

# Evaluation of Color Aerial Photography in Some Aspects of Highway Engineering

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To understand the usefulness of color aerial photography in its application to specific highway engineering problems, the State Highway Commission of Kansas has conducted a color aerial photography evaluation program. An evaluation criterion is established to guide the photographic interpreter and to emphasize the various facets of the photo interpretation techniques most instrumental in evaluating the various types of aerial photography for road condition surveys and material inventories. Procedures used in the program and a discussion of factors affecting the interpretation process used for each engineering project are presented. Most of the findings are based on the fact that the usefulness of color aerial photography is governed by the objectives of the investigations, the photographic interpretation pattern elements most instrumental in the photographic analysis, and the natural conditions existing in the area being investigated. In essence, these factors determine whether or not the color imagery or a change of color of the imagery provides additional information pertinent to the objectives of the investigation as opposed to the quality and quantity of information extracted from black-and-white photography.

•COLOR AERIAL photography provides the photographic interpreter with the additional dimension of color contrast and a more natural image to observe and study. However, the usefulness of such photography is not fully known in many fields of endeavor.

It is the purpose of this paper to evaluate color aerial photography for specific uses in the engineering field. The evaluation pertains to photography used on two specific engineering studies, materials inventories and road condition surveys. The former is associated with a statewide materials inventory program being made by the State Highway Commission of Kansas in cooperation with the U. S. Bureau of Public Roads. The manuscript of the color evaluation report has not been reviewed by the Bureau.

The road condition surveys are a part of a research project on the performance of concrete pavement being conducted by the Research Department of the State Highway Commission of Kansas. The use of color aerial photography as a phase of this study is being investigated by the Photogrammetry Section of the Commission. Special emphasis is being given to a particular type of surface deterioration associated with a surface staining of the pavement. Various sections of pavement are characterized by different stages of stain development; i.e., some sections have only a few stains that can be detected, whereas others have a large percentage of the surface covered with a stain associated with extensive pavement disintegration. The rate at which the staining spreads on the concrete surface, the pattern of stain development, and the stage of stain development at which initial distress is first detected are all factors that may be useful in determining the cause of such stains and, ultimately, the cause of the deterioration.

To learn more about stain "activity," aerial photography of selected sections of highway pavement will be studied periodically for stain appraisal and mapping purposes. In this paper, the term road condition survey refers to the proposed stain appraisal and mapping process.

To ascertain the most effective aerial film for road condition surveys, an evaluation program was conducted. The objective of the program was to determine the degree to which a given type of photography will increase the usefulness of a given pattern element. To complete the evaluation, the information derived from the pattern element must be appraised as to its significance to the objective of the project.

The general procedures used to evaluate the usefulness of color aerial photography on the two engineering studies are similar; however, the nature and magnitude of the problems encountered on each were quite different. The objectives of the road condition surveys are less extensive but more detailed in nature, and the ground conditions are uniform. The objectives of the materials inventories are larger in scope and the ground conditions are highly variable. Therefore, even though similar procedures are used, each evaluation is discussed separately.

To provide a consistent evaluation procedure throughout the investigation, an evaluation criterion was established. As each facet of the investigation was being completed, the following questions included in this criterion were answered:

1. What information is desired or what are the objectives of the investigation?
2. What area and, consequently, what type of ground conditions are being investigated?
3. How much and what type of ground information is available?
4. How instrumental is ground information in the photographic interpretation process in obtaining the objectives of the investigation?
5. What photographic interpretation clues are most essential or are used the most in the photo analysis?
6. Does color photography make any particular clue or pattern element more perceptible or meaningful to the objectives of the investigation?
7. Does color photography provide any additional clues that cannot be detected or used on black-and-white photography?
8. How much time is required to complete the photo analysis using the various types of aerial film?
9. What is the cost of each type of film?

On the basis of the answers of these questions, the usefulness or the effectiveness of each type of aerial photography used in this investigation is presented in the conclusions of this paper in terms of time required to complete the photographic interpretation, the quality and quantity of information derived from the interpretation process, the cost of the film, and other factors relevant to the objectives of the investigation.

