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Anaglyphic stereograms – Preparation and viewing

Philip Gimbarzevsky

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Cover:

This anaglyphic stereogram was made from 1:60 000 black-and-white aerial photographs showing the confluence of the South Nahanni and Flat rivers in Nahanni National Park in the Northwest Territories (Prints 13-14, Roll A17428) (NTS 95-F/11).

A three-dimensional effect can be observed by viewing this anaglyph through the spectacles inside the back cover. The spectacles should be held such that the blue filter is on the left. Direction Mountain, between the two rivers, rises about 400 m above water level.

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Abstract

A method is described for producing color stereograms from conventional black and white aerial photographs. It is based on the anaglyphic principle of binocular vision, in which the two components of a stereo-model are superimposed in complementary colors to provide a three-dimensional effect when viewed through corresponding color filters. The working procedures involve the alighment of stereoprints, exposure through complementary filters on color film and printing of superimposed images. Also described is the preparation of two-color viewing spectacles from a commercially available material.

Résumé

On décrit une méthode d'obtention de stéréogrammes en couleurs à partir de photographies aériennes traditionnelles en noir et blanc. La méthode se fonde sur le principe de l'anaglyphe par lequel les deux images d'un modèle sont superposés en couleurs complémentaires pour donner un effet de relief lorsqu'elles sont vues au travers de filtres en couleurs complémentaires. La réalisation comporte l'alignement des clichés stéréoscopiques, leur exposition à travers des filtres en couleurs complémentaires sur un film couleurs et le tirage des images superposées. On décrit aussi la préparation de lunettes deux couleurs à partir de matériaux vendus dans le commerce.

Introduction

Stereoscopy is a fundamental attribute of aerial photography that permits the recognition and precise measurement of objects on a three-dimensional visual model produced from two images. The stereoscopic effect results from the merging of dissimilar images of an object seen by each eye, causing the object to be perceived in its actual shape and to assume a relief appearance (Wright 1954).

Three-dimensional viewing has many practical applications in photogrammetry and air photo analysis. Stereograms are particularly valuable in such fields as terrain analysis, resource survey, or the training of photointerpreters.

Such stereograms may be presented as conventional (mounted) stereograms or as anaglyphs. Conventional stereograms are made from black-and-white or color stereoscopic prints, properly oriented and permanently mounted for viewing through a folding stereoscope. Anaglyphs are stereograms in which two views of a black-and-white stereoscopic pair are superimposed in complementary colors (usually red and blue-green) and viewed through corresponding color filters. This superimposition permits the viewing of the entire area of a stereoscopic pair on a single print or slide. Also, anyone with binocular vision can perceive a three-dimensional effect without any previous training in stereoscopy.

Although conventional stereograms are a regular part of the technical literature on photo interpretation, anaglyphs are not as common. Because of the rather complicated color processing involved in their preparation, the use of anaglyphic prints was for a long time limited to an occasional two-color plate in some textbooks to emphasize the value of stereoscopy in topographic mapping and forest surveys (Breed *et al.* 1938; Rubner 1942), or in commercial brochures to advertise stereoscopic instruments or services. Interest in anaglyphs was revived in the 1950s. With the advances in color processing technology, several experiments were conducted in Europe and the United States to develop less expensive techniques for producing anaglyphic prints, which would permit their widespread use as a photointerpretation tool.

Anaglyphic stereograms are still considered special illustrations and are produced mainly for technical reports intended for limited circulation. In many cases, for example in the description of regional landforms (MacLean 1973), integrated survey of biophysical resources, or as visual aids in photo interpretation (Gimbarzevsky 1977, 1978; Gimbarzevsky *et al.* 1979), anaglyphs have been found superior to conventional stereograms.

This report describes a simplified "in house" method for preparation of anaglyphic stereograms and the color spectacles for three-dimensional viewing of anaglyphs using widely available equipment and materials.

Historical background

Appreciation of the ability of human vision to see in three dimensions is not new. The Greek mathematician Euclid (300 BC) knew that the merger of the dissimilar images of a sphere or globe seen by each eye caused the sphere to be perceived as round and assume a relief appearance. Leonardo da Vinci (MacLeish 1977), recognized that the reason his masterpieces never showed a relief equal to that of natural objects was the dissimilarity of images seen by each eye.

This physio-psychological phenomenon of relief afforded by binocular vision led to further investigations and inventions of means for three dimensional viewing: a reflective stereoscope invented by Wheatstone in 1838, a refractive stereoscope by Brewster in 1844, a twin lens stereoscopic camera by Brewster and Quinet in 1847, and in 1853 the anaglyphic system (Rollman 1853; D'Almeida 1858). The anaglyphic system was incorporated into the design of optical instruments for plotting from aerial photographs. In 1917, a patent for the stereoscopic projection by the anaglyph method was issued to Ernermann (Gruber 1932). Anaglyphic prints were often used as illustrations in German and French scientific papers, textbooks, and in pamphlets describing the use of photogrammetric instruments. The first known commercial use of anaglyphs in the United States of America was a typographic advertisement in the December 22, 1860 issue of Harper's Weekly.

