*Progress in Spectral Reflectance Film-Filter Research Applicable to Engineering and Geologic Studies**

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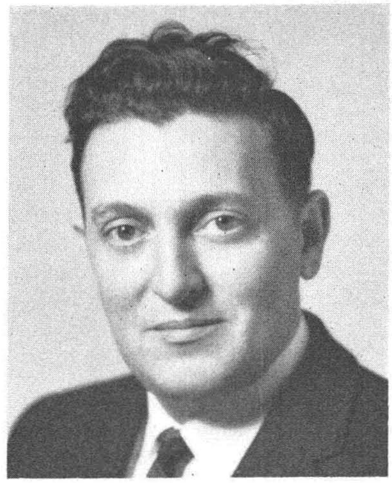

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BACKGROUND

THE use of aerial photo interpretation by our armed forces, during World War II and Korea, served to introduce many engineers and geologists to a potentially useful tool for their chosen professions. Following these conflicts, there was a rapid growth of small companies which offered a photo interpretation service to larger well established engineering and geologic firms. These companies flourished because the service was of a reconnaissance or general type, and the users had no precedent, other than their own experience with photo interpretation, by which to judge the quality of the resultant photo interpretation survey. As this wave of success grew, two factors brought it to a crest; from this peak it has tapered off to its present status. The first factor was the adoption of photo interpretation services by aerial photogrammetric mapping companies as an integral part of their mapping package. This forced the smaller service companies into offering more detailed interpretations in order to remain competitive. As this pressure grew, the claims of the smaller companies began to border on the impossible. Needless to say, as the accuracy of the photo surveys decreased so did the user's enthusiasm for the product. The outcome of this period of overselling interpretation was the establishment of a limit for applying the photo interpretation tool to engineering and geologic studies. In general, this limit was to utilize interpretation only as a reconnaissance tool to obtain only gross information such as: rock location, stream location, basic land forms, land use, etc.

RESEARCH

To the engineering and geologic interpreter it became obvious that if aerial photo interpretation was to become a more useful tool it must have the capability of collecting more accurate and detailed information than was presently possible. The improvement had to come from one or the other of the two basic components to this data collection system: 1) the aerial photograph or 2) the photo interpreter. Although the latter could undoubtedly stand considerable study, the variables of the former are more readily controllable and therefore offer greater possibility of rapid improvement for the system.

Basically, the aerial photograph is no more than a record of the reflectance properties of objects within a landscape. Standard exposure, processing, and printing procedures are used to obtain a correct photographic reproduction of the objects being photographed. This simply means that as many images as possible will be recorded having a brightness value proportional to the brightness of the objects on the ground. This results in the most realistic rendition of the greatest number of ground objects within the limits of the photographic system used. Photography of this type can be used very successfully on a

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reconnaissance basis where *all* imagery is of interest. However, if the interpretation function was the detection of specific imagery, the photographic exposure should be determined primarily from the reflectance properties of the ground objects themselves so that the resultant images would have maximum contrast with their backgrounds. This is the area of research in which Broadview Research Corporation has been active for the past three years.

This research has been sponsored by the U. S. Army Engineer Research and Development Laboratories, Fort Belvoir, Virginia. Although not performed for the specific purpose of improving engineering and geologic interpretation, many of the results of this research are applicable to this purpose.

A major part of the research studies was the collection of reflectance properties for various types of soils and vegetation found in widely separated geographic areas of North America. The aerial photography which was collected over these areas records the effect of the reflectance properties which were collected over the soils and vegetation. Since other imagery of interest to both engineers and geologists is also recorded, the photography can be used to illustrate the effects of utilizing specified film-filter combinations for engineering or geologic data extraction. Although specific reflectance properties may not have been collected over this imagery, it is possible to determine the object's gross reflectance properties by noting the contrast differences exhibited on the photography due to the use of filters having different transmittance characteristics. Therefore, even though complete data were not always available, the results have indicated that analysis of even the incomplete data is meaningful.