## ROAD CONDITION SURVEYS

### Area of Investigation

The test areas in which this investigation took place were a 2-mi strip of a 4-lane highway in northeast Kansas, and two test strips in the Topeka area. The former was characterized by advance stage staining; the latter was characterized by initial stage stains. These areas were photographed by the State Highway Commission of Kansas using Kodak Aero Ektachrome film and Agfacolor Negative film at an approximate scale of 1:1,200. The conditions under which the two types of photography were taken were as uniform as possible; i.e., all photography was taken at nearly the same time of day under similar atmospheric conditions.

Color transparencies were obtained from the Kodak Aero Ektachrome film and both color and black-and-white prints were printed from the Agfacolor Negative film. The black-and-white photographs were printed on a single weight matte as well as a glossy photographic paper to evaluate both types of prints.

## Procedure

Initially, all stains were classified on the basis of information obtained through field work and the discernible stain characteristics observed on the aerial photography. The stain classification system was developed for identification purposes and to provide a basis of pavement panel classification. Subsequently, pavement panels were classified as to the type and number of stains in each panel that could be detected on aerial photography. It is beyond the scope of this paper to present a detailed description of the stain classification system.

Each test strip was mapped and appraised by using the various types of photography, the poorest quality photography being used first and the best quality last. The mapping indicated the number and length of pavement panels included in the test strips and each stain was classified according to the classification system adopted for this investigation. The test strips were then mapped in the field using the same mapping procedure and classification system. The field data were used to evaluate the results obtained from the interpretation of the aerial photography.

## Evaluation of Photography

When conducting road condition surveys, the interpreter has to associate the severity of the pavement disintegration with the discernible characteristics of the pavement stains. Initially, it was thought that a variation in stain color would be indicative of the severity of the pavement's condition. This was found to be true only to a limited extent. Early stage or initial stains (when the stains are first detectable) are very light compared to the more advanced stains. This is true not because of color or tone difference, but because of the degree to which small individual stained areas have merged or interconnected. The merging of the smaller spot stains ultimately governs the size of the area which the stain covers. For the most part, it is the degree of concentration of spot stains that governs the detectability of this particular highway stain on aerial photography. The stain, especially in the advanced stage of development, is fairly consistent in color and, consequently, is quite readily discernible on color prints.

Severity association is accomplished by noting stain width and number during the stain and panel classification. To classify the stains and panels accurately, the interpreter had to be able to distinguish significant highway stains from other highway discolorations. Typical discolorations discernible on aerial photography are finishing marks, "road scum," asphalt stains, areas ground off for leveling purposes, tire marks, and the concrete itself. Many of the discolorations have either a distinct color of their own or a very inconsistent color pattern. However, some are rendered in a tone similar to significant highway stains on black-and-white photography. Figure 1 illustrates finishing marks and a significant stain on black-and-white photographs. The insignificant finishing marks and the highway stain are rendered in nearly the same shade of gray on the black-and-white photography; however, a color change is observed when comparing the same two discolorations on color photography.

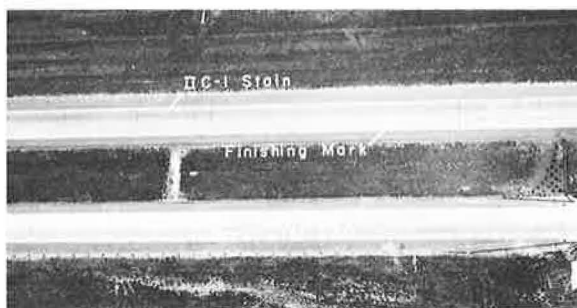


Figure 1. Black-and-white photograph portraying insignificant pavement finishing mark and significant highway stain.

In essence, the biggest problem of completing road condition surveys was differentiating between significant highway stains and insignificant highway discolorations. The effectiveness of the various types of film used in this study was measured in terms of number of significant stains detected compared to the number present and the number of insignificant stains erroneously mapped on a given section of pavement.

**Black-and-White Photography (Single Weight Matte Prints).**—Only 24 percent of the stains that were in the initial stage of development were detected when black-and-white single weight matte prints were being used for the photo analysis of the selected pavement test sections. On many occasions, the stains in the more advanced stage of development were difficult to detect; however, because of their larger size, approximately 50 percent of the advanced stage stains were detected and mapped accurately.

When mapping the advanced stage stains, little difficulty was encountered in differentiating between significant and insignificant stains; however, during the process of mapping initial stage stains, 62 insignificant stains were mistaken for significant stains.

