J. Ph. Poley
Koninklijke/Shell Exploration and Production Research Lab. Rijswijk, The Netherlands

Contrast Enhancement in Photogeology by Selective Filtering

Suitable filtering is designed so that obscure color differences can be recognized as distinctive gray tones on black-and-white photographs.

Introduction

Although in an increasing number of papers it has been urged that color photography be used in photogeological work, the bulk of aerial reconnaissance is still dressed in the conventional black-and-white photography. One of the reasons why the advent of aerial exploration in color is only hesitantly welcomed is that photogeological interpretation of black-and-white prints or mosaics has become an established and highly sophisticated art. In several decades of practice during war and peace, photo-interpreters have assembled an impressive amount of systematic knowledge.

The introduction of aerial exploration in color as a standard reconnaissance procedure will require a vast amount of factual interpretational knowledge. The basis for this is being laid at the moment, for instance, by U. S. governmental services (Geological Survey, Coast & Geodetic Survey, Forest Service), which are actively busy assembling the necessary photographic material.

In the meantime, however, it is still possible to improve the traditional black-and-white armory somewhat further by adding to its discriminative capacity.

One of the drawbacks of black-and-white photography is that many different surface colors or color tones register in the same featureless gray tone. In those cases, the presence of surface differences does not manifest itself on the aerial photos, thus withholding useful information from the interpreter. The existence of these differences may indicate, nevertheless, geological or surface changes (for instance in rock type, mineral, ground-water level or vegetation) in which one may be, in fact, quite interested. This will in particular be true in open arid areas, where there are no vegetational clues for the interpreter.

It therefore seemed worth-while to investigate the possibility of making up somewhat for this deficiency. Laboratory experiments started in 1960 and experimental aerial trials have resulted in a reasonably successful filter technique for contrast enhancement. Some details of this investigation are reported in the following sections.

A certain gray tone in a black-and-white photograph is dependent on the distribution of the spectral reflectance intensity of the pictured spot (area) and the spectral sensitivity of the film.

For a certain type of film, the integrated reflection energy forms the incident energy that excites the sensitive emulsion. The main contribution to this energy results from the spectral range of largest reflectance, in other words, from the dominating color.

This means that those regions that show color-tone differences which are not too large, are bound to register in almost the same gray tone. This loss of information is only due to the fact that the existing differences in spectral reflectance intensity are not strong enough to register separately.

Our technique of enhancing gray contrasts is based on stressing these differences: a suitable filter rejects the main color, while the retained color differences may still register by applying an increased exposure time and aperture.

Comparison of these filtered photographs with normal black-and-white ones will indicate regions where the contrast has changed, thereby indicating regions of surface-color changes.

The principle of main-color rejection is one of the various possibilities for "wave length selective photographing" or, in the expression recently coined "spectrozonal photography." Interpretation of infrared aerial work already purposely used the difference in reflectance properties at visual and infrared wave lengths several decades ago; also the Kodak Camouflage Detection film has an infrared-sensitive emulsion layer.

ABSTRACT: *A technique has been developed that may provide better discrimination in those regions that normally register in rather even and featureless gray tones. This technique works on the principle of main-color rejection by suitable filtering.*

Differences in a certain surface-color tone in open areas may not be strong enough to register as distinctly different gray tones on the normal unfiltered black-and-white aerial photograph. Physically, such a shift in color tone means a spectral reflection that differs somewhat from that of the main color. If this main color is rejected by the use of a suitable filter, and the remaining color content can still be registered by increasing the exposure time and aperture, a black-and-white photograph will be obtained with a gray tone pattern that may differ considerably from that of the unfiltered photograph. Comparison of filtered and unfiltered photos may demonstrate these differences in contrast, thereby revealing important geological or surface changes.

Some results obtained in two experimental flights show the possibilities of this technique.

During the last few years, several other attempts to make use of contrast enhancement in the visual wave-length region have been published, all based upon the idea of selective photography, by use of a film-filter combination best suited to the intended application. See for instance references [1–5].

LABORATORY WORK

LABORATORY SET-UP

The spectral curves needed for the filter analysis have all been made on a Beckmann DK-1 spectrophotometer, covering the wave-length range between 3,000 and 8,000 Å.