With the increased use of aerial photography for photo interpretation and mapping, the interest in anaglyphs was revived in the 1930s and 1940s. German technical literature of that period covers various aspects of this system such as the production of anaglyphic stereograms (Martin 1934), the mathematical derivations of constructed anaglyphs (Graf 1941), application of the anaglyphic principle in the rectification of aerial photographs (Cziszar 1942), or use of anaglyphic prints for presentation of three-dimensional terrain features in the preparation of stereo-mosaics (Brucklacher 1950; Burkhard 1950).

General principles of anaglyphic viewing

To obtain a three-dimensional effect, images must be separated so that one of the photographs in a stereo-pair is visible to one eye only and the other is visible to the other eye. This separation may be achieved by simply placing a piece of cardboard between the eyes, by the use of a stereoscope, or by viewing through color filters. The human eye is sensitive to light with wavelength from 400 to 720 millimicrons (mμ). Maximum sensitivity occurs at about 560 mμ, separating the red (over 560 mμ) and the blue-green (400 to 560 mμ) spectral regions. By using two filters — one to cut off all light with a wavelength over 560 mμ and the other to cut off all light with a wavelength under 560 mμ — the two images of an anaglyph are separated into blue-green and red components. In practical application of this anaglyphic principle, a three-dimensional model is perceived when a stereoscopic pair of black-and-white photographs, printed or projected in two different colors (usually red and blue-green), is viewed by placing a corresponding filter over each eye. The image observed by each eye is fused with the image observed by the other eye to produce the optical illusion of three dimensions.

Preparation of anaglyphic stereograms

Previous Work

Spurr (1952, 1953) described two methods for producing anaglyphic transparencies using subtractive three-color film, which was commercially available at that time and the No. 21 (monobromofluoresceine) and No. 39 (duplicating) filters as both exposing and viewing filters. In the first method a standard copying camera was used to register the two components of a stereo-pair on the copy holder and successively the left-view and the right-view images through their respective filters, on the same sheet of film. In the second method, the left-view and the right-view images were exposed simultaneously, each through its respective filter, in superimposition on a single sheet of color film. This method employed a standard camera and an optical device which, by means of a split beam mirror and a total reflecting mirror, superimposed the two images at the film plane.

Kasper (undated) described the production of anaglyphs on Agfa anaglyphic paper. This double-coated color printing paper for the complementary orange-red and cyan-green colors was exposed through the Agfa Foil No. 8 (red) and Agfa Foil No. 562 (cyan-green) complementary filters.

Kodak Linagraph 705 paper was also used for anaglyphs (Kodak - undated) by exposing stereo-negatives through complementary Wratten filters (No. 34 and 12). This special product was manufactured by Eastman Kodak in the 1960s but was discontinued in 1974.

Theis (1959) used a stereo plotting instrument (the Bausch and Lomb Multiplex plotter) to record the projected anaglyphic stereo model directly on a color film. Good quality anaglyphs were obtained by making separate exposures for each projector on orthochromatic topo-base film placed 340 mm under the oriented model. The individual pieces of film were oriented properly by means of registration marks, photographed using a half-tone contact screen, and printed by the rub-on process.

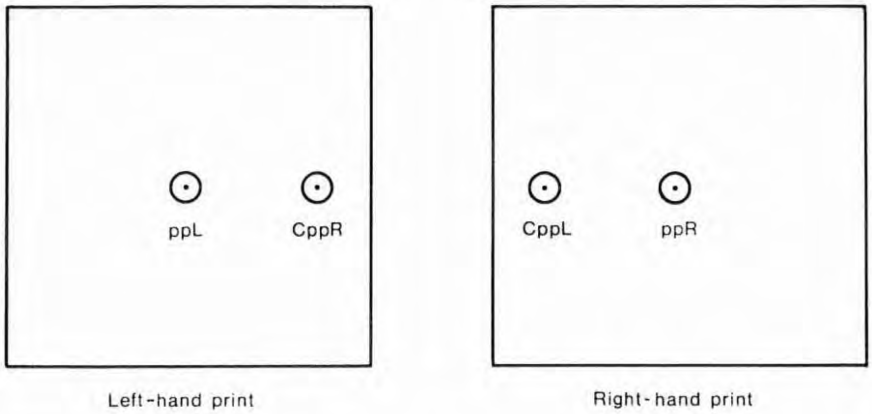

Figure 1. Orientation and marking of a stereo-pair.

