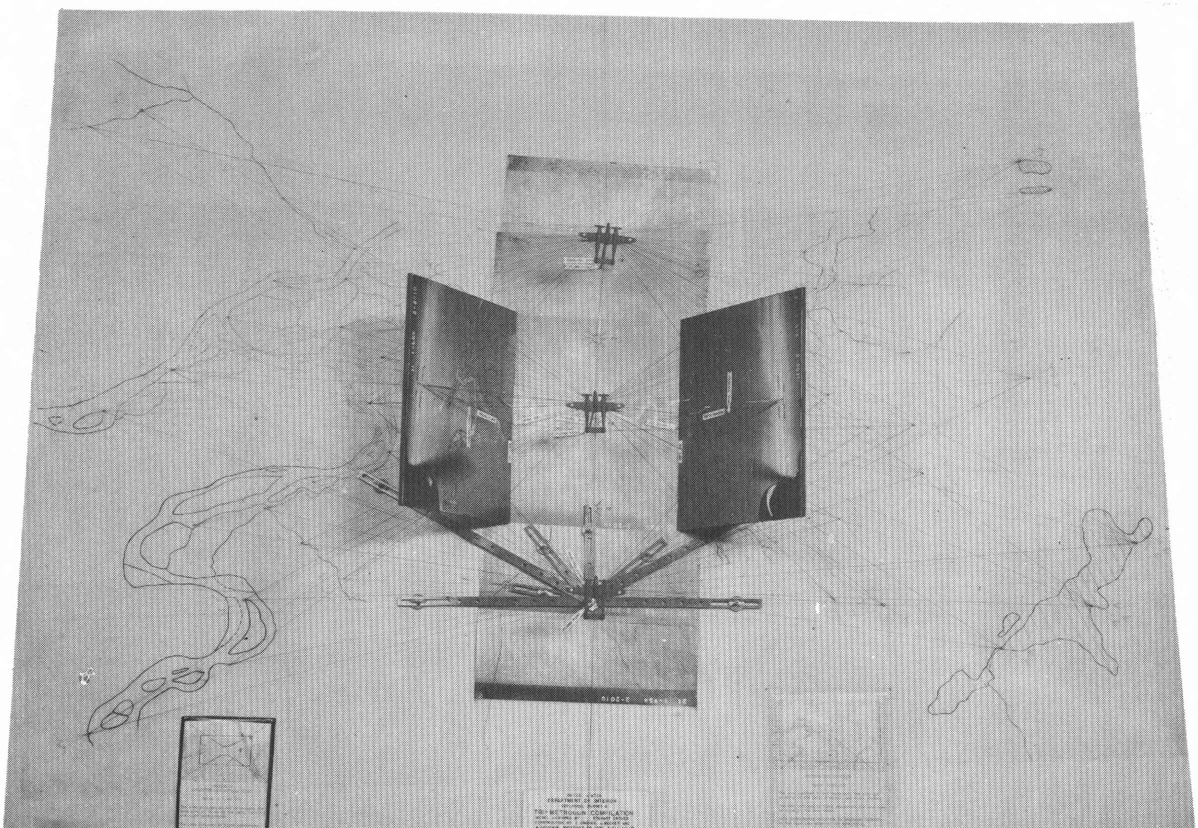

Figure 11. --Model showing trimetrogon method.

Mahan plotter

This instrument (Van Camp, 1945), developed by R. O. Mahan in 1942, is a comparatively simple stereoscopic mapping instrument designed to use ordinary contact prints of aerial photographs. It provides for plotting on a constant scale and approximate tilt correction but does not provide refinements such as correction for lens distortion.

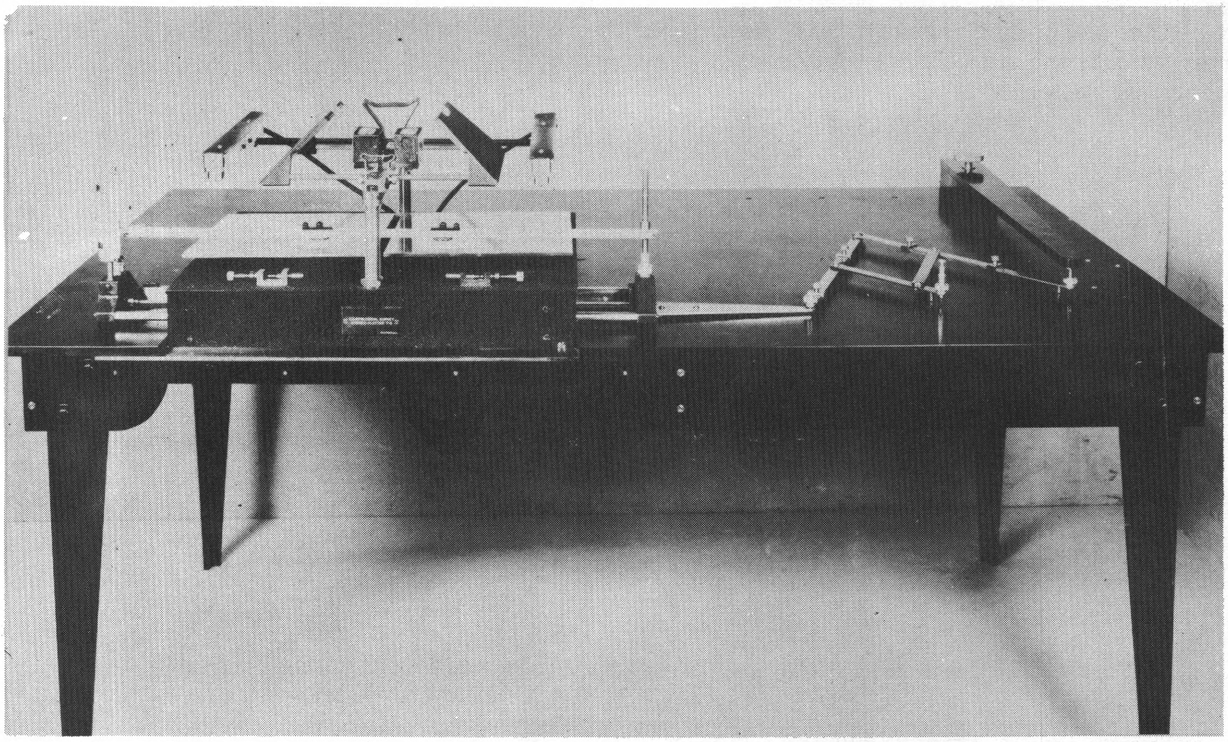

Figure 12. --Mahan plotter.

Improvements in multiplex equipment

The present design of American multiplex equipment is based to a large extent on research conducted cooperatively by Bausch & Lomb and a Geological Survey group supervised first by T. P. Pendleton and later by R. K. Bean (1940). These investigations, beginning in 1938 and still in progress, have resulted in the construction of diapositive printers with built-in distortion correction, improved illumination of the multiplex projectors, improved methods of interior and exterior orientation of the projectors, improved tracing tables having increased range and reading directly in feet at the desired scale, and many other detailed improvements.

