Technical Papers

The ER-55 Projector for Aerial Mapping[1]

Russell K. Bean

U. S. Geological Survey, Washington, D. C.

For many a scientific or engineering venture of today, one of the most vital prerequisites is accurate topographic maps. The ever increasing demand for more and better maps has placed a heavy burden on our mapmaking facilities. Only by the development and application of new mapping techniques based on aerial photography have we been able to keep pace with the growing need. The story of the development of photogrammetry, the science of obtaining reliable measurements by means of photography, is documented in very extensive literature covering this field.[2] A single new development in the field of photogrammetry, the ER-55 projector, is described here.

Many instruments have been developed for converting the data available on aerial photographs to topographic maps. These instruments range from simple inexpensive gadgets of limited application to complicated and costly machines capable of producing maps of the highest precision. In the United States, the principal device for compiling topographic maps

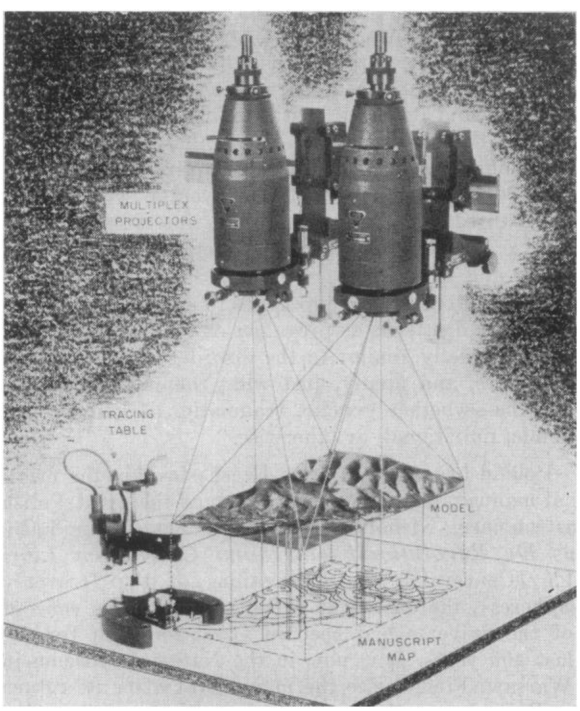

FIG. 1. Principle of the multiplex.

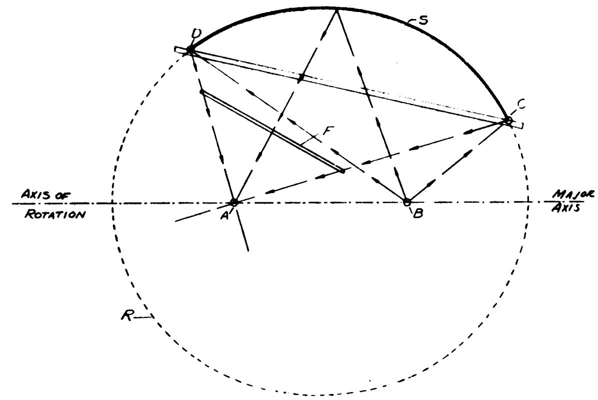

FIG. 2. Prolate ellipsoid of resolution showing paths of light rays.

from aerial photographs has been the multiplex projector, a relatively simple instrument for stereoscopic plotting of maps by the direct double-projection method (Fig. 1). Details of the operation of this instrument are available in the *Manual of Photogrammetry* published in 1952 by the American Society of Photogrammetry.

The ER-55 projector is a new kind of photogrammetric projector for stereoplotting by the direct double-projection method. It has a number of advantages over the multiplex projector. The principal distinctive feature of the instrument is that the light for projecting the image is condensed by an 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 mm.

The development of the ER-55 projector was planned and carried out in accordance with three guiding principles:

1) It was recognized that there are certain exploitable advantages in double-projection instruments, such as the multiplex, as compared to the highly complex instruments of the optical-train type. These advantages are: low initial cost; low maintenance costs; ease of operation, requiring brief training; minimum of moving parts, including a stationary light source; direct anaglyphic viewing of projected images; and rapid stereotriangulation.

2) It was recognized that previous instruments of this type had certain disadvantages, namely, loss of resolution due to the process of greatly reducing the aerial negative to a small diapositive in a diapositive printer; poor illumination; limit of permissible magnification imposed by resolution and illumination limits; and aberrations of the condensing lens system.

3) It was recognized that if a practical instrument could be developed retaining the advantages of the simple double-projection instruments while overcom-

[1] Adapted from a paper presented at the 19th Annual Meeting, American Society of Photogrammetry, January 14, 1953.
[2] See bibliography in *Manual of Photogrammetry*, American Society of Photogrammetry, 1952.

ing previous disadvantages, the product would be one of great usefulness, efficiency, and economy for both vertical and low-oblique photography.