More recently, Zeiss (1970) described the mounting of stereopairs for making the color offset plates, and provides information on printing inks and anaglyph spectacles.

In Canada, MacLean (1973) made anaglyphic prints from 35-mm color slides by double-exposing the stereoscopic pair of black-and-white photographs through red and blue filters. The enlarged anaglyphs were used in full-page illustrations in technical reports prepared by his consulting firm. In 1976, MacLean established International Anaglyphs Ltd.[1], probably the only commercial laboratory for the production of anaglyphic prints and slides in Canada.

Anaglyphs and viewing spectacles were prepared experimentally by the author in the early 1970s at the former Forest Management Institute in Ottawa. A large-format copying camera was used to expose the left and right black-and-white stereoscopic prints on separate sheets of Ektachrome film. The two positive transparencies were superimposed to form an anaglyph. The red and green viewing spectacles were constructed by placing cellophane pieces into a paper frame.

Working Procedures

Regardless of the method used for the construction of anaglyphs, the resulting print or transparency is basically a superimposition of the two components of a stereo-model registered in two complementary colors. This method involves three steps: a) alignment of stereo-pairs; b) exposure through complementary filters on color film; and c) film processing and printing.

a. **Alignment of stereo-pairs.**

1. Select good quality, high contrast black-and-white stereoscopic prints (the stereo pair).

2. Mark principal points (pp) on the right (ppR) and left (ppL) stereo components. (The principal point is the exact centre of the photo, corresponding to the optical axis of the camera.)

3. Using a lens stereoscope, transfer the principal point from the right-hand photograph (ppR) to the left-hand print. The resulting point on the left-hand print is (CppR). Repeat the procedure for the left-hand principal point (ppL). (Figure 1).

4. Place both prints on a 30-x 50-cm flat surface such as a piece of cardboard or strong plastic.

5. Tape the left-hand edge of the left-hand print with masking tape near the left-hand outer edge of the cardboard mak-

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[1] 5435 Alderly Road, Victoria, B.C., V84 IX9

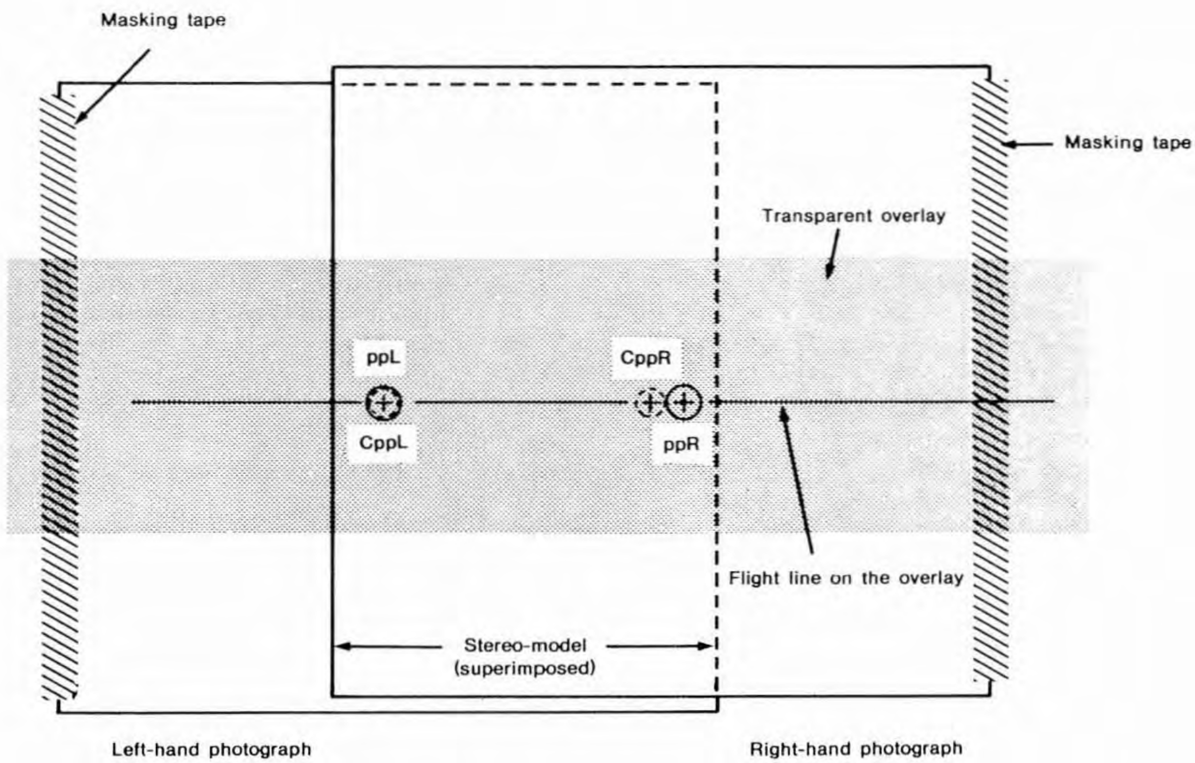


Figure 2. Orientation and mounting of stereoscopic prints.

ing a hinge-like connection which will allow the print to be turned left like a book page without disturbing the alignment (Figure 2).