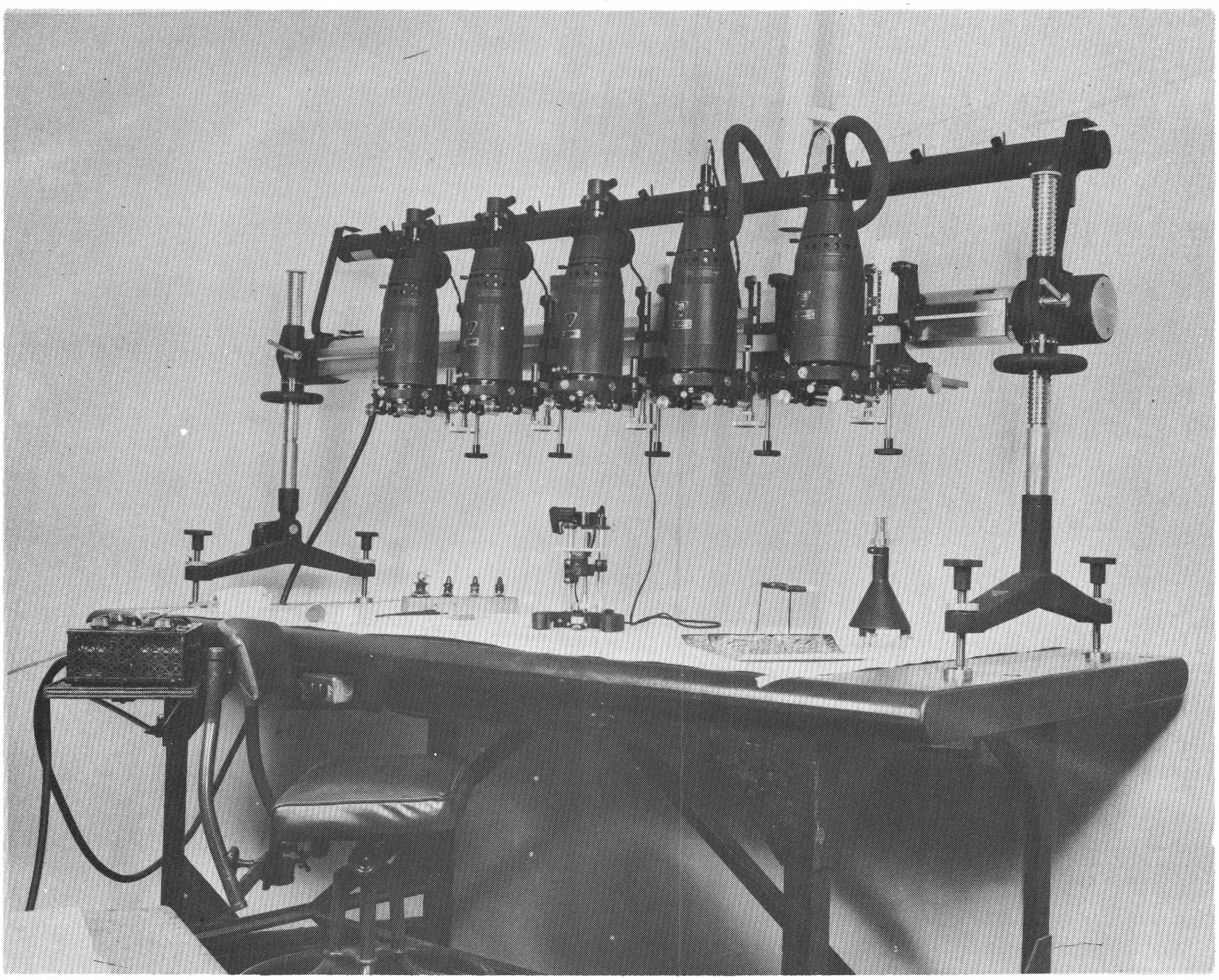

Figure 13.--Improved multiplex equipment.

Kelsh plotter

The basic principles of this instrument were conceived by H. T. Kelsh in 1943 (Kelsh, 1947), prior to his association with the Geological Survey, and were developed by him and other members of the Survey's technical staff beginning in 1947. This plotter has passed through an extremely rapid metamorphosis. The basic improvements over previous double projection plotters have, however, remained the same, namely: (1) the swinging light source, (2) correction of camera-lens distortion through adjustment of the projector principal distance by means of an arm-and-cam arrangement, and (3) contact-size diapositive plates.

In 1951, an experimental adaptation of the Kelsh plotter was constructed by the Trimetrogon Section to demonstrate the possibility of its use with oblique (trimetrogon) photographs.

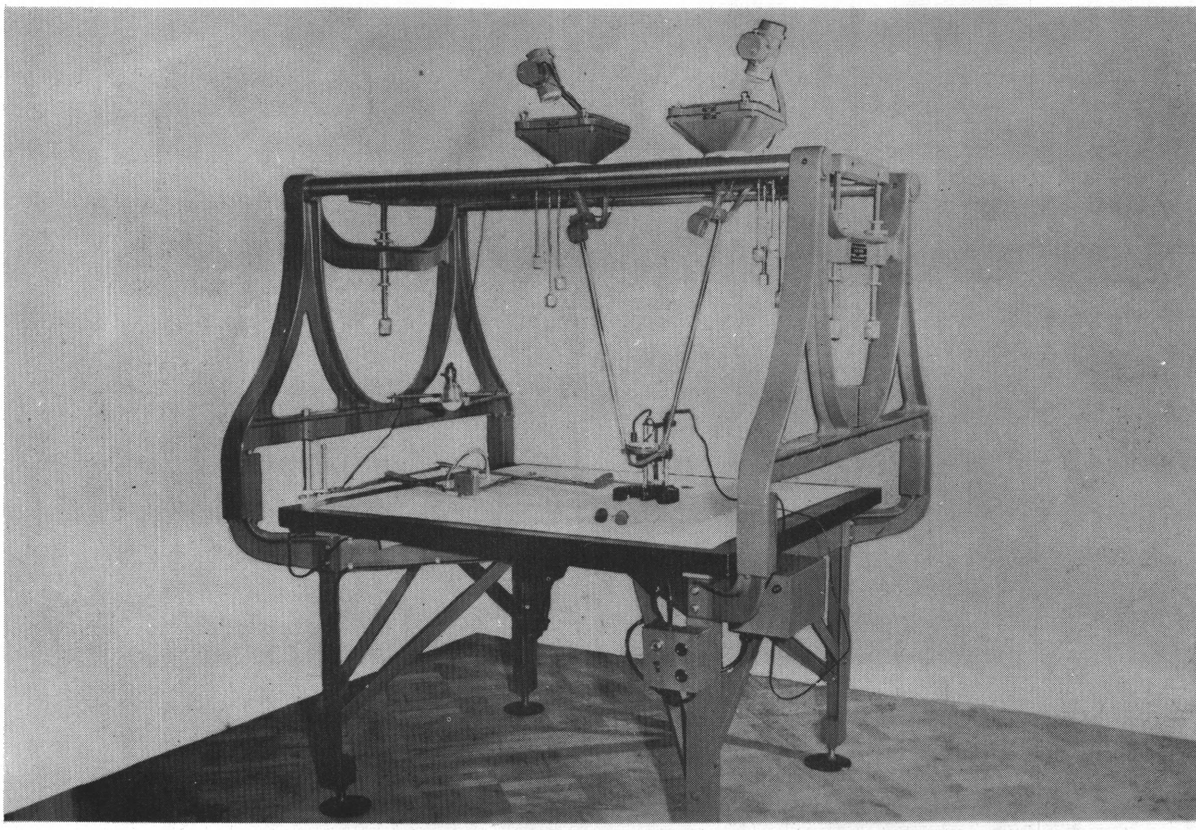

Figure 14.--Kelsh plotter, 1951 model.