The principle of the new projector is based on a well-known property of a concave mirror conforming to a prolate ellipsoid of revolution, (Fig. 2); light rays emanating from a light source located at one focus of the ellipsoid are directed by reflection toward the second focus. The main components of the projector, namely the light source, the reflecting surface, and the projection lens, are so configurated and oriented as to exploit this property. It will be noted that the reflector is unsymmetrically positioned with respect to the axes.

A diapositive plate, *F,* is suitably positioned in the system at the appropriate principal distance from the lens. Light rays emanate from the light source at one focus, *B,* of the ellipsoid of revolution, pass through a red or blue filter and strike the ellipsoidal reflecting surface, *S.* The rays are then reflected so that they pass through first the diapositive, *F,* then the projection lens, *A,* at the second focus, and thence to the platen of a plotting table. This system results in the projection of the image of the photography in a color corresponding to the color of the filter. From this point on, the operation is the same as that of multiplex-type instruments.

A vital feature of the system is that because of its unsymmetrical configuration 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 reflecting surface consists essentially of only that portion of a complete ellipsoid required for the reflection of the bundle of rays which encompasses the entire area of the diapositive, with the lens as a perspective center for the reflected rays. This surface is represented by *S,* extending from *C* to *D.*

The primary problem in designing an ellipsoidal-reflector projector that would fulfill the desired objectives was to determine suitable values for the following interrelated factors: size of diapositive, principal distance and projection distance of the projector, focal length of the projection lens, and size and shape of the ellipsoid. Figure 3 shows the design finally adopted.

The final design, arrived at after several trial calculations, represents the optimum combination of the interrelated factor—the diapositive size being increased to yield better resolution, while still keeping the instrument size within practical working limits. Principal distance and optimum projection distance of the projector were selected keeping in mind the desired plotting scales as well as the projector spacing on the supporting frame.

The size and shape of the ellipsoid were selected by determining the most compact physical arrangement that would accommodate the lens placed at one focus, the light source at the other focus, and the diapositive plate properly placed at the correct principal distance

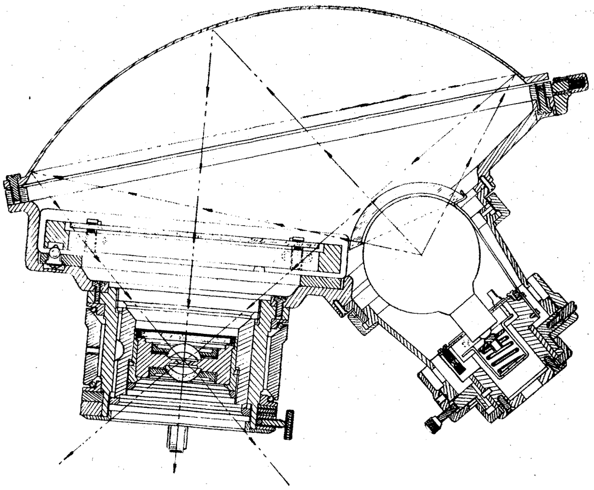

FIG. 3. Cross section of ER-55 projector.

from the lens. The focal separation and the length of the major axis were chosen to give the smallest ellipsoid that would physically accommodate the parts and provide the necessary clearances.

A companion design and development problem, carried on concurrently with the development of the ER-55 projectors, has been the production of a highly efficient diapositive printer designed for the specific purpose of making diapositive plates for these projectors. The new printer, recently completed in prototype form, is capable of capturing and transferring to the diapositive practically all of the detail appearing on the negative. This printer was constructed by the Geological Survey with optical parts, including a virtually distortion-free high-resolution lens and an aspheric correction plate, furnished by Wild of Switzerland.

The difficulties of developing the ER-55 projector were by no means confined to problems of design. There remained some formidable manufacturing problems before the first pair of projectors could be delivered. The most difficult of the manufacturing problems was the production of the precise ellipsoidal glass blank to be used as the pattern about which the reflecting surface is electroformed. The rough blank was made of high-quality glass by the Corning Glass Works. The first blank to be produced successfully was delivered by Corning to J. W. Fecker, Inc., of Pittsburgh, Pa., who had the contract for finishing and polishing the ellipsoid to its final precise dimensions. The Fecker organization designed and built a machine solely for the grinding and polishing operations required on this job. The hazardous operation of reducing the blank to the precise dimensions required was successfully completed after many weeks of painstaking effort. A testing apparatus, especially designed for the purpose, was then set up for inspecting the finished blank for conformance to specifications.