The main defect of black-and-white photography printed on matte photographic paper for road condition survey purposes is poor resolution. All highway stains, regardless of their nature, were obliterated by the grain size of the photographic paper which contributed to the difficulties discussed previously.

**Black-and-White Photography (Glossy Prints).**—When compared with matte surfaced photographs, glossy prints greatly improve the resolution of black-and-white photography, resulting in a higher percentage of stain being detected. Approximately 57 percent of the initial stage stains and 95 percent of the advanced stage stains were detected when using the glossy prints. No insignificant stain was mistaken for a significant one when working with the advanced stage of stain development; however, 57 insignificant stains were recorded on pavement in the initial stage of staining.

The black-and-white glossy prints improve the detectability of all stains, significant and insignificant; however, the main difficulty encountered when using this type of photography is differentiating between these types when mapping pavement characterized by stain in the initial stage of development.

**Color Transparencies.**—When comparing the mapping results produced from black-and-white glossy prints with those obtained from color transparencies, a lower percentage of significant stains was detected, and a greater number of insignificant stains were erroneously mapped. When the initial stage stains were being mapped by use of the color transparencies, only 43 percent of the significant stains were detected, and 91 insignificant stains were mapped. Better mapping results were obtained from stains in the advanced stage. In all cases the color transparencies provided better results than the photography printed on single weight matte photographic paper.

Even though color transparencies provided the interpreter with color contrast and excellent resolution, several factors influenced the quality of the information extracted from the transparencies. The main factor detrimental to the interpretation process was the quality of the photography for road condition survey purposes. The Kodak Aero Ektachrome film exposure was based on the terrain adjacent to the highway and not on the light-colored concrete pavement. Consequently, the pavement was overexposed and the adjacent terrain was rendered in natural color. The pavement appeared to be washed out on the color transparencies. Much of the stain was not recorded on the film and some of the more conspicuous insignificant stain was mistaken for significant stain. This discrepancy was especially apparent on the pavement characterized by stain in the initial stage of development.

Better results could probably have been obtained if better equipment had been used to interpret the color transparencies. For example, a light table equipped with lights of different intensities and different colors would provide optimum conditions for the detection and evaluation of a given size and color of stain.

**Agfacolor Negative Film.**—Color prints proved to be far superior to any other type of photography in detecting and mapping initial stage stains. Approximately 84 percent of the initial stage stains were detected, and only 24 insignificant stains were erroneously recorded. When working with the advanced stage stains, the color prints proved to be no more effective than the black-and-white glossy prints; i.e., approximately 95 percent of the advanced stage stains were detected and few if any insignificant stains were erroneously mapped.

The color prints were of good quality. The areas adjacent to the highway pavement were slightly underexposed and good quality color prints for road condition survey purposes were obtained. The better photography was a result of experience gained from previous test photography.

## MATERIALS INVENTORIES

### Procedures

For the purpose of this investigation, three counties (Ellis, Mitchell and Brown) included in the current State Highway Commission of Kansas statewide county materials inventory program were selected as test areas. Each county has different geological conditions. Materials inventories were completed in all three counties using black-and-white photography printed from DuPont Cronar Safety Film at a scale of 1:24,000.

As each county was being investigated for the location of construction materials, areas providing typical problems encountered during the photo analysis of the county (approximately 10 percent of the area of the county or 90 sq mi) were selected to be photographed with color aerial photography. These areas were selected on the basis of the type of geological source beds present, amount of overburden, and other properties that may be peculiar to the specific area.

The selected areas in Ellis and Brown Counties were photographed with black-and-white photography (DuPont Cronar Safety film) and Kodak Aero Ektachrome film at a scale of 1:12,000. Black-and-white photographs were printed on single weight matte photographic paper from the Cronar Safety film, and color transparencies were developed from the Kodak Aero Ektachrome film. The same procedure was followed in Mitchell County; however, instead of using DuPont Cronar Safety film to obtain the larger scale black-and-white prints, Agfacolor Negative film was used. Black-and-white prints and a limited number of color prints of the area being investigated were made from the Agfacolor Negative film. The selected area in Mitchell County was also photographed using Kodak Aero Ektachrome film to obtain positive color transparencies. The photography used in each of the test counties was as follows:

Ellis and Brown Counties—DuPont Cronar Safety film, black-and-white single weight matte prints at scales of 1:12,000 and 1:24,000; and Kodak Aero Ektachrome film, color positive transparencies at a scale of 1:12,000.