6. Attach a transparent overlay of clear acetate, about 10 cm wide and 30 cm long over the left-hand print. Tape the left hand edge of the transparent overlay to the cardboard.

7. Draw a line on the transparent overlay joining the principal point (ppL) and the point transferred from the right-hand print (CppR). Extend this line some 15 cm to the right of CppR.

8. Mark on the overlay the exact location of the two points ppL and CppR.

9. Place the right hand print under the overlay such that i) the point CppL (on the right hand print) coincides with the position of ppL (marked on the overlay), and ii) the points CppL and ppR (on the right-hand print) and the point ppL (as marked on the transparent overlay) lie in the same straight line.

10. Without moving the right-hand print, tape the right-hand edge of the right-hand print to the cardboard, making a hinge-like connection as in step 5.

11. Mark on the overlay the exact location of ppR. There will be a distance of several millimetres between this new point and the location of the point CppR on the overlay marked previously from the left-hand print (Figure 2). This distance between the principal and the conjugate principal points indicates the required displacement of the superimposed anaglyphic model.

12. Remove the acetate overlay.

b. **Exposure through complementary filters.**

The following equipment is required:

- a camera with a provision for making double exposure on the same frame without advancing the film
- color film (negative or positive)
- red and blue filters (may be made from the same material to be used for making viewing spectacles — see page 12)
- copying stand (or tripod)
- adequate illumination

1. Attach the camera to the vertical column of the copying stand (or tripod).
2. Place the cardboard with two prints on the copying stand base (or on the wall facing the tripod mounted camera).
3. Align the right-hand print and the camera to photograph the portion of the right-hand print which overlaps the left-hand print (the stereo component).

Note: It is important that the prints and the camera not be moved until both exposures have been made.

4. Before attaching the **red** filter over the camera lens, adjust the camera for focus and sharpness.
5. After attaching the **red** filter over the camera lens, determine and set the required f-stop and exposure time.
6. Make the first exposure. To prevent any accidental disturbance of the camera the use of a cable release for the shutter is recommended.
7. Remove the red filter and cock the shutter **without advancing the film**.
8. Flip the right-hand print (to the right) to uncover the left-hand component of the stereo-pair.
9. After attaching the **blue** filter, determine and set the required stop and exposure time.
10. Make the second exposure and advance the film.

In the initial stages, some experimentation will be required to determine the best settings and illumination. The same stereo model may be photographed several times keeping notes on the settings used in each exposure for reference.

c. **Film processing and printing.**

Color film is most economically processed by a reputable commercial laboratory. The selection of color film depends often on the type of the camera. Both color negative and color positive films give good results. The advantage of color negative film is that it is less expensive, and may be processed in a relatively short time, providing negatives and color prints.

Examples of two single exposures of a stereo model through a blue and red filter are shown in Figure 3. When placed side by side, the two prints resemble a conventional stereogram and may be viewed under a lens stereoscope. Kodak color negative film was used in a 35-mm single lens reflex camera. Because the exposure was done through the red (right) and blue (left) filters, both prints, which are copies of black and white aerial photographs, show a slight coloration. The same stereo-model with a superimposed left and right stereo-components is shown in Figure 4. When viewed with complementary color spectacles, made from the same material that was used for filters to make a double exposure, a similar stereo-effect is observed as in stereogram on Figure 3.