A quantitative contrast measure was provided by making for each experiment a series of exposures of stepwise increasing exposure times, thus making for each case the entire gray-tone scale available. The ratio of those exposure times by which in two comparative cases the same gray tone was produced

$$C_{12} = E_1/E_2$$

may then serve as the gray-tone contrast value for a certain wave-length band. Comparison of this value for the filtered and unfiltered case gives the quantitative value of contrast change obtained by filtering.

Black-and-white recordings in the laboratory have been made on Kodak Panalure printing paper, the properties of which promised the best overall sensitivity over the entire visual spectrum.

LABORATORY EXPERIMENTS

The physics involved in the filter technique is best illustrated by the results of a series of laboratory experiments on three green colors which are visually very much alike.

The spectral transmission curves of these three greens are shown in Figure 1. From these it follows that the optimal contrast change may be expected from the use of a band-pass filter around 4550 Å. At that wave length, with the same amount of incident light for all three greens, the recorded transmitted intensity will vary from zero (sample "600") to values which are appreciably different for samples *G* and *P* respectively.

The experimental results confirm this expectation. Although it was not possible to create the "optimal" filter for this case, centering around 4550 Å, two adjacent filters already showed the contrast enhancement sufficiently convincingly.

Figure 2a shows the unfiltered gray scales

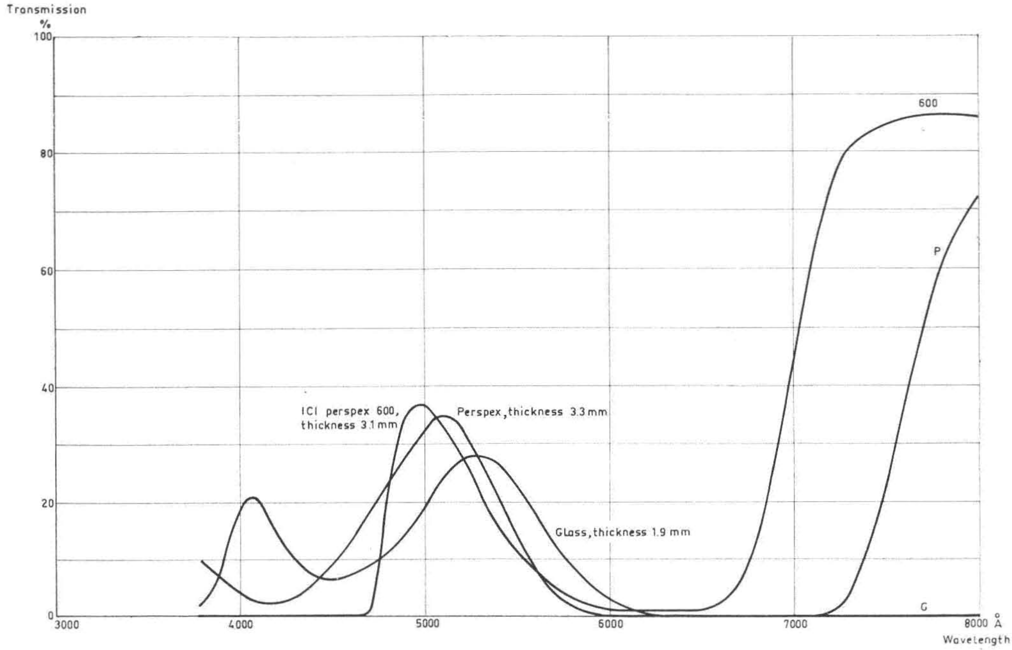


FIG. 1. Spectral transmission curves of three natural green colors.

for the three greens. It is seen that G and P yield the same gray tone, whereas "600" registers somewhat darker, with a contrast ratio of 1.7.

Application of a narrow band-pass filter M490AB, centering around 4900 Å, already results in marked differences among the three grays (Figure 2b), while a high-pass filter M440A, with cutoff wave length at 4400 Å, produces a complete contrast reversal, cutting out all the "600" intensity, and reversing the G/P ratio (Figure 2c).