ER-55 projector

The ER-55 projector, developed between 1945 and 1952 under the supervision of R. K. Bean (Bean, 1953), is a new kind of photogrammetric projector for stereoplotting by the direct double-projection method. The principal distinctive feature of the instrument is that the light for projecting the image is condensed by an unsymmetrically positioned ellipsoidal reflector instead of by a condensing lens system. The designation ER-55 is derived from two of the physical properties of the projector: ER signifies ellipsoidal reflector, and the principal distance of the projector is 55 millimeters.

The principle of the new projector is based on a well-known property of a concave mirror conforming to a prolate ellipsoid of revolution. Light rays emanating from a light source located at one focus of the ellipsoid are directed by reflection toward the second focus. A diapositive plate is suitably positioned in the system at the appropriate principal distance from the lens. Light rays emanate from the light source (at one focus of the ellipsoid of revolution), pass through a red or blue filter and strike the ellipsoidal reflecting surface. The rays are then reflected so that they pass through first the diapositive, then the projection lens (at the second focus), and thence to the platen of a plotting table. From this point on, the operation is the same as that of multiplex-type instruments. A vital feature of the system is that no light rays pass directly from the light source to the lens through the diapositive; as a result, there is no hot spot caused by direct light rays, and the light distribution is relatively even.

The chief advantages of the ER-55 projector over multiplex-type projectors are: improved illumination of the model due to more efficient use of the available light; increased resolution in the stereoscopic model due to the use of a larger diapositive plate (110 x 110 mm.); increased magnification; elimination of condenser lens; compactness; and versatility of use for either vertical or low-oblique photography.

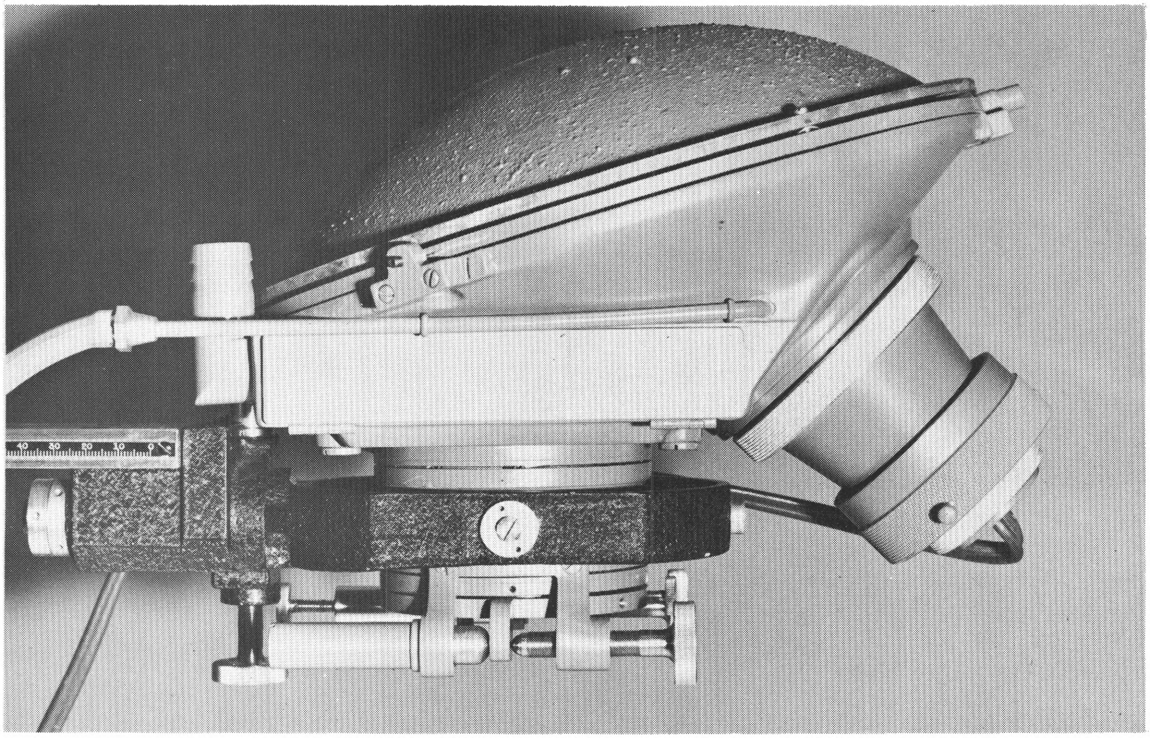

Figure 15.--ER-55 projector.

The twinplex

The prototype twinplex stereoplotting instrument (Topographic Division, 1952), developed by R. K. Bean, was completed in 1950. It is designed to utilize low-oblique, wide-angle photography obtained with two synchronized and rigidly coupled cameras. The two cameras may be alined either along the flight line for precision mapping, or transverse to the flight line for reconnaissance mapping. Two unrectified diapositives, corresponding to the two exposures made at one camera station, are used in a set of twin projectors. Each exposure must be paired with an exposure from an adjacent camera station in order to produce the stereoscopic model. Once either of the twin projectors has been oriented in projecting position, the other projector will be correctly oriented when it in turn is swung into projecting position.

Multiplex-type projectors were used on the prototype model. However, the improved model incorporates ER-55 projectors. The illustration shows two twin ER-55 projector assemblies arranged for convergent photography. The frame accommodates four twin-projector units mounted in this manner, or eight twin-projector units arranged for transverse photography.