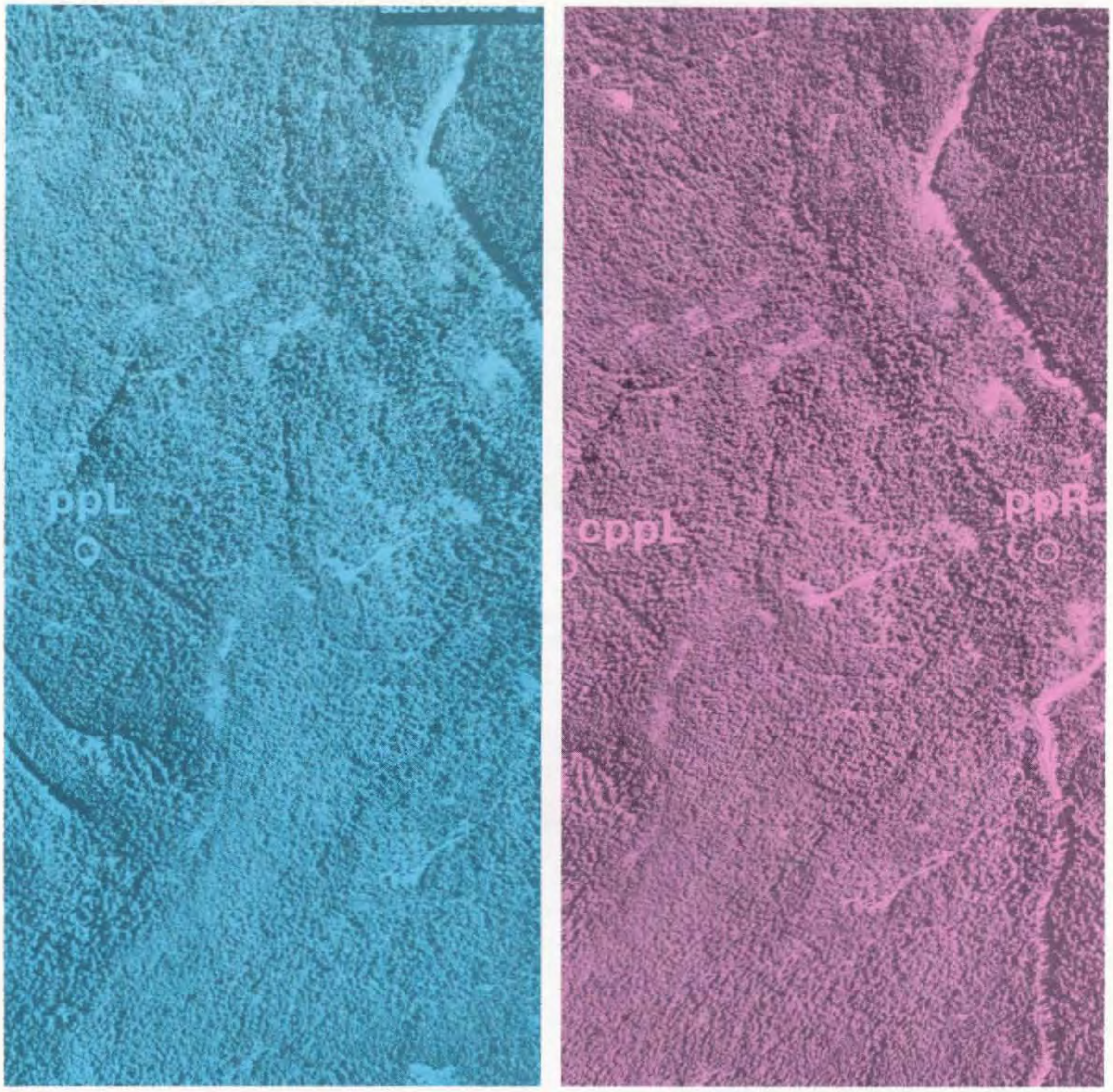
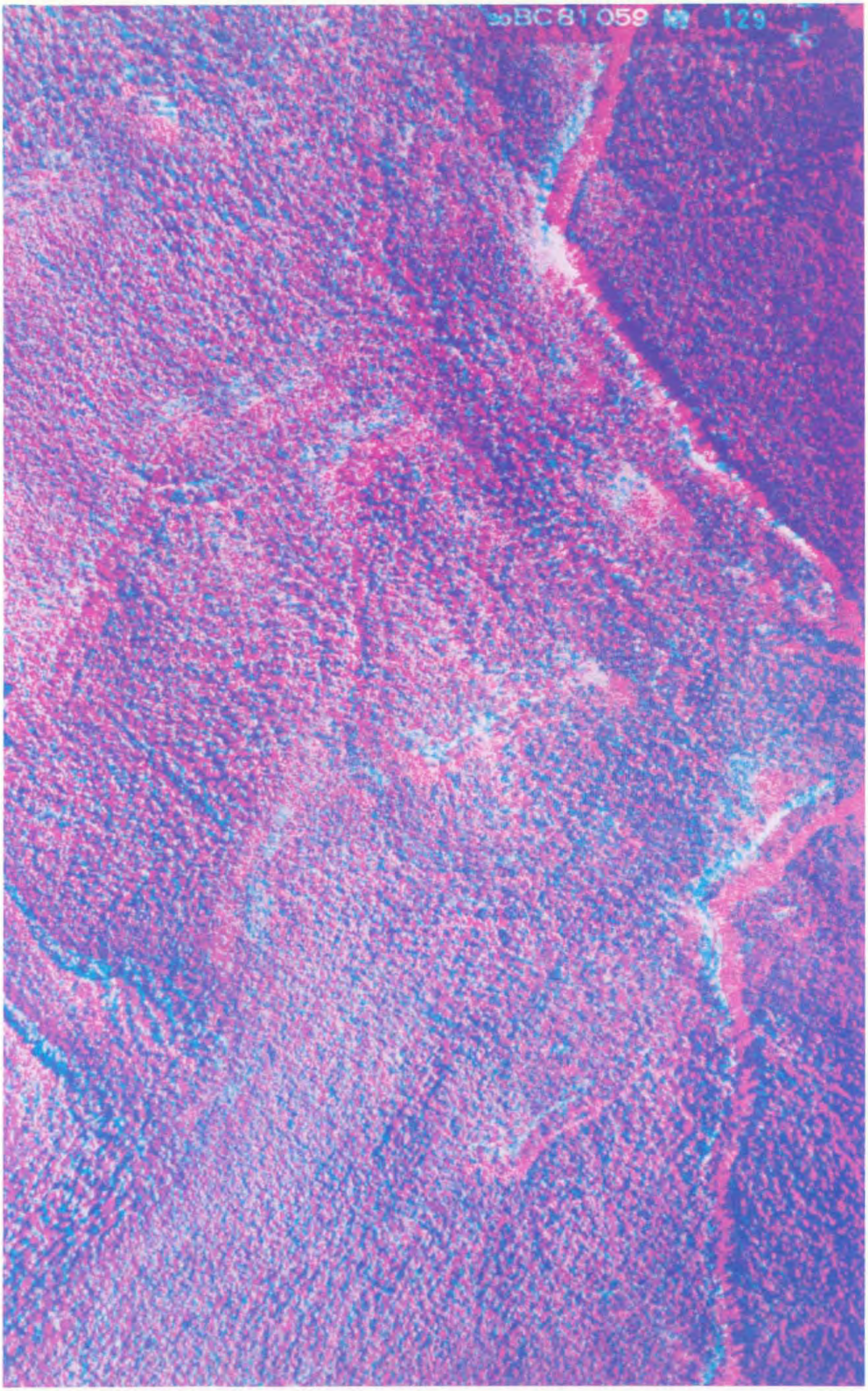