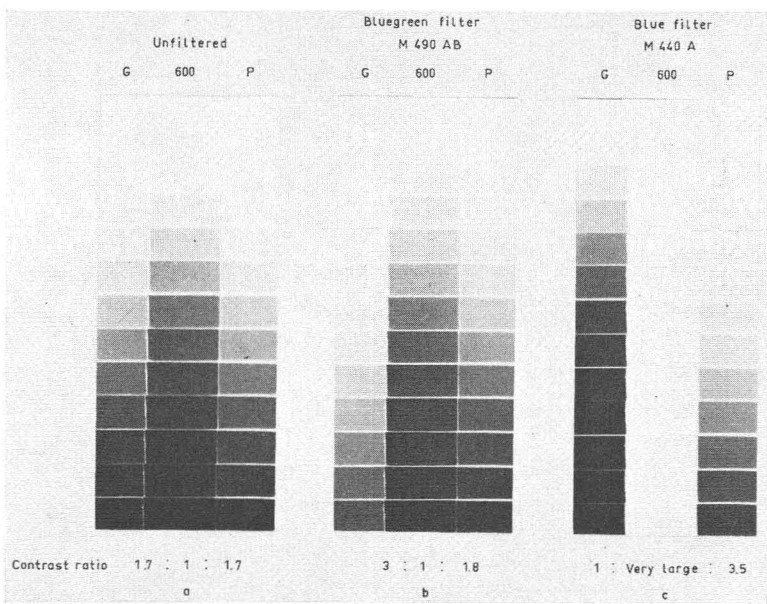


FIG. 2. Change in gray tone contrast by filtering for three natural green colors.

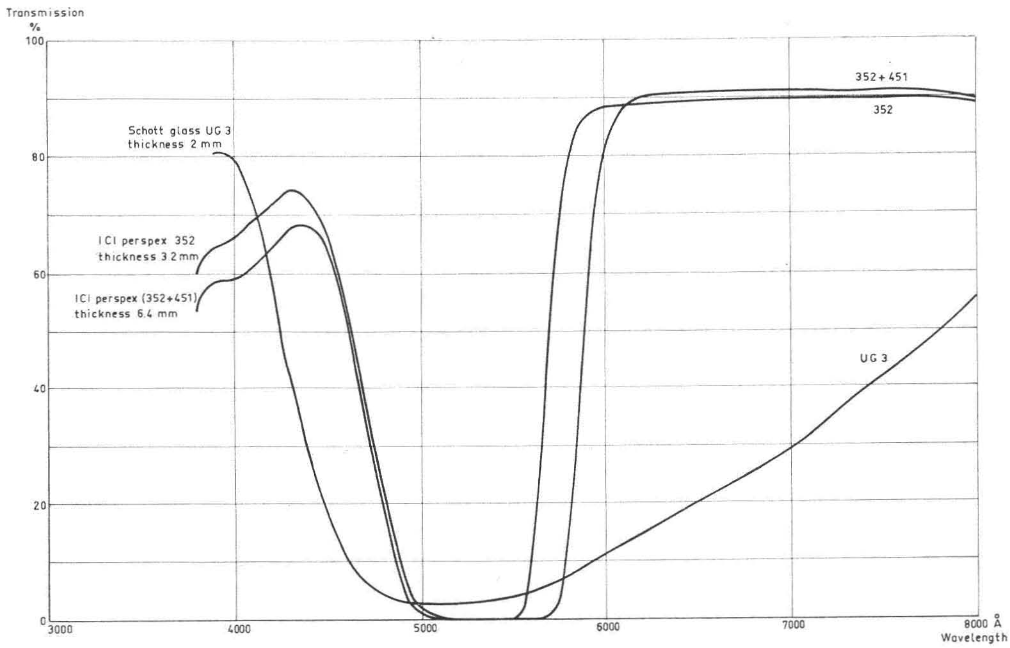


FIG. 3. Spectral transmission curves of three minus-green filters.

It is seen that by this type of filtering the main-color contribution is excluded, whereas the wave-length region of maximum difference is transmitted.

Rather extreme contrast changes, such as are obtainable in the laboratory experiments, are of course no measure for what can be expected in aerial photography, since the amount of light transmitted through these narrow-band "optimal" filters is much too small to be acceptable for aerial work.