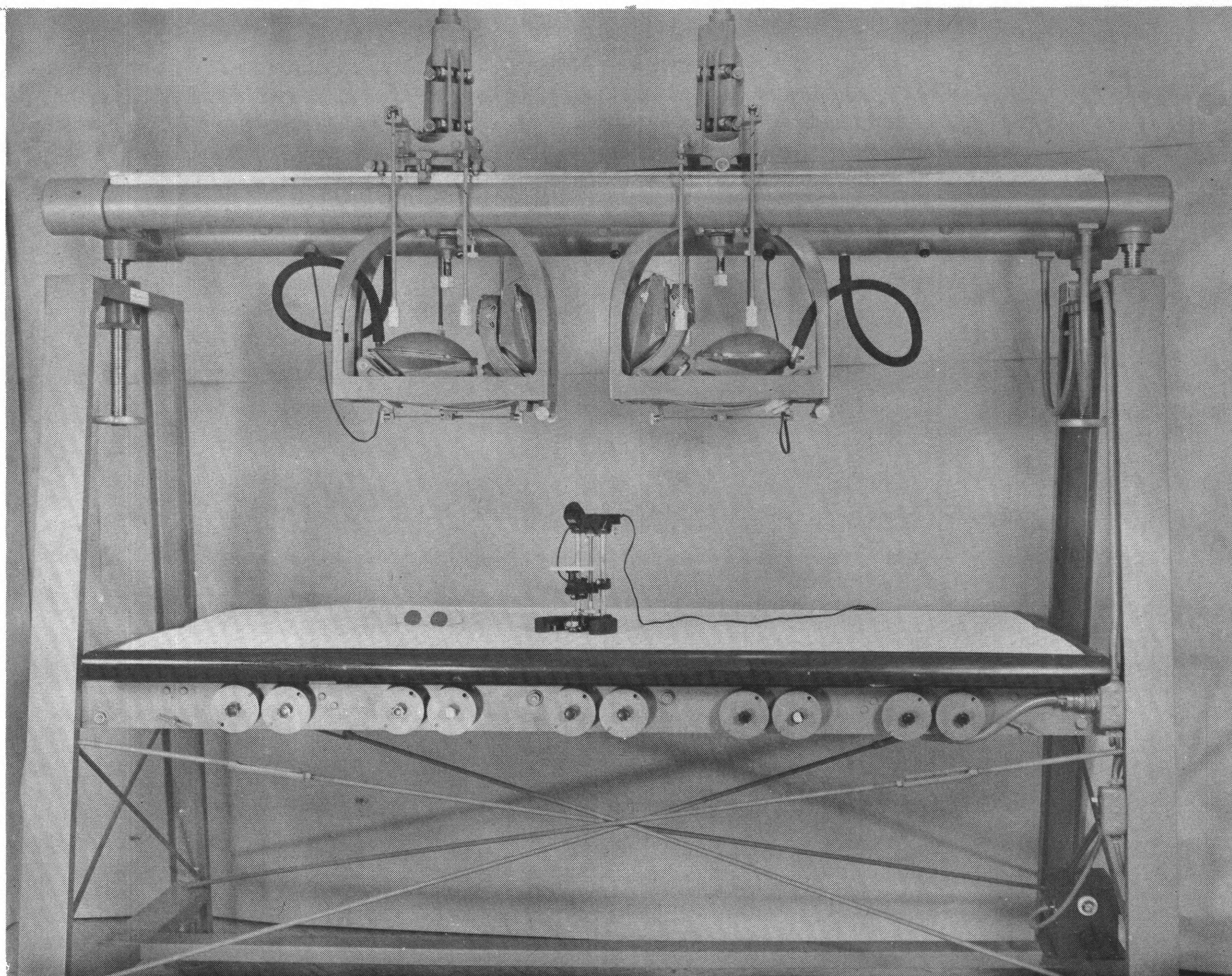

Figure 16.--Twinplex with ER-55 projectors.

Stereodetailer

This instrument devised by E. I. Loud, Jr., in 1951, is used in compilation review to transfer certain detail from aerial photographs to multiplex manuscripts. It applies the principle of the sketchmaster to a simple lens stereoscope. The instrument can be visualized as a sketchmaster in which the map and photograph have exchanged positions, with a left eyepiece added so that another photograph can be viewed with the left eye to give a stereoscopic image. Only one eye sees the superimposed image, with the effect that the lines of the map give the illusion of relief, seeming to conform to the relief in the photo model. No provision is made for tilt, but this is not necessary since it is intended to position only small areas at a time to the abundant detail of the completed manuscript. Enlargement ratios ranging from two times to five times can be obtained by changing the distance between the eyepiece and the large mirror, and inserting a suitable lens at the eyepiece.

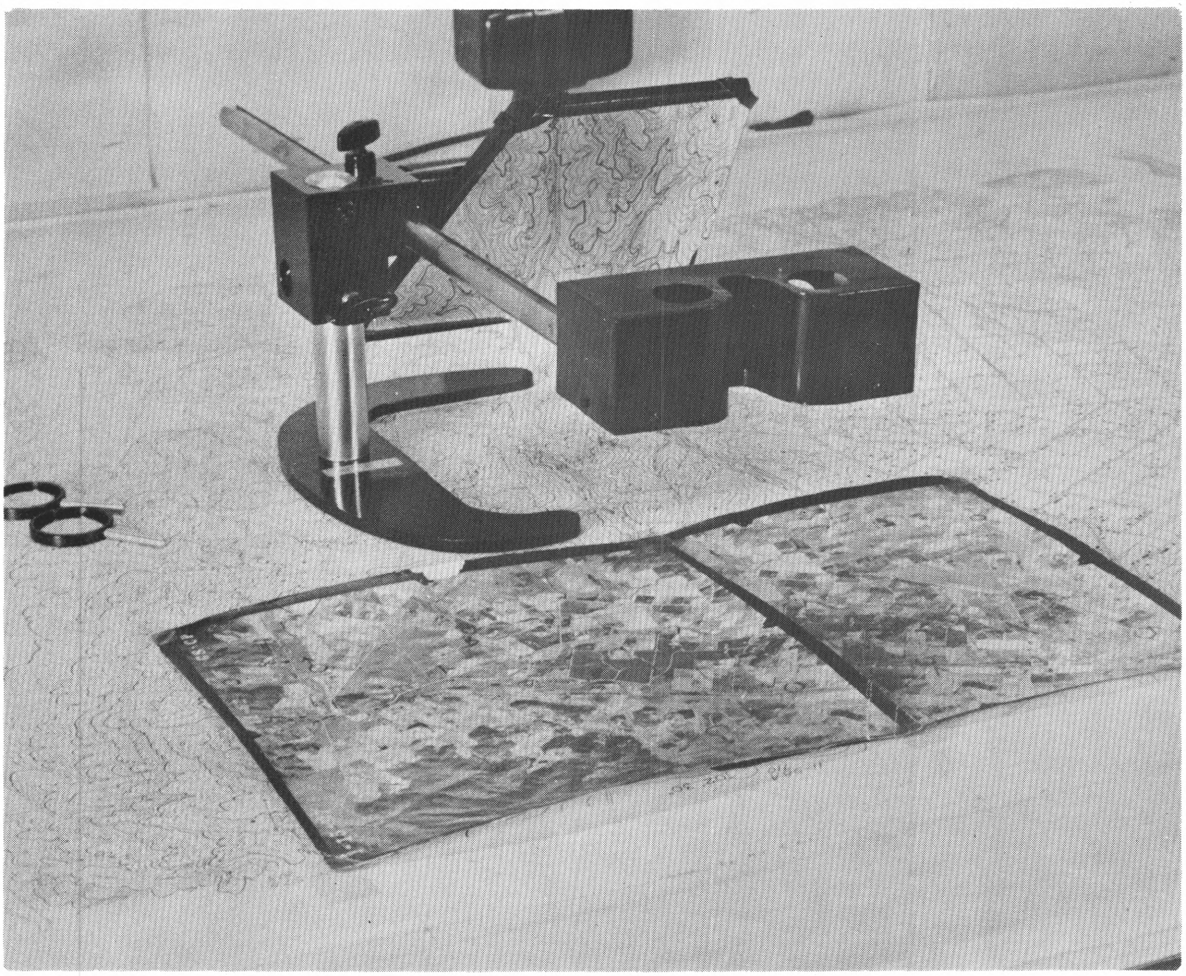

Figure 17.--Stereodetailer.

Portable reflecting projector

The portable reflecting projector (Maltby, 1952) was developed in 1951 under the sponsorship of the Geological Survey. This instrument fills the need for a compact, lightweight, autofocusing projector, suitable for use in field offices for transferring details monoscopically from aerial photographs to a map.

A unique feature of the projector is that it employs no counterweights, pulleys, chains, or cables. Operation of a single hand crank positions the lens and the copyholder automatically so that the projected image is kept in sharp focus throughout the entire range. This motion is accomplished with a simple but positive mechanical linkage. The hand crank is counterbalanced so that it turns easily; it requires less than 30 seconds to change from maximum enlargement to maximum reduction.