Figure 3. A Conventional Stereogram

A stereo-pair of black-and-white prints exposed on separate frames of 35-mm color negative film through complementary color filters—blue (left) and red (right).

Figure 4. Anaglyphic Stereogram →

Two components of a stereo-model superimposed in two colors (blue and red) on a single frame of a 35-mm color negative film. A three-dimensional effect is observed when this anaglyph is viewed through complementary (blue and red over the left and right eye respectively) filters.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Preparation of Viewing Spectacles

The stereoscopic effect of an anaglyph may be perceived only by viewing through complementary color filters. The commercially available spectacles made of a high quality red and blue optical glass, such as the glasses used by the operators of stereo-plotting instruments, are ideal for the stereo viewing, but rather expensive. They may be substituted by inexpensive spectacles made of transparent plastic.

Material

For general use, the commercially available transparent red and blue (or green) cellophane foil, or "one thou" (0.001") thickness transparent vinyl, is suitable. The same material may be used for the exposure filters. To test if the materials will provide a proper color separation, join the red and blue (or green) transparent sheets and place them over a photographic print or a white paper. When superimposed, the two colors should completely obscure any detail on the print and the white paper underneath should look almost black.

Preparation

Depending on the thickness of the transparent material the following two methods may be used.

a) **Cellophane foil**

This transparent, strong and waterproof material is available in several colors in 50-cm-wide rolls or sheets. Because it is very thin, a paper frame is required to hold the color filters in place. If many spectacles are required, a special die could be made for production of spectacle frames. The red and blue-green filters are cut into 4-cm x 5-cm sections and then pasted into the paper frame, as illustrated in Figure 5.

b) **Transparent vinyl**

This material is also commercially available in plastic or hobby shops. It comes in several thicknesses and colors. The "one thou" (0.001") vinyl is quite strong and can be used without a frame. The spectacles may be made by simply joining red and blue pieces with plastic glue. This material provides a very good color separation and is recommended for the exposure and viewing filters. A sheet of this material (50.8 cm x 127 cm) costs about ten dollars and a pair of spectacles can be made for about 10¢. To make the viewing spectacles, the sheets are first cut into 6.5-cm-wide strips, these red and the blue strips are joined with vinyl bond glue, and cut into 4.5-cm-wide red-blue spectacles.

Quality control

The technique is simple and good anaglyphic prints or slides may be made at low cost. The quality of the resulting anaglyphs depends largely on the quality of the stereo-pairs of black-and-white photographs, alignment of the stereo-model, illumination, camera, exposure filters and viewing spectacles, color film, and printing technique.

The selected pair of black-and-white aerial photographs should be sharp and rich in contrast. Under-exposed or flat prints will give weak anaglyphs.

Particular attention should be paid to an accurate alignment of the stereoscopic pair. Principal points should be marked on the prints and on the transparent overlay with utmost precision, and these should be checked before and after taping them to the cardboard base.