FILTER DESIGN FOR AERIAL CAMERA APPLICATION

The design of a filter suitable for application on an aerial camera during routine operation must be tuned to the margin that the present aerial photographic equipment leaves in exposure times and apertures: a compromise will have to be found between the optimal filtering requirements as discussed above, and the still acceptable light absorption caused by that filter. In general, a filter (absorption) factor of more than 8 cannot be compensated by longer exposure time and larger aperture without losing sharpness of detail in the photograph.

This means that we have to modify our laboratory claims considerably. Nevertheless, a judicious choice both of the filter spectrum and the filter thickness to be applied, may still give satisfactory results.

As an example, the results may be taken of applying three rather light minus-green filters to the three greens mentioned before. The spectral transmission curves of these filters are given in Figure 3. The colors resulting upon filtering are strikingly different from the original ones, and also the corresponding gray tone contrast has changed (Figure 4).

Therefore, the procedure for rejection-filter design can be described as follows: after determining the dominating surface color (if possible its reflectance spectrogram), an inventory must be made of the possible rejection-filter materials (by a study of an available catalogue of filter spectrograms) and of the available film materials. After deciding upon a promising film/filter combination, laboratory experiments must determine the filter factor for various filter thicknesses. Thus, the best and still acceptable filter thickness can be chosen.

The results of two flight tests, using filters designed in this way, are given in the following section.

FLIGHT TESTS

The first example is taken from an experimental flight made over a flat green meadow area. A minus-green filter, designed with a filter factor 4 for recording on Gevaert Avi-

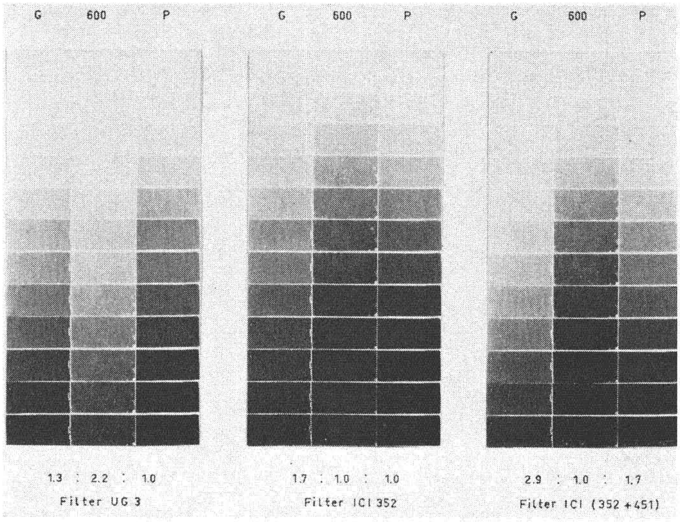


FIG. 4. Application of different minus-green filters to three natural green colors.

FIG. 5. Gray tone contrast enhancement over a green meadow region, obtained by minus-green filtering. Top: unfiltered. Bottom: filtered.

phot film, was supplied by our laboratory (filter material: ICI plastic 352).

The results turned out to be reasonably successful, when compared with the corresponding unfiltered black-and-white photos, taken on the same date the year before, as Figure 5 illustrates. Those fields with (visually) somewhat more yellow in their greens (which originally did not register as a different gray tone) now show up as the light parts, whereas the darker parts indicate those fields with grass types having a darker shade of green. In addition, the delineation of general landscape features, such as the older water courses, is much easier on the minus-green photo.

The second example is from an experimental filter flight during an aerial survey made over an area of yellowish-gray surface color.

Now, an overall gray surface is very unfavorable from the point of selective color filtering, since there is no predominant color in gray. The best that could be done in this case was to use a cyan filter (minus-yellow) to reject the yellow hue that appeared to be prevalent in the gray. Laboratory experiments on the absorption properties of various types of cyan-filter materials resulted in the construction of a filter using Gevaert C-100 material which achieved a substantial yellow rejection. The corresponding filter factor was about 4, for recording on Kodak Super XX Aerographic film.