General specifications of the latest model are as follows: the range of the instrument is from 1 to 2 enlargement to 3 to 1 reduction; any 7- by 7-inch portion of copy as large as 18 by 24 inches can be enlarged or reduced; over-all dimensions are 16 inches wide, 20 inches deep, and 34 inches high; the total weight of the instrument is 52 pounds. A carrying case is provided that takes the instrument completely assembled.

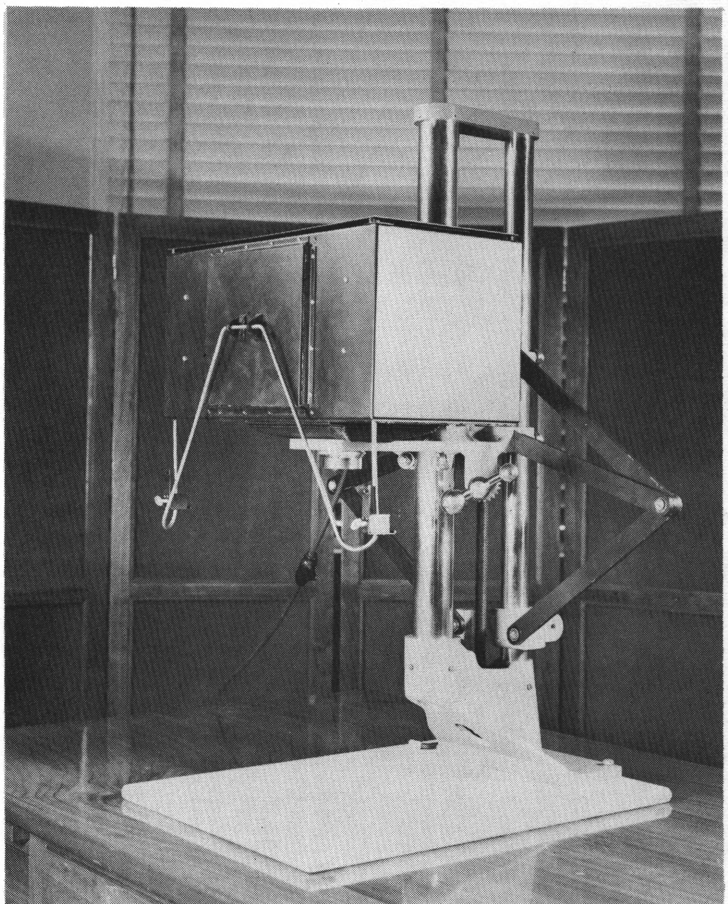

Figure 18.--Portable reflecting projector.

Stereotemplet triangulation

The stereotemplet method for establishing supplementary horizontal control positions required in photogrammetric mapping procedures was devised by M. B. Scher in 1949 (Scher, 1955). A stereotemplet is a composite slotted templet mechanically representing the horizontal plot of a stereoscopic optical model formed in a stereoscopic plotting instrument. (See fig. 19.) The positional data required for the preparation of the stereotemplet are stereoplotted from the geometrically faithful optical model. Positions of image points plotted orthographically from leveled models are rectified with respect to tilt and have no horizontal displacement due to relief. The function of the stereotemplet is to maintain a uniform scale relationship between any and all points plotted from a single model while allowing for the enlargement or the reduction of the overall scale of the templet. To develop control for an area covered by a number of models, the stereotemplets representing the various models are adjusted to the desired common scale when the templets are assembled to satisfy horizontal control positions.

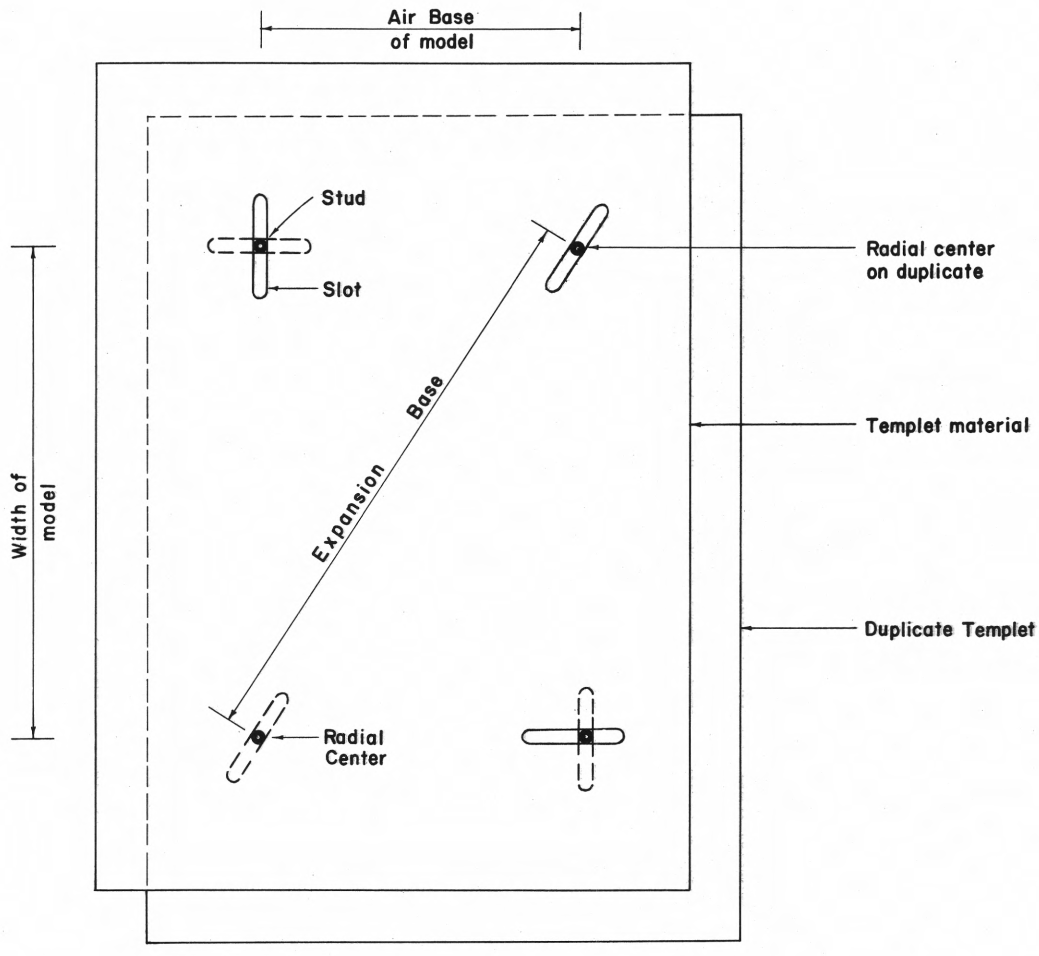

Figure 19. --Stereotemplet of a single stereoscopic model.

Orthophotoscope

The orthophotoscope (Bean and Thompson, 1957) is an apparatus developed by R. K. Bean for converting perspective photographs to the equivalent of orthographic photographs. In the photographs produced (called "orthophotographs") image displacements due to tilt and relief are virtually eliminated so that the scale is uniform throughout the image area. The orthophotoscope must be used in conjunction with a double-projection anaglyphic plotting instrument, such as the ER-55 or Kelsh plotter. The projectors of the double-projection instrument are oriented, and the anaglyphic model is viewed, in the same manner for producing orthophotographs as for producing maps.