Adequate illumination is required to obtain sharp and brilliant anaglyphic prints or slides. The required exposure time for daylight or flood lamp illumination should be measured through the lens with the color filter attached. If an electronic flash unit is used, it may be placed 1.5 — 2.0 m from the prints to be photographed, at a 45° angle, with the appropriate filter over the light source. However, the setting of the lens f-stop and exposure time should be determined by preliminary tests (MacLean, 1982).

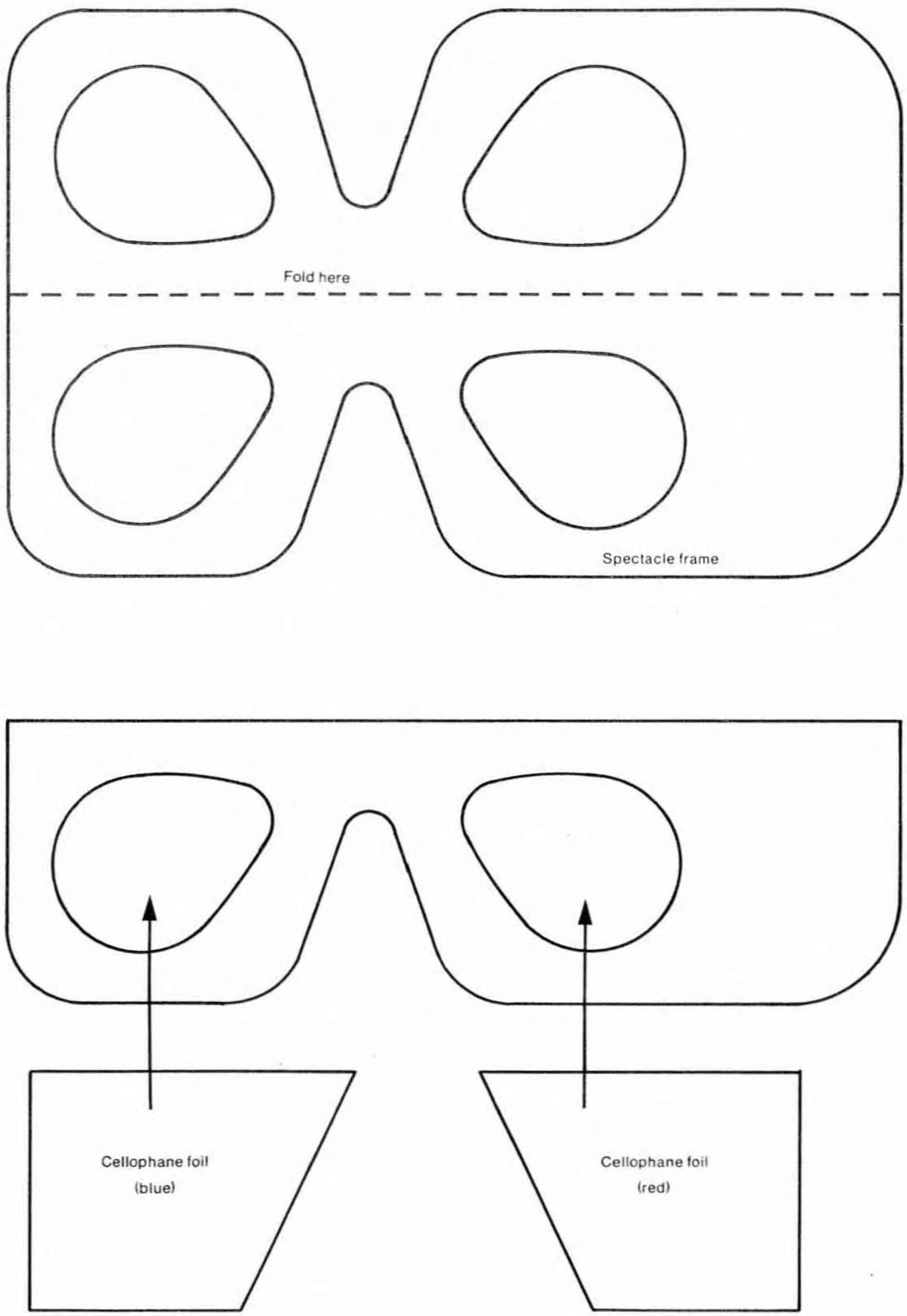

Figure 5. Template for viewing spectacles .

A 35-mm, or larger format camera, with a good quality lens and a provision for making double exposure on the same frame is required for the exposure of a stereo model. Larger format cameras, particularly older cameras, with a Compur-type shutter, are preferred because they provide a larger size negative and have a built-in provision for multiple exposure. The popular 35-mm single lens reflex cameras generally have a precise optical system which allows sharp focus, but, except for some older cameras, only the more expensive models can make the required multiple exposures. The anaglyph shown in Figure 4, for example, was exposed with a 35-mm Olympus OM-1. It has only a partial multiple exposure feature, which permits winding of the shutter without advancing the film by holding the rewind button. The anaglyph on the cover was made with an older, larger-format camera, equipped with a Compur shutter.