The basic theory of these studies is to increase the detectability of specific photographic imagery by using an aerial film-filter combination which is only sensitive to the spectral region over which the greatest reflectance difference occurs between an image and its background. This is done by using a spectrophotometer to record the reflectance properties of the objects of interest on the ground. Figure 1 is a reflectance curve for a flood plain gravel and a shrub which is found on the plain. It also shows the spectral region over which the greatest reflectance difference occurs between these two images. Figure 2 is a panchromatic photograph of the plain taken using a selective filter, and an infrared photograph of the plain taken using a filter which transmits over the range of maximum reflectance difference. On the panchromatic photograph, in the gravel bar areas, such as "*A*", it is virtually impossible to separate this particular shrub from the darker gravel areas or the shadow areas. On the infrared photograph, however, each of the shrubs is readily identifiable. It is also interesting to note how the old vehicle track (*VT*) within "*A*" is easily identified on the infrared but just barely visible on the panchromatic photograph. Since the track image is enhanced on the infrared film the reflectance difference between the track image and its background must be greater over the infrared filter range than the panchromatic filter range.

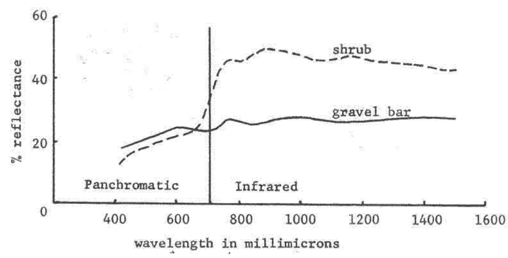

FIG. 1. Typical curves showing the reflectance properties of a soil and a vegetation sample.

Figure 2 is a typical example of how the use of a film-filter combination can enhance the detectability of specific imagery on black-and-white aerial photographs. The ultimate goal in using special film-filter combinations should not be merely to enhance the detectability of specific imagery, but should also be to identify specific images or conditions. Thus the interpreter's task would be to read the aerial photograph, rather than go through the normal interpretative deductions. The results of investigations to date are by no means completely positive or completely negative. However, effects on photo images caused by variables encountered in 1) the photographic system, 2) the spectrophotometric system, and 3) in nature, have been repeatedly observed to the point that considerable knowledge has been derived which indicates how they can best be utilized or avoided to improve the extraction of data from special purpose aerial photography. There is also evidence which suggests that extremely narrow spectral band photographs might prove to be an important aid in the process of detailed photo interpretation.

Two potential limitations have been encountered which must be overcome before it will be possible to determine whether the

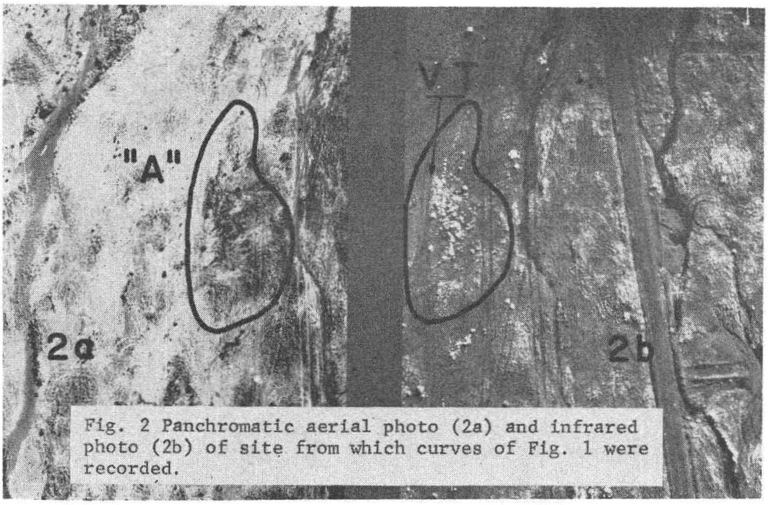

Fig. 2 Panchromatic aerial photo (2a) and infrared photo (2b) of site from which curves of Fig. 1 were recorded.