The orthophotoscope permits continuous variation in the height of a horizontal sensitized surface. The sensitized surface is scanned systematically by a small slit in a screen covering the surface. The slit permits piecemeal exposure of the surface and also serves as a floating mark. As the scanning proceeds, the slit is kept "on the ground" by the observer through operation of the height-changing mechanism. The slit exposes each differential area to two projected images of the same object, one in blue-green light and one in red light; but the blue-sensitive film is not affected by the red light. Thus, although both the red and blue projected rays are needed to create the stereoscopic model, only the blue rays have an actinic effect on the film.

When the entire model has been scanned, the film is developed by usual photographic procedures. From the resulting negative, enlargements or reductions can be made at the desired scale.

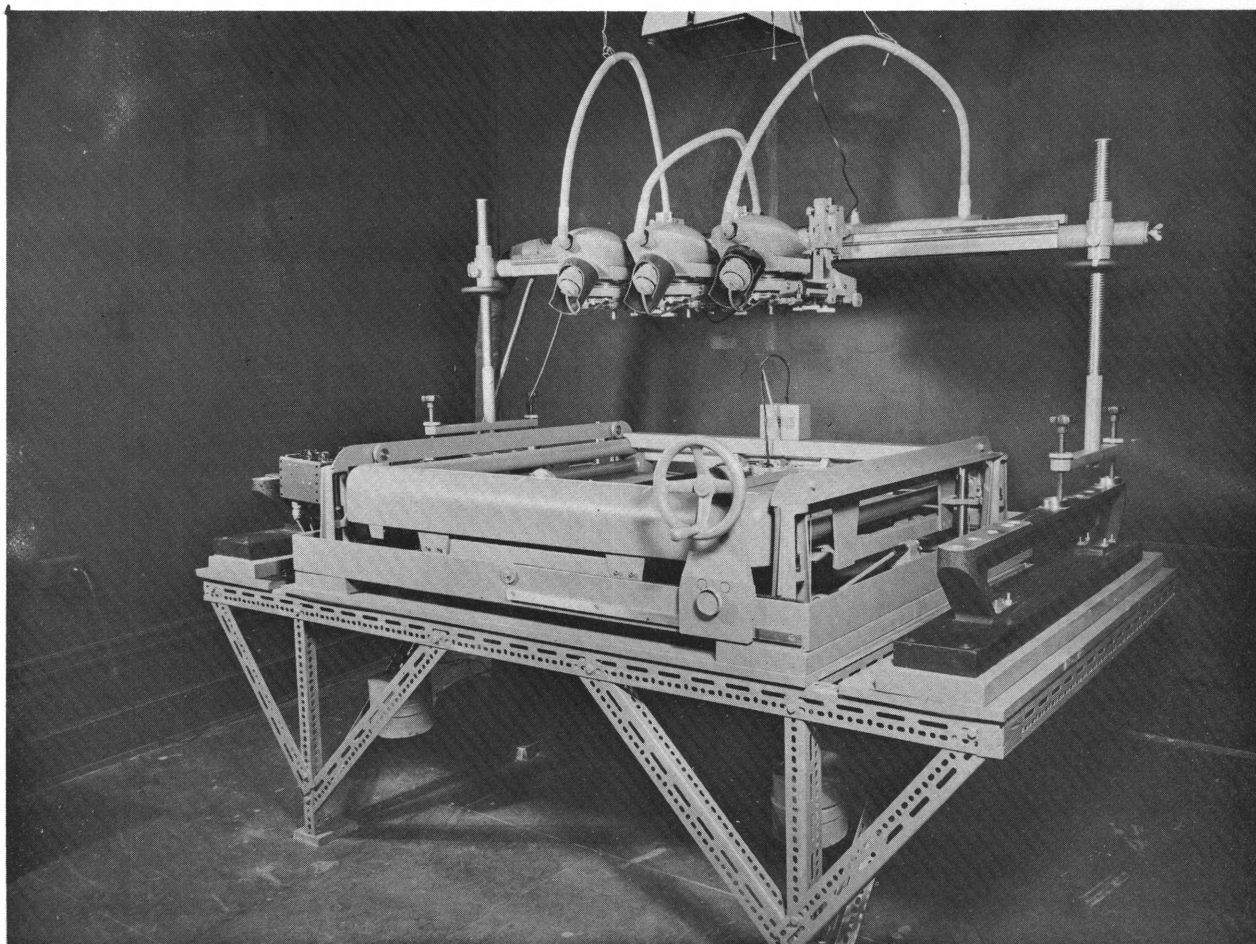

Figure 20.--Orthophotoscope, prototype model, 1956.

Hugershoff Aerocartograph

The Aerocartograph (Hacquinius and Shuster, 1929) is a highly complex stereoplotting instrument of the optical-mechanical projection class. It is capable of producing good maps using either vertical or terrestrial photographs but is now considered obsolete in comparison with the more efficient Stereoplanigraph and Autographs.