The electroforming operation for producing the mirror from the glass blank was done under contract by the General Electroforming Laboratories of the Silver Shop, Washington, D. C. In this process, a thin coating of silver is first plated on the glass blank for permanent protection. A coating of nonbonding material is then applied to the entire surface. The reflecting surface is then formed by electrodepositing silver (or other suitable material) on the nonbonding coating. Copper is next deposited to a thickness of 3/32 in., to form the body of the reflector. When the reflector is removed, it is thus composed of a copper backing with a silver reflecting surface on the concave side. Although silver was used for the prototype projectors as an expedient, the reflecting surface will eventually be made of a metal less subject to tarnishing. As only a portion of the complete ellipsoid is required for each reflector, and as the glass blank approaches a complete ellipsoid in extent, three reflectors can be electroformed simultaneously.

The Geological Survey is contemplating the utilization of the ER-55 projector in various ways.

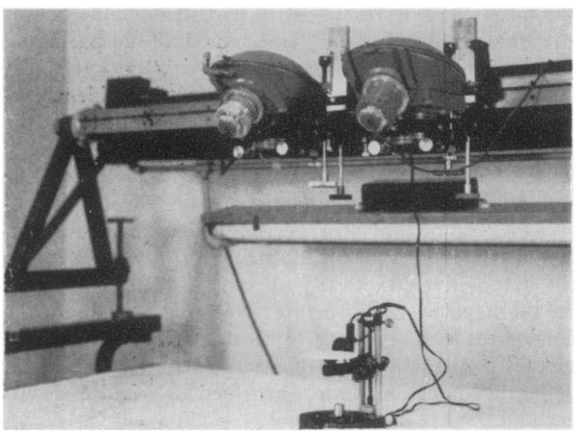

FIG. 4. Pair of ER-55 projectors mounted on standard multiplex supporting frame. The projectors are arranged for vertical photography.

For using vertical photography (see Fig. 4), ER-55 projectors can be mounted in pairs on a standard multiplex supporting frame. The main advantage of using the ER-55 projectors for mapping with vertical photography is that the area to be mapped can be photographed at higher altitudes as compared to multiplex flying, because of the improved illumination and resolution, and larger mapping scale. Since mapping costs generally decrease rapidly with an increase in flying height, the advantage is a substantial one.

The use of ER-55 projectors for compiling single-model convergent photography will provide, in addition to improved illumination and resolution and larger scale, all the inherent advantages of convergent photography.

Stereotriangulation of low-oblique photographic flights can be accomplished with a Twinplex plotter fitted with four twin ER-55 projectors. A simple swing adjustment applied to each projector-couple makes this instrument readily applicable to the bridging of either convergent or transverse low-oblique photography. The Geological Survey prototype Twinplex plotter is fitted with two twin ER-55 projector units. When completed four twin-projector units will be mounted on this instrument.

The ER-55 projector meets certain requirements, promises certain economies and constitutes a step forward in the field of simple double-projection plotters. It is expected that it will take its proper place with other photogrammetric instruments, each of which fills a certain need and is best adapted for the performance of certain jobs.

In addition to its use in stereoplotting instruments of the direct optical projection type, the principle of this invention can be used in other types of stereoplotting instruments and in enlarging or rectifying equipment. As pointed out in the patent application, the same principle can also be used in scientific fields other than photogrammetry. For example, an ellipsoidal-reflector system would provide brilliant illumination of a microscope slide. Or, such a system could be used in the reverse direction as a light gathering means for determining light values. In short, an unsymmetrical ellipsoidal-reflector system may prove advantageous whenever it is desired to concentrate light with the maximum efficiency and to obtain freedom from chromatic aberrations.

Manuscript received January 19, 1953.

A Note on the Lead Isotope Method of Age Determination

D. W. Allan, R. M. Farquhar, and R. D. Russell

Geophysics Laboratory, Department of Physics, University of Toronto, Toronto, Ontario, Canada

Recently several papers have been published which attempt to interpret variations in the isotopic abundances of common leads. An important contribution was made in 1951 by Alpher and Herman (*1*) who showed that the observed lead abundances could be related approximately to the ages of lead minerals by simple mathematical formulas. They assigned dates to a number of analyzed lead ores and calculated the constants in these formulas by a least squares analysis. This calculation was later repeated by Collins, Russell, and Farquhar (*2*), who used data from additional lead samples of known age.

Russell, Farquhar, Cumming, and Wilson (*3*) have recently proposed a method whereby the variation in common lead abundances can be used for dating certain galena samples. A possible objection to the proposed method is that the mathematical formulas used will not be correct if the galenas used by Collins, Russell, and Farquhar for the original calibration have not been correctly dated. The purpose of this note is to demonstrate that common lead abundance-time expressions can be obtained without the use of dated samples.