Mitchell County—Agfacolor Negative film CN 17, black-and-white single weight matte prints and color prints at a scale of 1:12,000; DuPont Cronar Safety film, black-and-white single weight matte prints at a scale of 1:24,000; and Kodak Aero Ektachrome film, color positive transparencies at a scale of 1:12,000.

After the procurement of the evaluation photography, each test section of each selected county was analyzed using the black-and-white matte prints and the color photography. The results obtained from each type of photography were compared with the results of a ground investigation of these same areas (ground reconnaissance and exploratory drilling).

### Criteria

The usefulness of color aerial photography is best realized when the color of the image improves and increases the amount of information above that normally obtained from the tonal qualities of the black-and-white photography. The evaluation, therefore, requires a knowledge of not only the type of geology (ground conditions) and, consequently, the construction material source beds in an area, but also the pattern elements used to accomplish the interpretation. It must also be determined whether or not a color image improves the pattern element or elements to such an extent that an additional amount of pertinent information is obtained to justify the higher cost of the color aerial photography. To have a consistent evaluation from one county to another, the evaluation criterion set forth previously was followed.

The objectives of material inventory investigations are consistent throughout the evaluation program—namely, detecting, mapping and describing construction material



source beds in the counties being investigated. The ground conditions of the sites being investigated were generally known, and a review of the existing information added to the general knowledge of the area. Such information includes data obtained from material quality tests, geological publications and maps, and soil reports based on field work accomplished in the county to be investigated or in adjacent counties. Geological reports, preliminary soil surveys, and groundwater reports were also available for all three counties included in the evaluation program. Usually, when ground information is available and can be correlated to the natural features as detected on the aerial photographs, the photographic interpreter uses the information derived from the pattern elements to supplement the ground information or vice versa, depending on the availability of the ground information. Consequently, the degree to which the photo interpreter relies on the information obtained through the interpretation of pattern elements will vary with the amount and type of ground information available.

The cost of each type of photography used in the evaluation program is given in Table 1. The evaluation criterion is referred to and discussed in the separate county discussions and in the conclusions of this report.

### Evaluation of Photography

**Ellis County.**—The geology of Ellis County is characterized by interbedded shale and chalky limestones of Cretaceous Age capped in places by silt and fine sand of the Tertiary Age. Silt of the Pleistocene Age blankets most of the county.

A small quantity of poor quality chalky limestone can be produced from the strata of Cretaceous Age and a limited amount of poor quality fine sand and silt can be produced from the Tertiary beds. The main sources of construction material in Ellis County are the terraces of various ages located in the Smoky Hill and Saline River valleys.

The specific tasks used for evaluation purposes in the test area in Ellis County are as follows:

TABLE 1  
PHOTOGRAPHY COST

Film	Factor	Cost (\$)
DuPont Cronar Safety	Cost of roll ( $9\frac{1}{2} \times 230$ ft), approx. 300 frames	71.50
	Negative film	0.24 per exposure
	Paper and chemicals <sup>a</sup>	0.10 per print
	Aircraft and labor (avg.)	0.36 per print
		0.70 per print for negative and first set of prints
Kodak Ektachrome Aero	Cost of roll ( $9\frac{1}{2} \times 75$ ft), approx. 90 transparencies	126.00
	Color reversal negative film	1.40 per transparency
	Chemicals	0.36 per transparency
	Aircraft and labor (avg.)	0.46 per transparency
		2.21 per transparency
Agfacolor Negative CN 17	Cost of roll ( $9\frac{1}{2} \times 100$ ft), approx. 115 frames	152.50
	Film cost	1.33 per frame
	Chemicals	0.22 per frame
	Aircraft and labor	0.38 per frame
		1.93 per negative frame
	Color prints	
	On contract <sup>b</sup>	3.00 per print
		1.03 per negative
		4.93 per print and negative
	State Highway Commission lab.	
	Cost of paper	0.28 per print
	Labor and chemicals	0.80 per print
		1.08 per print
		1.93 per negative frame
		3.01 per print and negative
	Black-and-white prints	
	Labor, paper, chemicals	0.10 per print
		1.93 per negative frame
		2.03 per print and negative
	Color and black-and-white prints <sup>c</sup>	
	On contract	
	Agfacolor negative	1.93 per negative
	Color print	3.00 per print
	Black-and-white print	0.10 per print
		5.03
	State Highway Commission lab.	
	Agfacolor negative	1.93 per negative
	Color print	1.08 per print
	Black-and-white print	0.10 per print
		3.11

<sup>a</sup>Add \$0.02 per print if glossy prints are desired.