FIG. 2

ultimate goals can be attained. The first factor is the limitation of the minimum spectral reflectance band width which can be used with conventional aerial photographic techniques and materials. The aerial photographic system which was used on this research program was: 1) stock aerial film including a panchromatic film, an infrared film, and two color films; 2) a standard aerial camera with a 12-inch focal-length; 3) a Cessna 182 aircraft, flown at various altitudes; and 4) filters with filter factors through 10. With this system, experience showed that under the best conditions, no filter could be used effectively which had a filter factor greater than 8. In effect, this limited the spectral band width which could be used to a minimum value of between 50 and 70 millimicrons, provided the filter which was used had a high transmittance over the entire 50 to 70 millimicron band. Figure 3a is a typical example of the contrast effect which is obtained when using what is presently considered a narrow spectral band filter of this type. Comparing this to the broader band photograph 3b it can be seen that there is more detailed imagery present on 3a, yet the over-all print contrast is not as good as 3b, due to underexposure. A third filter was used to take photograph 3c. This filter differed from the filter used to obtain 3b by a very narrow spectral band, yet the increased contrast and detail at points over the entire photograph is quite evident as shown by the outlined areas. Since all three photographs came from the same negative roll, and then underwent the same processing and printing procedures and since greater detail is present on the underexposed narrow spectral band photograph and the photograph 3c which differs from 3b by a very narrow spectral band, the improved detail is attributed to better contrast by using narrower band filters. Therefore, it appears that the next logical step toward reaching either the partial goal of improving detection of specific images or the ultimate goal of image identification will require a study of more highly selective filters. Unfortunately, filters which have very narrow transmittance bands also have very high filter factors and cannot be utilized with conventional aerial photographic techniques and materials.

The second factor which presents additional limitations is a very complex subject, namely the effect of background reflectance conditions on interpretation of black and white photographs. The complexity of the subject stems primarily from the dynamic nature of ground object's reflectance properties. The reflectance property changes are primarily attributed to three factors: 1) vegetation growing cycle, 2) soil and/or rock composition, and 3) soil moisture. In addition to these reflectance changes, there is normally a very random distribution in nature of the ground objects which results in a heterogeneous background reflectance over the entire photograph. The result of this background condition is that the photo interpreter is confronted with a multitude of imagery, only part of which has any value to his interpretation. Being unable to distinguish between the valid and invalid imagery, his interpretation

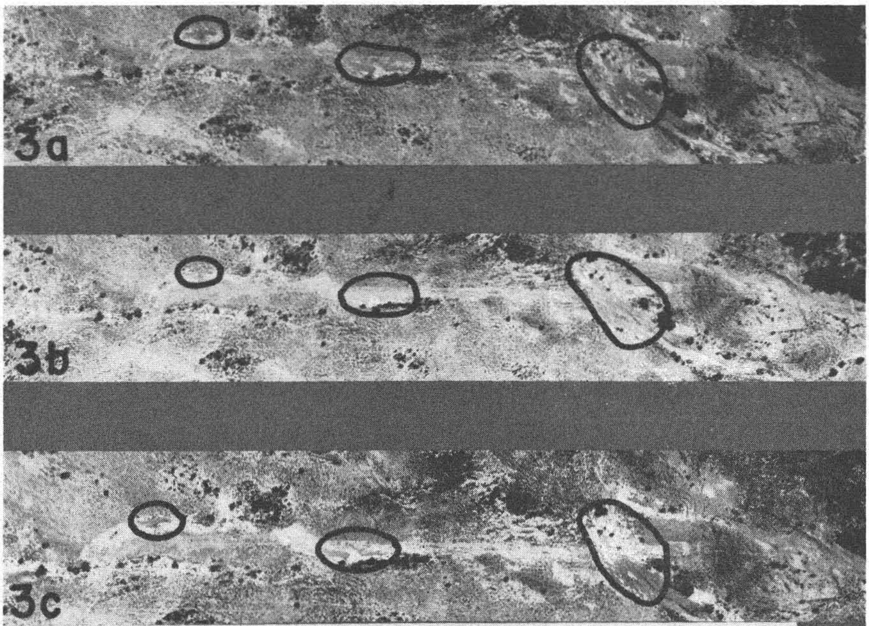

Fig. 3 Panchromatic aerial photos showing the effect on soil image delineations by selective filtering.