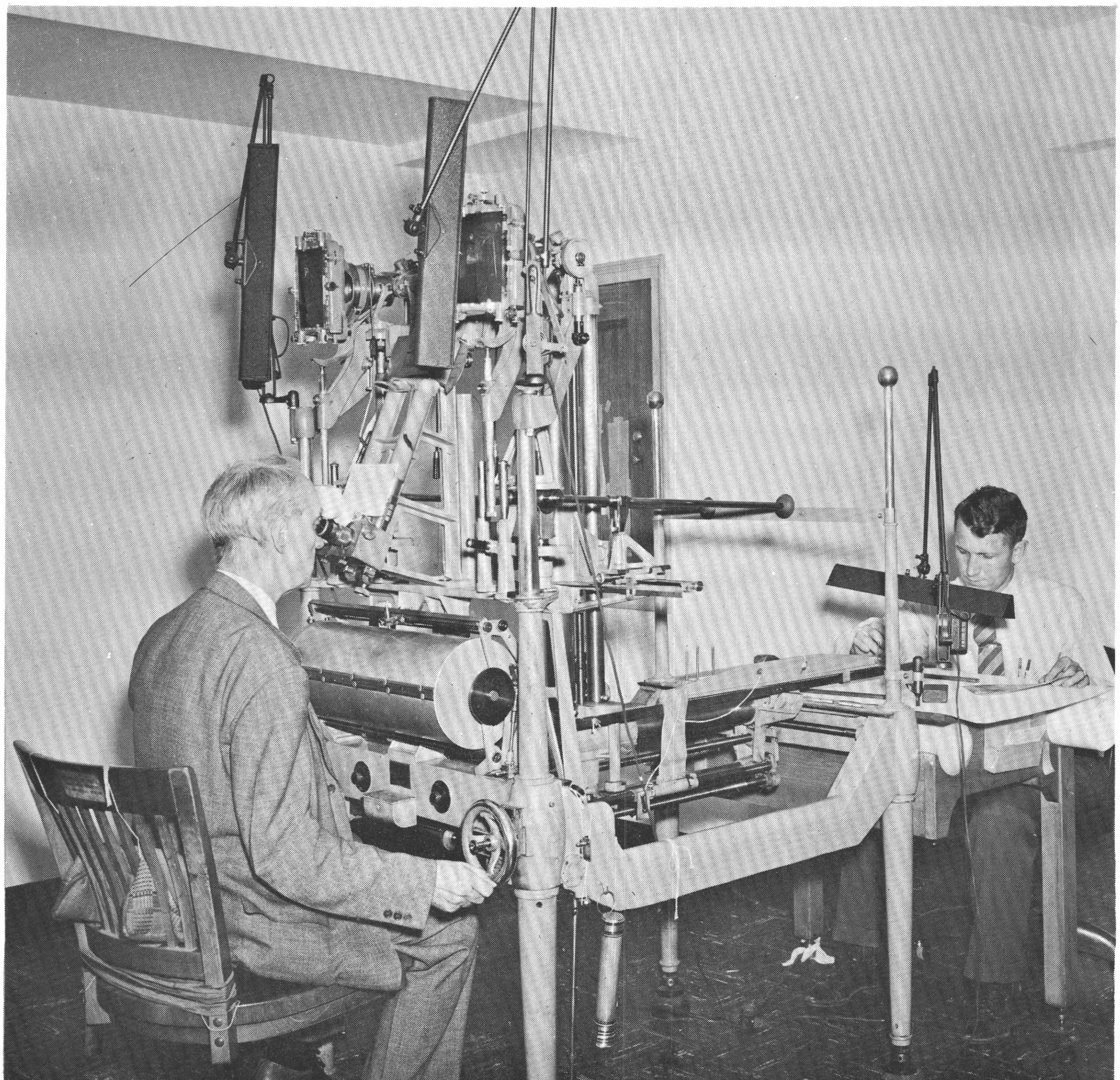

Figure 21. --Hugershoff Aerocartograph (German).

Wild Autograph A-6 and A-8

The Autographs A-6 (Altenhofen, 1951) and A-8 are mechanical-projection type stereoplotting instruments of medium complexity, utilizing vertical photography. They can be used for aerial triangulation by a semianalytical method, but they are not as convenient for this purpose as the Autograph A-5 and the Stereoplanigraph, which afford continuous solutions. The accuracy of map compilation by means of the A-6 and A-8 is of a very high order. The A-6 is operated by one man, whereas the Aerocartograph, A-5, A-8, and Stereoplanigraph each usually require an operator and an assistant.

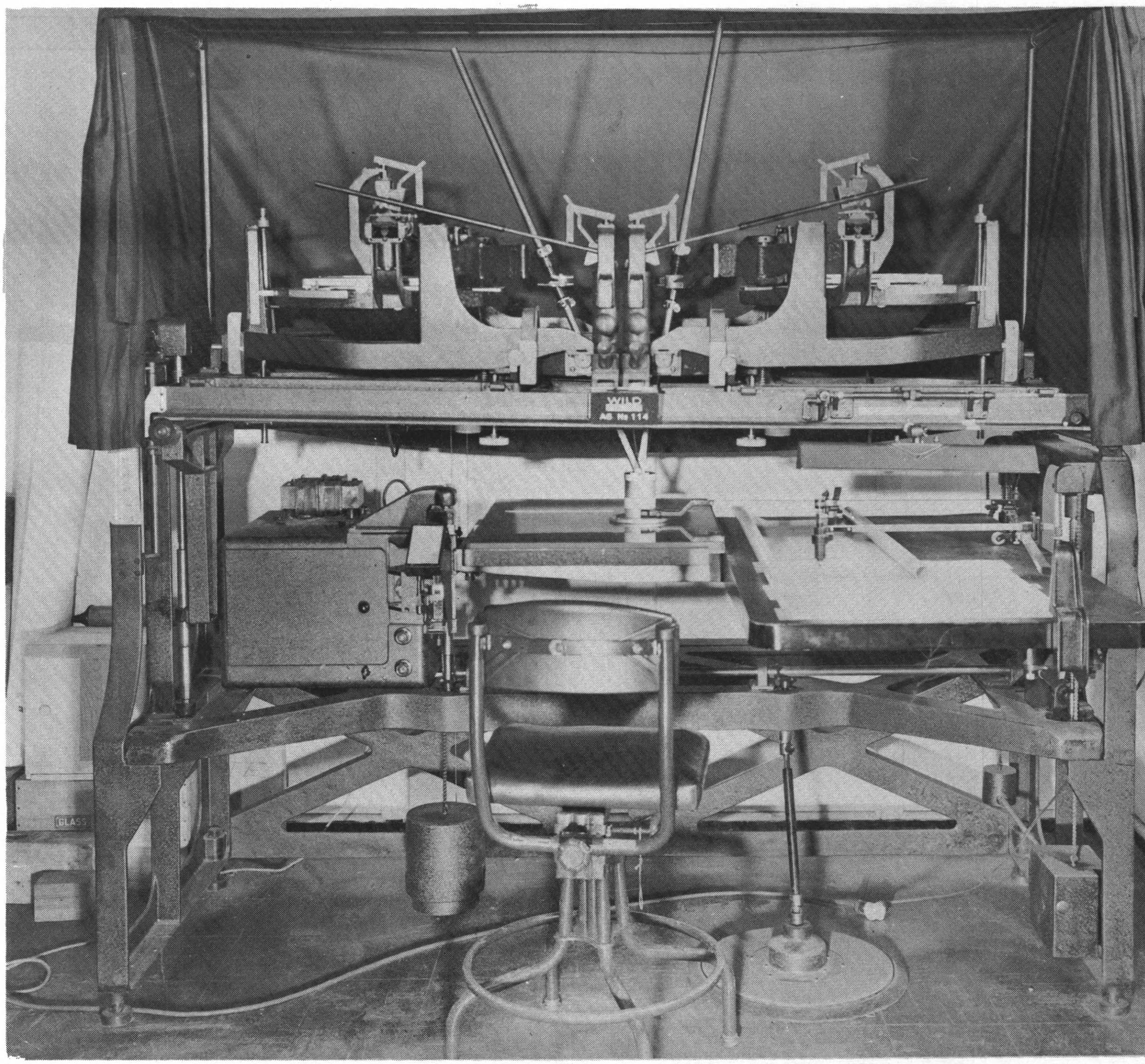

Figure 22. --Wild Autograph A-6 (Swiss).

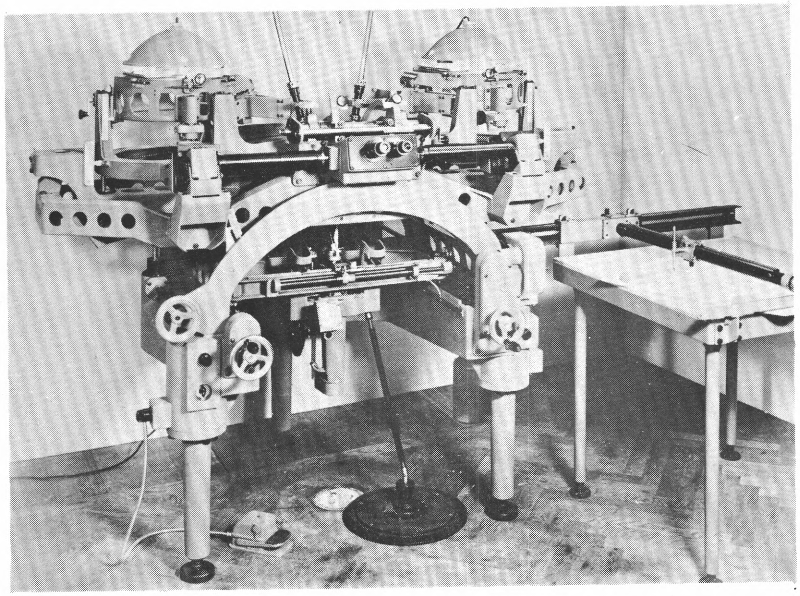

Figure 23.--Wild Autograph A-8 (Swiss).