<sup>b</sup>At present all color prints are contracted; State Highway Commission of Kansas plans to print its own color prints on completion of proper facilities.

<sup>c</sup>If both color and black-and-white prints desired, cost of Agfacolor negative included only once.

1. Locating volcanic ash for mineral filler,
2. Differentiating between the Ogallala Formation (Tertiary Age) and the Ft. Hays limestone formation (Cretaceous Age) when both formations have a thin veneer of Pleistocene silt; and
3. Differentiating between different aged terraces (Pleistocene Age) containing different types of construction materials located in the Smoky Hill and Saline River valleys.

Ground information played a very important role in the materials inventory of Ellis County. The photo interpreter had a good knowledge of Ellis County geology before the interpretation process was started. Most of the material source beds were known and after the results of the available quality tests were correlated with the source beds, the quality of the material that could be produced from each source bed was also generally known.

Several different pattern elements were utilized in different areas for interpretation purposes. Volcanic ash deposits can be located by having some knowledge of the mode and time of deposition of the formation in which the ash is found; however, unless the ash is exposed, prospective sites can not be located using aerial photography. If the ash is exposed, a light colored band can usually be located. Volcanic ash deposits are unconsolidated and, consequently, do not form a distinctive ledge but blend into the relief of the surrounding terrain. Ash deposits are normally found in unconsolidated material. Even though Cretaceous bedrock has a similar color, the bedrock forms a distinctive ledge. Therefore, if the ash deposit is exposed, color imagery would not be required to differentiate between bedrock and the ash deposit. Ash deposits in Ellis County are rarely exposed, and if they are near the surface, they are discolored by the overlying silts and are not easily distinguishable on any type of aerial photography.

The Cretaceous limestone mapped in Ellis County was distinguished by a distinct tone pattern combined with a very distinctive topographic ledge and topographic position. The Ogallala Formation (Tertiary) was detected and mapped predominantly on the basis of topographic expression combined with a tone pattern peculiar to that formation.

Terraces of different ages were detected and mapped on the basis of topographic position, topographic expression, land use, and drainage characteristics. The first two pattern elements were utilized the most.

Color photography made the terrain easier to observe and more pleasant to study. Consequently, the elements used for interpretation were easier to analyze. This is especially true for interpreters with limited experience; however, although some additional information could be extracted from the color photography by virtue of the color images, it is generally conceded that the additional information would not alter or add enough to the materials inventory in Ellis County to justify the increase in cost. Figure 2 portrays the Fort Hays Limestone of the Cretaceous Age and Pleistocene terraces

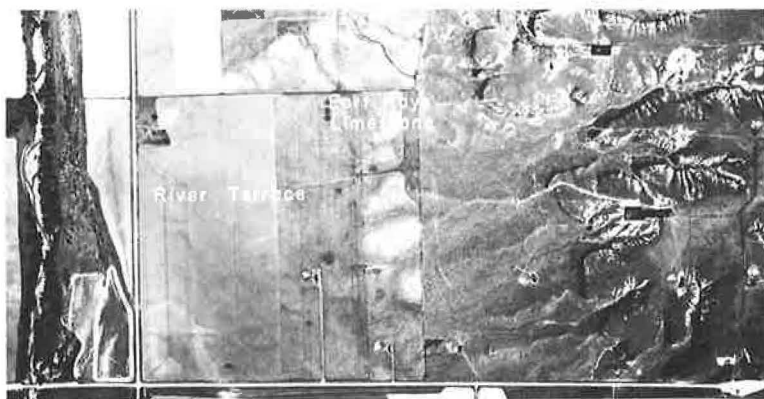


Figure 2. Black-and-white photography of Fort Hays Limestone and Pleistocene terraces in Ellis County, Kansas.

along the Smoky Hill River valley in southeast Ellis County as they appear in black-and-white photography. Color is an important factor in delineating Cretaceous bedrock in Ellis County; however, the color of the bedrock is rendered in a very distinctive tone on black-and-white photography.