Color filters (red and blue or green) are required for both producing and for viewing anaglyphs. The Wratten No. 26 (red) and Wratten No. 55 (green) provide good results. Since the exposing and viewing filters should be identical, and the Wratten filters are too costly to be used in viewing spectacles, the transparent "one-thou" vinyl material is an inexpensive and adequate substitute. Such spectacles are inexpensive, unbreakable, and may be conveniently placed in an envelope at the back cover of a publication containing anaglyphic illustrations.

Both types of color film — color-negative (print film) and color positive (slide film) may be used for the production of anaglyphs (Kodak 1976). The first provides negatives, which can be enlarged to inexpensive prints of a desired size, (about 50¢ for a 10-cm x 15-cm print, as illustrated in Figure 4 and on the cover). The positive film provides 35-mm anaglyphic slides that may be projected on a screen for group viewing. The slides may be used to make color prints or color separation plates for publication.

References

D'Almeida, I. Ch. 1858. Nouvel Appareil Stereoscopique. Bulletin de la Société Française de Photographie, Paris.

Breed, Charles and George L. Hosmer, 1938. The Principles and Practice of Surveying. Vol. II. Higher Surveying. Fifth Edition. John Wiley & Sons, New York.

Brucklacher, W.A. 1950. Der Gefugte Raumbildplan, Bildmessung und Luttbildwesen, No. 1, 1950, Berlin.

Burkhard, R. 1950. Hohenmessung aus Luftbildanaglyphen, Allgemeine Vermessungsnachrichten, No. 3, 1950.

Cziszar, A. 1942. Entzerrung von Luftbildern Mittels der Anaglyphenpyramide, in Photogrammetria, No. 3. 1942.

Gimbarzevsky, P. 1977. Analysis and interpretation of aerial photographs in the evaluation of biophysical environment. Part II: Laboratory Workshop. The University of Calgary, Div. of Continuing Education. Calgary, Alberta.

Gimbarzevsky, P. 1978. Air Photo Analysis of landscape elements and patterns. Laboratory Seminar, Dept. of Geography, Queen's University, Kingston, Ont.

Gimbarzevsky, P., J.P. Peaker, P. Addison, and S. Talbot. 1979. Nahanni National Park, NWT. — Integrated Survey of biophysical resources, Volume 3: Water Resources., Parks Canada, Prairie Region, Winnipeg, Manitoba.

Graf, u. 1941. Konstruirte Anaglyphen, Bildmessung und Luftbildwesen, No. 2, 1941.

Gruber, von O., 1932. (Editor) Photogrammetry, Collected Lectures and Essays, Translated from German original by G.T. McCaw and F.A. Cazalet, London, Chapman & Hall, Ltd.

Kasper, H. (undated) The Production of Stereoscopic Pictures on Agfa Anaglyphic Paper, Wild Heerbrugg Instruments, Switzerland.

Kodak (undated). Anaglyphic Paper - Linagraph 705.

Kodak. 1976. Kodak Data for aerial photography.

MacLeish, K. 1977. Leonardo da Vinci. A man for all ages. Natnl. Geogr. v. 153, No. 3.

MacLean, D.A. 1973. Landforms of Kluane National Park, Yukon. Report to Parks Advising Services, CWS. Thurber Consulting Ltd. Victoria, B.C..

MacLean, D.A. 1982. Personal communication.

Martin, G. 1934. Anaglyphes. Luftbild and Luftbildwesen, No. 10 (Periodical of the Hansa Luftbild Gmbtt., Berlin).

Rollmann, W.A. 1853. Poggendorf's annals., Stargard.

Rubner, K. 1942. Neudammer Forstliches Lehrbuch, II Band. Verlag J. Neumann, Neudamm, Germany.

Spurr, Stephen H., 1952. Three-Dimensional Prints from Color Film, Photogram. Eng., Vol. 18, December 1952.

Spurr, Stephen H., 1953. Color film for making anaglyphs from black and white prints. Photogram. Eng. Vol. 19.

Theis, Joseph B. 1959. The potentials of the photogrammetric anaglyph, Photogram. Engineering Vol. XXV, No. 4, September, 1959.

Wright, W.D. 1954. Stereoscopic Vision Applied to Photogrammetry, Photogrammetric Record. Vol. 1, No. 3, London, England.

Zeiss, 1970. Hinweise fur die Herstellung von Anaglyphen-Raumbildern, Carl Zeiss, Oberkochen, Bms/Glr/Frs/VIII/70.