FIG. 3

becomes no more than an educated guess. For example, assume an interpreter is given Figure 4a and asked to determine how many large boulders are present on the surface of the gravel deposit. Even with stereo and optimum sun-angle this task would be comparable to looking for needles in a haystack. By photographing this deposit during a different stage of the vegetation's growing cycle, during a period of lower soil moisture, and using a different filter, background conditions can be improved. Photograph 4b illustrates how a more uniform background condition can be obtained for the individual reflectance domains such as "*A*", "*B*", "*C*", and "*D*". However, the improvement does not materially aid the interpreter in locating the surface boulders. For this particular case, a larger scale photograph, combined with the film-filter combination of photograph 4b should provide the photo interpreter with photography which is suitable for his analysis.

Finally, these studies have indicated that film-image density variations resulting from the combination of processing and printing can readily reduce the desired effects normally obtained through the use of a specific film filter combination. This, however, is beyond the scope of this paper and is mentioned only to point out the need for controls on this part of the data collection system.

Summary of Progress and an Example

In summarizing progress which has been made in spectral reflectance film-filter research, as it applies to engineering and geologic photo interpretation studies, two major factors should be noted.

First, by selecting presently available film-filter combinations to be flown at specific times under specific conditions it is possible to increase the amount of detailed information extractable by photo interpretation.

For example, assume that an engineering firm is commissioned to investigate a specific site for the location of a large industrial plant. Assume further that the nature of the industrial activity dictates that differential foundation settlement cannot be tolerated and that the basement level must have a low humidity at all times. Figure 5a is a conventional panchromatic aerial photograph of a possible site. An interpretation of this photograph shows the exposed rock contains many joints (*J*), that there are two small seepage channels (*SC*), and that there are a few possible springs (*S*) at the rear of the site. In general, from an analysis of this photograph, this site appears

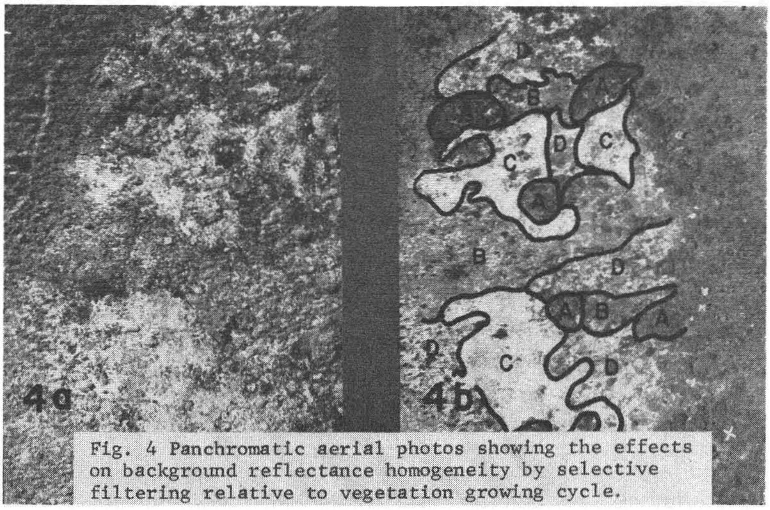

FIG. 4

worthy of a field investigation.

A field check of the site reveals that only two of the springs are active and that the channels are dry. One additional area is located which has a very damp surface. The joints in the exposed rock are all dry and the largest joint observed is less than six inches. Had an infrared film and filter combination been used at the same time the panchromatic photograph was taken, it would have given the same data as obtained by the field check. Figure 5b is such a photograph. The damp surface area is shown at "*A*" and the two active springs at (*AS*). If the joints and seepage channels were actively carrying ground water they would appear as dark images.