**Brown County.**—The geology of Brown County is characterized by interbedded limestone and shale of the Permian and Pennsylvanian Ages capped by heterogeneous glacial drift deposited by the Nebraskan and Kansan glaciers. A thin veneer of silt of the late Pleistocene Age covers most of the high terrain with thicker deposits located in the northeast corner of the county.

The best sources for crushed limestone aggregate are the Permian limestone beds located in the western third of the county. The Pennsylvanian limestones are softer, have more overburden, and are characterized by thinner limestone units. A poor quality of clay-bound siliceous sand and limestone gravels can be produced from the glacial drift. A limited amount of clay-bound chert gravel can be produced from high terraces of the late Pliocene Age in the northwest quarter of the county, and locally derived limestone gravels can be produced from Recent terraces and floodplains of some of the larger drainage channels in the area.

Ground information was used extensively in the mapping and correlating of limestone beds suitable for construction material. A limited amount of ground information was useful in detecting, mapping, and describing the high chert gravel terraces located in the larger drainage channels. Ground information in the form of drill logs was available in areas characterized by thick glacial drift. Because of the heterogeneous nature of the glacial drift, this information supplied data for only the point where the hole was drilled and could not be used for correlation purposes.

Various pattern elements were utilized for the detection and mapping of the different source beds in Brown County. The high chert gravel terraces were mapped predominantly on the basis of topographic position and expression, whereas the limestone units were mapped on the basis of landform, tone and ground information. Limestone gravel deposits in Recent terraces and floodplains were detected and mapped primarily on the basis of landforms, drainage characteristics, and general similarities to locations of known deposits and ground information. Prospective material sites were selected in the glacial till on the same basis, and when the deposits were near the surface, on gully analysis.

All of the primary pattern elements used in the Brown County evaluation were more perceptible on color than on the black-and-white photography. However, the elements used to detect and map bedrock and unconsolidated material in terraces were just as meaningful on the black-and-white photography as the color photography insofar as the objective of this investigation is concerned. This was not true of material investiga-



Figure 3. Black-and-white photograph of glacial till in Brown County, Kansas.



tions in the glacial drift. Since the use of ground information was limited, the photo interpreter was largely dependent on the pattern elements of the photo interpretation process to detect prospective material sites. In some areas, this method was limited because of the thickness of the overburden. The inconsistent nature of the glacial drift made correlation of ground information from one area to another nearly impossible. The main pattern elements used in the interpretation of the drift areas were tone, topographic expression, and gully analysis. During this evaluation, it was discovered that different colored drift material (red clays, yellow sand, etc.) would render a similar gray tone on the black-and-white photography. Certain deposits of coarse and fine sand in the glacial deposits can be associated with a red silty clay to clay deposit. Consequently, it was the detection of these red areas on the color photographs that tentatively located a prospective material site. Although this association may or may not be true in other drift areas, similar associations involving different types of material may be possible.

Figure 3 illustrates an area characterized by glacial till in Brown County, Kansas. Initially, this area, as observed on black-and-white photography, was not considered a prospective material site until the color photography was studied. A very distinctive orange material associated with siliceous sand and gravel was detected at point "A" by use of color photography. Because of the heterogeneous nature of the glacial till, color photography can be profitably used if a potential material source of desirable quality can be located on the basis of material color change. However, unless the photo interpreter has a detailed knowledge of the material present, the association of color of material to location and quality of material may not be established until a portion of the investigation has been completed or color photography was initially used on an experimental basis.

Other than a more extensive use of tone as a pattern element, no other photo interpretation clues other than those used with the black-and-white photography were used or discovered on the color photography for the exploration of construction materials in this particular county.

**Mitchell County.**—The geology of Mitchell County is characterized by interbedded shale and chalky limestone of the Cretaceous Age capped in places by silt of the Pleistocene Age.

A poor quality chalky limestone can be produced from the Cretaceous bedrock. The main sources of construction material in Mitchell County are terraces of the Illinoian Age (Crete terraces). These terraces are composed of locally derived limestone from some Cretaceous bedrock units and siliceous sands and gravels derived from the Ogallala Formation. These terraces were laid down by the Solomon River and some of its larger tributaries.