Wild Autograph A-5

The Autograph A-5 (Altenhofen, 1951) is a highly complex mechanical-projection type of stereoplotting instrument, which can be used with either vertical or terrestrial photography. Both aerial triangulation and map compilation can be performed on the A-5 to a very high order of accuracy. The initial cost of the instrument is very high, but by careful planning of the special projects performed on it, the instrument affords long-range economies in operation.

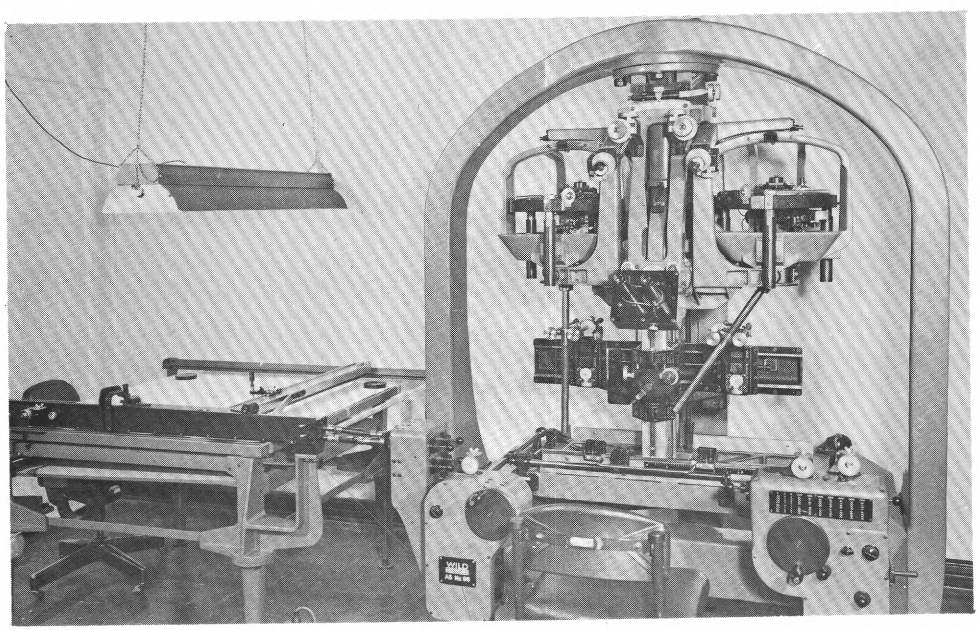

Figure 24.--Wild Autograph A-5 (Swiss).

Zeiss Stereoplanigraph

Like the Autograph A-5, the Stereoplanigraph (Altenhofen, 1951) is a highly complex and costly instrument, capable of performing very accurate aerial triangulation and map compilation. It is classified as a double-projection type of instrument, but the double projection of the conjugate images is viewed through a complex optical system rather than directly as in the multiplex or Kelsh plotter. The Stereoplanigraph accommodates vertical, terrestrial, or oblique photography.

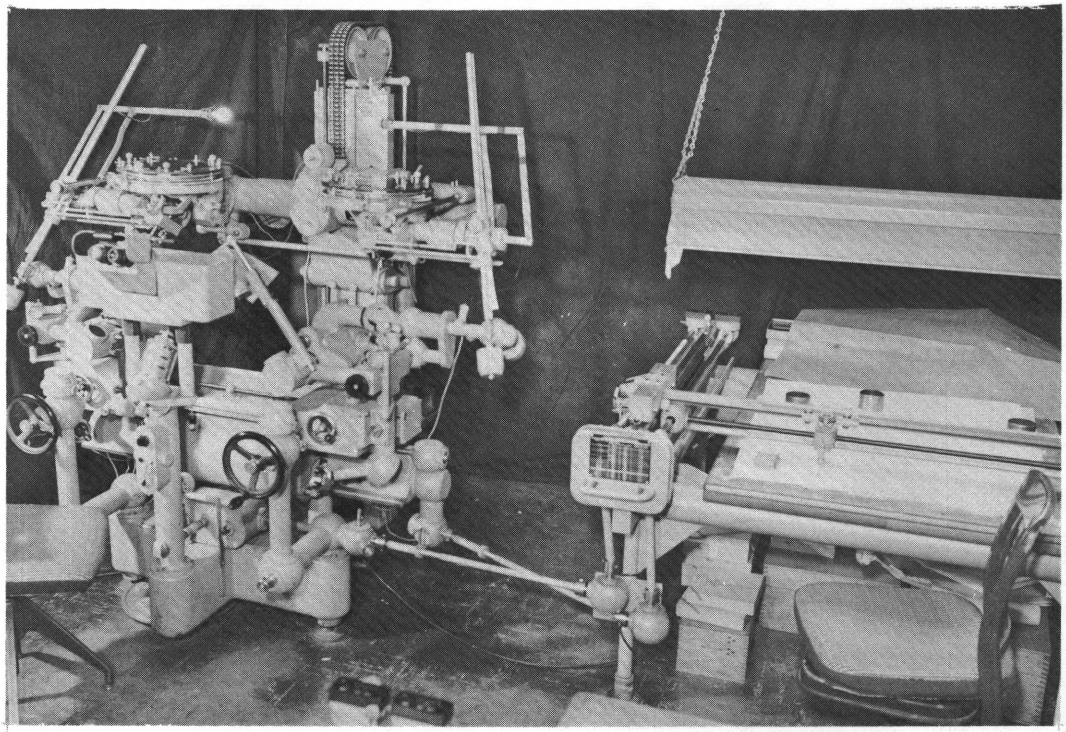

Figure 25.--Zeiss Stereoplanigraph (German).

U. S. PATENTS ISSUED TO GEOLOGICAL SURVEY PHOTOGRAMMETRISTS

R. K. Bean

No. 2,696,752, Stereoscopic photographic projection mapping instrument (twinplex), Dec. 14, 1954.

No. 2,737,846, Ellipsoidal reflector projector for stereophotogrammetric map plotting, Mar. 13, 1956.

App. Ser. No. 606,788, Orthophotoscope.

J. L. Buckmaster

No. 2,342,640, Optical transfer instrument, Feb. 29, 1944.

No. 2,352,614, Transfer methods and instruments.

No. 2,370,143, Camera lucida instrument and prismatic units therefor.

No. 2,670,655, Aerial photograph viewing stereoscope, Mar. 2, 1954.

H. T. Kelsh

No. 2,341,031, Map making and projection instrument, Oct. 12, 1948.

No. 2,492,870, Stereoscopic projection map-making instrument, Dec. 27, 1949.

No. 2,552,975, Photogrammetric projection machine, May 15, 1951.

David Landen

No. 2,487,814, Mapping instrument (topoangulator), Nov. 15, 1949.

J. G. Lewis

No. 2,321,033, Rectoblique plotter, June 8, 1943.

No. 2,364,082, Map making from aerial photographs (photoangulator), Dec. 5, 1944.

No. 2,561,386, Stereoblique plotter, July 24, 1951.

R. M. Wilson

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INT.-DUP. SEC., WASH., D.C. 36232