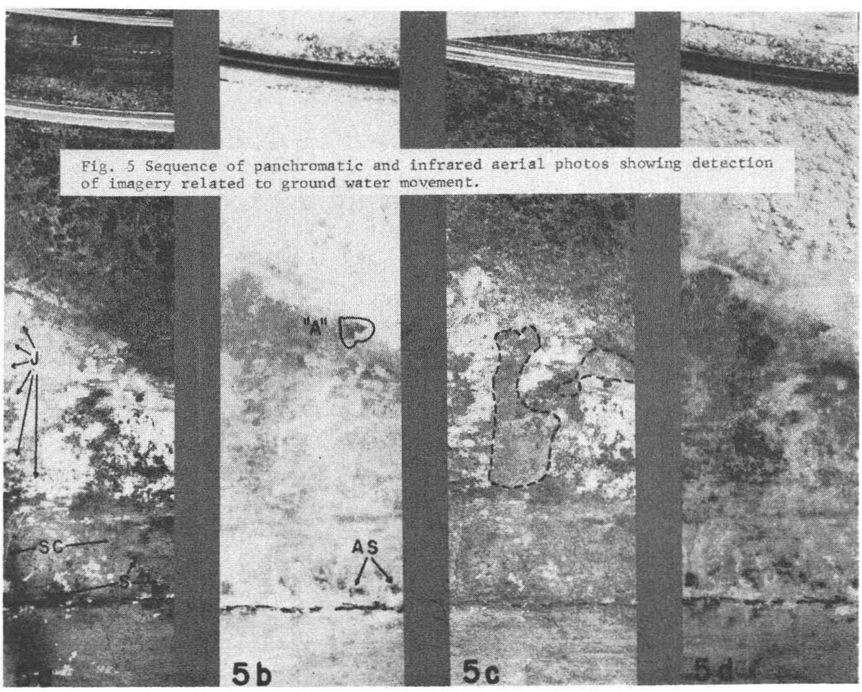

FIG. 5

Assume now that a week or so later it rained for a few days. Upon returning to the site the day after the rain there was little evidence of the rain on the surface. Figure 5c is a panchromatic photograph of the site area taken the day after the rain. Comparing this to the panchromatic photograph taken earlier (5a) it is obvious that to the camera's eye there has been a major change in the areas enclosed by the dotted lines. Since this change is not man-made it could only be attributed to a growth of vegetation or a change in reflectance due to moisture. Because of the short time interval involved and the recent rain, the change is definitely attributable to moisture. It is doubtful, however, that even the most experienced interpreter could deduce the significance of this dark area without having the comparison photograph of an earlier date (5a). Yet, if the interpreter were given an infrared film-filter combination photograph of this site, taken after the rain, he would immediately realize the severity of the subsurface drainage problem and the reason why this section of exposed rock appears dark on the later panchromatic photograph and not on the earlier photograph. Figure 5d is an infrared film-filter combination photograph taken the day after the rain. The black areas are locations where ground water movement is present, moisture content of the soil is very high, or surface water is present. It is interesting to note that the surface channels are light-toned on this print, indicating that they are dry. In order to have obtained the maximum amount of information regarding this site on a single photograph, camouflage detection film should have been used after the rain. Not only is the subsurface water condition detectable but the joint patterns are also present.

The second major factor to be noted is that there are indications that narrower reflectance band aerial photography than is presently possible may provide a means of increasing the quantity and quality of engineering and geologic data which can be extracted by photo interpretation. Until an aerial photographic system is developed to obtain this type of aerial photography, improvements can be obtained by using aerial photography taken specifically for interpretation tasks rather than merely using aerial photography taken for purposes of mapping or photography which can be inexpensively obtained from some organization which has libraries full of aerial photographic negatives. Expecting an interpreter to extract the whole story from a photograph which was not taken specifically to record the whole story is like trying to extract a cork from a bottle of wine with a jacknife. The best to be expected are bits and pieces.

Additive Color Photography and Projection for Military Photo Interpretation

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(*Abstract is on next page*)

INTRODUCTION

IN THE past the value of color aerial photography for photo reconnaissance has been limited by the nature of available color emulsion films. Except for special cases the additional information provided by color has not been believed to justify its use.

This paper describes a research program investigating the potential of additive color techniques for satisfying the requirements of aerial photography.[1] This effort is prompted

* 1532 Third St., Santa Monica, Calif.

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