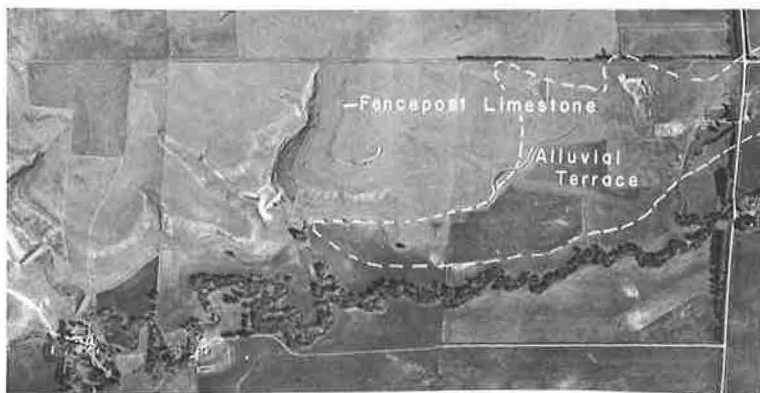


Figure 4. Black-and-white photography portraying Fencepost Limestone and alluvial terrace in Mitchell County, Kansas.

Ground information played a very important role in the material inventory of Mitchell County. The photo interpreter had a good knowledge of the area geology before the interpretation process was started. Most of the material source beds were known and after the available quality tests were correlated with the source beds, the quality of the material that could be produced from each source bed was also generally known.

Some different pattern elements were utilized in different areas for interpretation purposes. Cretaceous limestone formations were mapped on the basis of a distinct tone pattern and topographic position. The Crete terraces were mapped on the basis of ground information, topographic position and expression, general similarities to locations of known deposits, and in some areas, land use.

Color photography greatly improves the usefulness of tone, but tone was not considered a primary pattern element for exploration of construction material in Mitchell County. No other photo interpretation clues other than those used with the black-and-white photography were utilized or discovered on the color photography for the exploration of construction material in this county. The additional information that could be extracted from the color photography by virtue of the color imagery was not relevant to the objectives of the material inventory and, therefore, did not alter or add to the investigation.

Figure 4 is a portion of a black-and-white photograph portraying the Fencepost Limestone member and an alluvial valley in Mitchell County. Even though the limestone source bed is easier to detect on the color photography, the unit can be mapped just as effectively on the black-and-white photography.

#### SUMMARY AND CONCLUSIONS

Color aerial photography is pleasant to view, and it is conceded that when speaking in general terms, more information can be extracted from it than can be extracted from black-and-white photography; however, unless this additional information is pertinent to the objectives of the investigation, the color photography would only add to the expense of the investigation. The additional information that can be extracted from the color photography is obtained by virtue of color contrast that cannot be detected as a significant tonal change on black-and-white photography. Color photography, in most cases, improves the discernibility of all pattern elements, but unless the color imagery increases the quantity and quality of the information deciphered from the pattern elements, the same information can usually be obtained from good quality black-and-white photography. Concerning the objectives of this investigation, color aerial photography has a distinct but limited use in Kansas.

The conclusions derived from this investigation pertain to two specific engineering problems. Even though these conclusions can be applied to similar projects in different areas, different conclusions may result when the same photography is evaluated for different problems with different objectives. For example, color photography of a given area may not be necessary to complete an accurate construction material investigation but may be indispensable when analyzing and mapping soils of the same area.

The effectiveness of color aerial photography when used to complete road condition surveys and materials inventories can be measured in terms of cost of the film (Table 1), the time required to complete the photo analysis, the amount and type of information extracted from the photography, and other factors that may be peculiar to a given project. The conclusions presented in this paper are based on these factors.

