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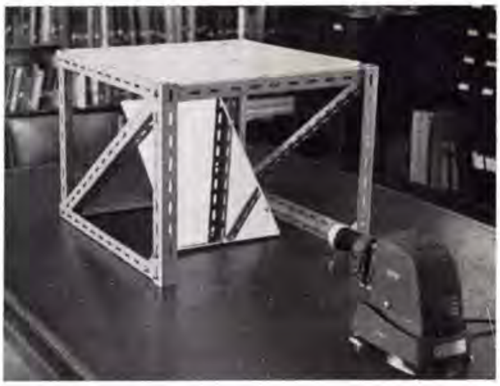

Fig. 1. A 35-mm projector is directed toward a mirror where the image is reflected upward onto a horizontal translucent screen.

Monocular Mapping by Micro-Film

A low-cost map projector is useful for field offices where more elaborate equipment is not available.

(Abstract on next page)

Introduction

One of the simplest methods of producing a map is to provide basic control by mechanical slotted templets and to transfer the photographic detail by means of a vertical sketchmaster. To the forester or ecologist in the field, the method has the disadvantage of requiring considerable expenditure on equipment, which may be a major item of a small budget and thereafter the equipment may not be in continual use.

Frequently the area of immediate interest is covered by not more than about a dozen photographs. It is then relatively easy to prepare a base map to the required scale, but the transfer of detail remains a problem. If more than a few photographs are used, it may be possible to have the slotted templets cut on contract and forwarded to the field station. Often large organizations have a central mapping unit, which includes a slotted templet cutter.

The object of the present study is to determine the precision likely to be obtained in transferring detail when using single 35-mm transparencies of single aerial photographs, to compare the results with a standard reflecting projector and a vertical sketchmaster, and to develop a suitable technique for monocular mapping from transparencies.

Materials and Methods

In all studies an Exacta Varex IIc, $f/2.8$, 35-mm camera was used for taking color transparencies with Kodachrome II film. Later the positive transparency film was processed in the normal way by the Kodak laboratories. A spirit level was used for checking that the camera was in a horizontal plane when taking the transparency exposures. Two level readings were made at right angles to each other. The spirit level was also used to ensure that the aerial photograph was parallel to the camera plane. Side glare was eliminated by surrounding the setup with black velvet. Thirty-five millimeter color transparencies were preferred to black-and-white transparencies, as flight lines, control points, and important features can be separately marked in distinctive colors which reproduce clearly when projected. There is little difference in total cost between black and white and color transparencies. If required, forest types and plant communities

ABSTRACT: *A graphic enlarger is devised through the use of a 35-mm projector pointed toward a mirror inclided at 45° so as to bend the light upward onto the underside of a horizontal translucent screen. 35-mm color transparent photographs are first taken of aerial photographs or other materials annotated with colored pencil lines. The system is economical for map compilation following a radial-line plot, and is particularly applicable for small, infrequent jobs where more elaborate equipment may not be justified.*

may also be clearly delineated in distinctive colors before taking the transparencies. Colors to be preferred were observed to be red, blue, green, and orange.

An Aldis, $f/2.8$, 500-watt, fan-cooled 35-mm projector (Figure 1) was used to project the photographic detailed of the processed transparencies on to the map base. That the incident beam was perpendicular to the mapping surface can be checked by placing a mirror on the latter so that the light is reflected back towards its source. For the map base, both white cartridge paper and semi-transparent *Herculene* tracing film were used. In the case of the latter the projected transparency image was formed on a screen cut from polyethylene and the *Herculene* tracing film was then attached to the surface by Scotch tape prior to transferring the detail. By introducing a mirror into the projection system to bend the beam through 90°, it was possible to have the polyethylene screen in a horizontal position. Differences in scale between 2:1 and 1:2 were provided by varying the distance between the projector and the screen.

Two methods of study were adopted. In the first, transparencies were taken of selected photographs or their effective areas as described below. In the second method under control conditions of constant-relative-humidity, test patterns sere scribed on both 90-pound cartridge paper and Herculene, and then transparencies were taken of these test patterns.

The processed transparencies were projected back onto the test pattern at several scales (1:1.25, 1:1.5, 1:1.75, 1:2)* and examined for differences produced by the pattern and the transparency image not coinciding at all points. Each test pattern comprised five concentric circles of radii one inch to three inches and divided into four quadrants. The intersections of the quadrant lines and the circles provided twenty points for measuring the differences, if any, caused by the distortion of the transparency image.

In the first method, photographs at a nominal scale of 10,000 and with negligible tilt were selected of an area which had been covered by a large scale planimetric map. A Williamson camera and an Eagle IX 10-inch focal-length lens had been used for taking the photographs. It was judged that part of the city area would be the most satisfactory as the streets provided a network of easily identifiable points at a scale of 1:4800. Displacement was not a problem, as the terrain was level. On each photograph the principal point, the conjugate principal points, the flight line, and wing points were marked in purple ink. The wing points defined the effective area of the photograph. To provide a grid for reference, concentric circles were scribed outwards to the wing points using the principal point as center, and six radial lines were extended outwards to the outermost wing points. This provided a total of eight radial lines including lines to the two conjugate principal points. The intersection of the radial lines and circles provided 32 reference points.