The normal and filtered mosaics of the surveyed region are shown in Figure 6. A

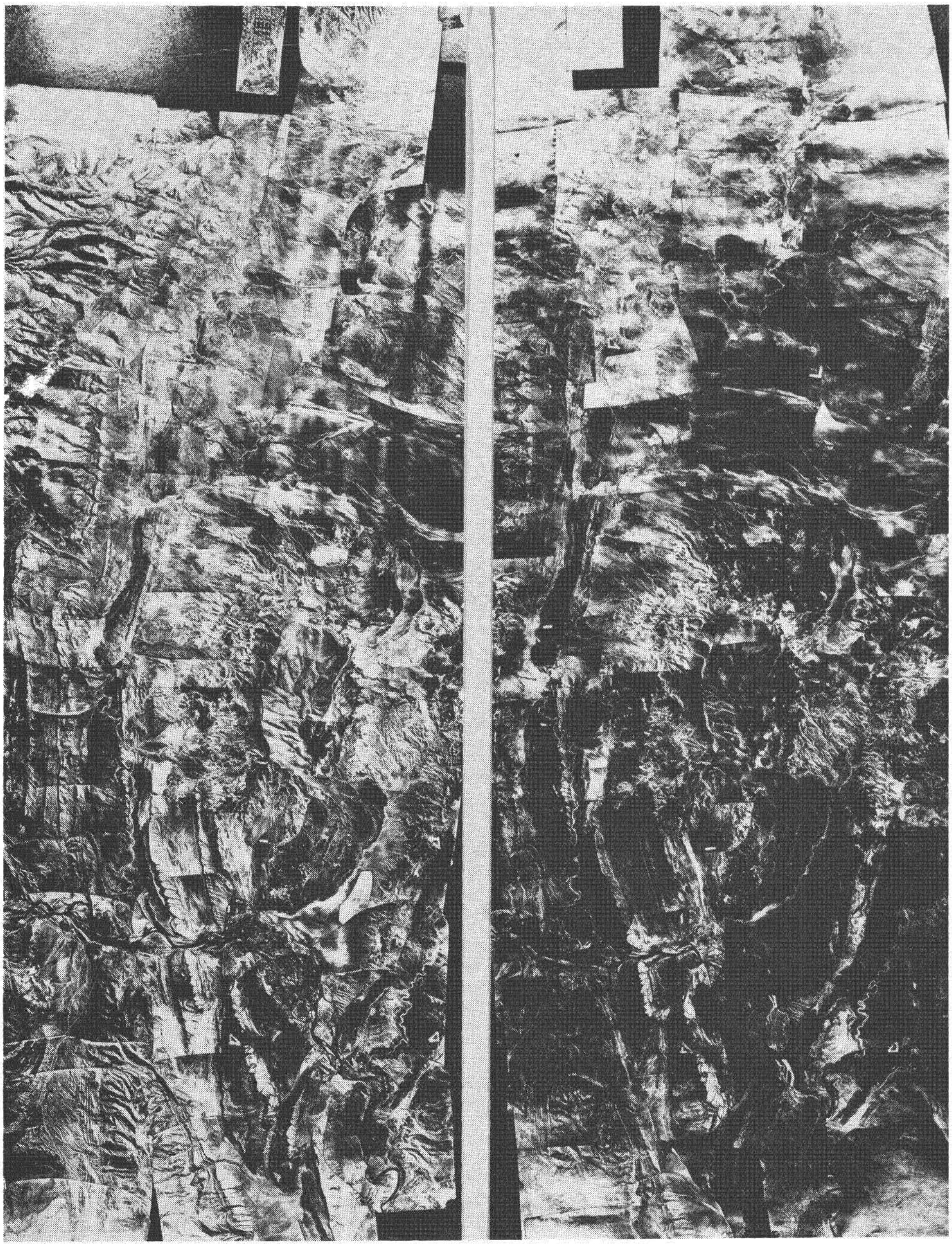
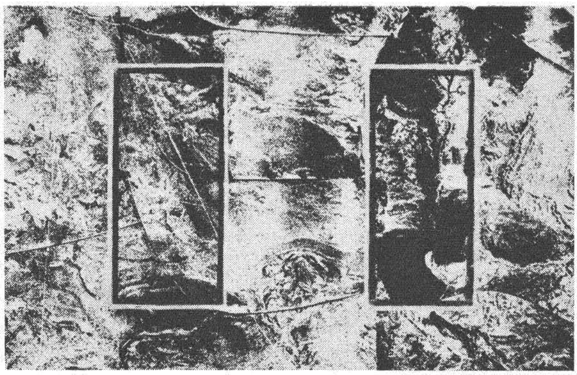
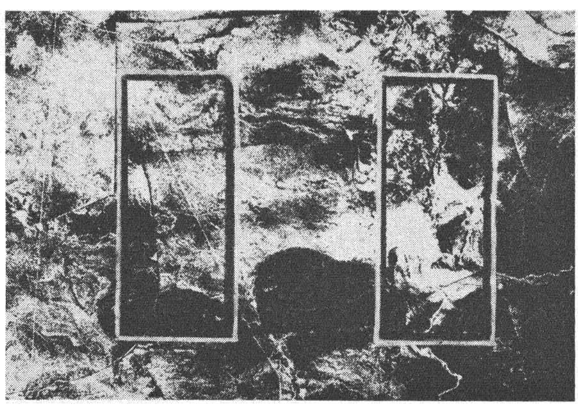