During this investigation, emphasis was placed on the type of information that could be extracted from the various types of film; however, although no detailed time log was maintained during the interpretation process, the relative amount of time required to complete the evaluation, using the different types of aerial photography, was noted. Less time was required to complete the interpretation process when using color photographs printed from the Agfacolor Negative film. The color image, when used to extract information pertaining to the objectives of the projects, would on many occasions identify or delineate a particular item of information by virtue of its color, and the time-consuming activity of further studying and correlating other features was not required. Compared to the color transparencies, all color and black-and-white prints

were easier to handle in the office and in the field. Because of better resolution, black-and-white glossy prints were easier and faster to interpret than the black-and-white photographs printed on single weight matte paper. Color transparencies took the longest time to interpret, but the authors feel that this time would be substantially reduced if better quality transparencies (for road condition survey purposes) and better interpretation equipment were available. Assuming good quality transparencies were available, they would provide the photographic interpreter the added benefit of the color images, as explained previously in the color prints discussion, and excellent resolution. However, the added size of the transparencies (all transparencies were inclosed in a plastic jacket) hampered their positioning for stereoscopic vision. This situation could be improved by proper interpretation equipment.

### Road Condition Surveys

Of all the photography used during this evaluation program, Agfacolor Negative film is best adapted to road condition surveys. One of the outstanding qualities of this film is the possibility of obtaining color or black-and-white prints. Color prints are a necessity to complete an accurate survey on pavements characterized by initial stage stains. Black-and-white glossy prints would suffice for pavement characterized by advanced stage stain. Even though color prints are more costly, the speed of interpretation and the higher quality of data that can be extracted from the color image of initial stage stains offset the higher cost. Because a similar quality of data can be extracted from good quality glossy black-and-white prints when mapping and evaluating the advanced stage stains, these lower cost prints can be utilized.

Good color transparencies can conceivably provide the same quality of image as the color prints at a slightly lower cost; however, the additional time to complete the photo analysis and the fact that a single purpose negative is used (only color transparencies or prints can be obtained from Kodak Aero Ektachrome film), the Agfacolor Negative film is considered more adapted to this particular project. Therefore, if a given pavement is to be surveyed, the portion of the pavement having advanced stage stains may be mapped and evaluated using black-and-white glossy prints, and the portion of the pavement having initial stage staining would have to be mapped using color photography. If Agfacolor Negative film was being used, black-and-white glossy prints, and color prints could be obtained from the same negative. The difference in cost of the color print and the black-and-white prints is such that savings could be realized in areas having widespread advanced stage staining. This situation is more flexible and, consequently, more adaptable to road condition surveys. One flight would suffice for both black-and-white and color photography.

It should be noted, however, that if the pavement to be surveyed is characterized by predominantly advanced stage stains, Cronar Safety film could be used. It is less expensive than the Agfacolor Negative film and has better resolution than the black-and-white photographs printed from Agfacolor Negative film.

### Materials Inventories

In general, color photography did not significantly add to the materials inventory investigation except in isolated cases. Areas where the use of color photography is most beneficial are characterized by inconsistent and erratic geology as in southeast Kansas or by thick overburden consisting of heterogeneous material as in glacial terrain in northeast Kansas. Ground information pertaining to the same areas is difficult to project and correlate and, consequently, more reliance must be placed on photographic interpretation techniques.

Ordinarily, the photographic interpreter in Kansas has knowledge of the general conditions of any county that might be investigated for construction material sources. Therefore, the need for color aerial photography can be anticipated once the location of the county to be investigated is known.

The procedure currently being used for materials inventory investigations in Kansas involves investigation of photographs printed from black-and-white DuPont Cronar Safety film. The cost is relatively low, and with only a few exceptions, the quality of data extracted is as good as information extracted from color photographs. The amount

of time to interpret the black-and-white prints for materials inventory purposes is less than that required for color transparencies and nearly the same as the time required to interpret color prints.

If color photography is desired for use in material inventories, Kodak Ektachrome Aero film would be most desirable. Color transparencies are more time consuming to interpret but the lower cost of the transparencies would offset the extra cost of interpretation. Although Agfacolor Negative film is a dual purpose film (since both black-and-white and color prints can be printed from the same negative), this dual purpose would not, under existing conditions, be utilized. As mentioned previously, the photo interpreter is able to anticipate the use of color photography when conducting material inventories in Kansas. Once the counties are studied on black-and-white photography, the areas to be analyzed on color photography can be selected. On many occasions, color photography may not be required. The areas selected will usually be relatively small compared to the area of the county being investigated. Consequently, to photograph the entire county using Agfacolor Negative film would only add to the cost of the project because only a small percentage of the film would be used to print color photographs.