Transparencies were than taken of both the entire photograph and the effective area of the same photograph. By comparison of the displacement of the same reference points on each photograph it was possible to evaluate the error (if any) introduced by lens distortion of the 35-mm camera and the projector. Once this possible source of error had been observed to be negligible, transparencies were taken only of the effective areas (see Results). As in normal monocular mapping from photographs, the radial displacement of images increased with increasing distance from the centre of the photograph. It will be appreciated that the effective area delineated on an aerial photograph is commonly easier to fit into a 35-mm frame than the square provided by a photograph.

* Scale refers to the ratio of the test pattern scale being photographed and the scale of the transparency projected onto the screen or onto the enlarged pattern.

A series of observations to determine the most suitable exposure time, in accordance with Weston lightmeter readings, indicated that the stop-number required to be increased by ½ when photographing the effective area of matt photographs and the full 9×9-inch format of glossary photographs in sunlight.

Results

Early in the photographic study, attention was focussed on the need to examine the dimensional stability of printing papers and papers used for the map base. The results are summarised in Table 1 for relative humidities of 30 per cent and 70 per cent for each paper measurements were made at right angles to each other, and were termed *x*- and *y*-movements according to whether the movement was along the *grain* or across the *grain*. All measurements were made to the nearest 0.01 inch. Samples. were examined of single weight and double weight photographic printing papers commonly used in Melbourne when printing aerial photographs, glazed paper as used in the city plan of this project, 90-lb and 116-lb off-set papers used for printed maps, commonly as the map base in Victoria, Polyethylene as used for test patterns in the study and tracing paper (Table 1). Movement is usually greater in the *x*-direction, glaze paper excepted. Single-weight photographic paper had less movement than double-weight paper.

When 35-mm transparencies (i.e., the first method) of an aerial photograph, and its effective area, were projected separately at a magnification of 1:1.25 and 1:2 onto city plans at two different scales, 13 to 15 control points out of the 32 on each transparency were observed not to coincide with the same points on the plans. Approximately half of the differences were radial but did not exceed 0.02 inch. In two observations at 1:1.25, the differences were between 0.02 and 0.03 inch. Scattered (i.e., non-radial) differences exceeded 0.02 inch in 16 observations, and were as large as 0.06 inch. At the 95 per cent probability, points within 3.5 inches of the photograph center, were located within 0.025 inch of their true position on the base map. Examination of the scattered differences suggested that these are probably due to map sheet movement across the grain and to movement in the photographic papers along the grain.

To ascertain whether these discrepancies resulted from the photographic projection techniques using 35 mm transparencies, or were inherent in paper movement of the original map or photographs, the patterns of concentric circles were projected directly onto similar concentric patterns at scales between 2:1 and 1:2 (i.e., the method the second). It was found in all cases that a perfect fit of the 20 points of the curve were obtained; and from this it was concluded that paper movement was the main cause of differences.

Table 1. Stability of Selected Papers

Type of paper	*Directional movement*	*Change per inch (R.H. 30% to 70%) (inches)*
Single weight photographic paper	*x* *y*	.005 0
Double weight photographic paper	*x* *y*	.007 .003
Glazed paper (plans)	*x* *y*	.001 .003
90lb. offset paper	*x* *y*	.004 .001
116lb. offset paper	*x* *y*	.003 .002
Tracing paper Polyethylene	*x* *y*	.016 .016

In addition to direct projection the bean light from the projector was turned through 90° before being incident on the test pattern using (i) a front-surfaced silvered mirror (ii) a 1/4-inch plate glass rear-surfaced mirror. Using the former, results similar to direct projection were obtained; but with the latter distortions up to 0.20 inch and 0.04 inch resulted at magnifications of 1:1.75 and 1:2, respectively, at 3 inches from the center point.

Finally, the test pattern scribed on Herculene at each scale was projected onto similar patterns scribed on the cartridge paper using a vertical sketchmaster and a standard reflecting projector at scales between 2:1 and 1:2 in the conventional manner set out in the respective instruction manuals. In the monocular projector, the Herculene pattern replaced the conventionl photograph and the cartridge paper pattern represented the map base. The reflecting projector provided results similar to the direct projection of the transparency, but the sketchmaster gave differences of up to 0.02 inch at 2 inches, and 0.03 inch at 3 inches from the center point of the circular pattern at a scale of 1:1.25. At the scale of 1:2, a difference of 0.04 inch was recorded at 3 inches from the center point! The center point of the pattern can be considered as corresponding to principal points of a photograph.

Conclusion

It was surprising that a higher degree of accuracy using test-patterns was attained than by the conventional sketchmaster. This suggests that for simple field mapping, the method developed and examined in this study should prove useful. There was no intention, however, in the study to evaluate the accuracy of the sketchmaster, but only to use the machine for a comparison of methods. In comparison with the sketchmasters examined, the transparencies-projection method provided a view of the entire effective area of a photograph, which may be an additional advantage.

A second interesting result accruing from the study of the test patterns is that errors introduced from using transparencies for mapping under controlled laboratory conditions may be less than errors inherent in some papers used in general mapping and arising from a change in humidity. Obviously, the movement in tracing paper is so large that it should not be used as a base for field sketch maps.

If a good quality camera, tripod, and projector are available, then the only purchase is a spirit level, and possibly a sheet of polyethylene. Even the purchase of a camera and accessories, including a close-up lens and light meter should be considerably less than the cost of a vertical sketchmaster (e.g., $350 or more). A reflecting projector is bulky and would probably cost $2000 or more. The micro-film method does, however, have the disadvantage of not using the photograph directly, and the copying position of the observer is not as confortable as with a sketch-master, or a reflecting projector unless a mirror is introduced into the projection system so as to provide a horizontal projection on the polyethylene surface.