FIG. 6. Example of filter application during a regional survey.
Left: unfiltered. Right: filtered.

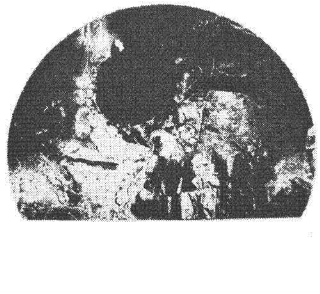


a. Unfiltered



b. Filtered

c. Unfiltered



d. Filtered

FIG. 7. Enlarged examples of regions of contrast change from Figure 6.

detailed study of these mosaics gave some interesting results, showing several locations of complete contrast reversal, and some regions where appreciable contrast enhancement was obtained.

Enlarged details of Figure 6 are given in Figure 7.

Conclusion

The experiments described here have shown that main-color rejection filtering may result in an appreciable contrast enhancement in otherwise rather featureless gray-tone regions on aerial black-and-white photographs. The surface-color changes distinguished in this way may be a useful additional source of surface information for the photo-interpreter.

The filter (which should preferably be mounted in a second camera working in parallel and synchronously with the normal aerial camera) should be designed separately for each survey so as to be best adapted to the main-surface color of the surveyed area.

Acknowledgements

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"Water Stealing" Plants

A new U. S. Department of the Interior Geological Survey publication describes a number of research projects, doubled in the past five years, and carried out by several Federal and State agencies in efforts to fight phreatophytes (free-at'-oh-fites)—a group of "water stealing" plants in the western States.

"In the arid regions of the western States," said T. W. Robinson, of the Geological Survey's Water Resources Division, and author of the report," more than 25 million acre-feet of water are wasted each year by the plants." The hydrologist said that "they grow where water is within easy reach of their roots—along river banks, in the flood plains of streams, and around reservoirs—using up badly-needed water. They pose a serious threat to farmers and ranchers in their quest for precious ground water."

Itek—Chicago Aerial

Franklin A. Lindsay, president of Itek Corporation, Lexington, Massachusetts, and Fred T. Sonne, president of Chicago Aerial Industries, Inc., announced today that tentative agreement has been reached on a plan providing for combining the businesses of the companies.

Terms of the plan call for the acquisition by Itek of all of Chicago Aerial Industries' net assets for a total consideration of $6,760,000 in cash and 28,000 shares of Itek common stock and for the dissolution of Chicago Aerial Industries, Inc. This is equivalent to $12.00 in cash and 1/20 of a share of Itek stock for each share of Chicago Aerial Industries' stock now outstanding. The plan is to be submitted to Chicago Aerial Industries' stockholders for their approval.

Mr. Lindsay stated that Chicago Aerial Industries is a leading company in the tactical reconnaissance field and its personnel and products are highly regarded by those in the industry. CAI's business will add a new line of products to those now manufactured by Itek and will further diversify Itek's activities in the military field.

He further stated that the plan calls for continuation of Chicago Aerial's business as a major operating division of Itek with headquarters located in Barrington, Illinois, present location of CAI's corporate offices.