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Color Aerial Photos in the Reconnaissance of Soils and Rocks

Color yields a more accurate and rapid means of identifying culture and land use, and allows greater soils differentiation and crop identification.

(Abstract on next page)

INTRODUCTION

MAN'S CONTINUING SEARCH for a more intimate knowledge of the earth's structure extends from the earliest periods of the Stone Age when survival depended upon selection of the densest stones to make keen cutting edges and sturdy spear points to the present Space Age in which scientists design elaborate instruments for reconnaissance of the composition of the universe. Exploration of our Earth has been accelerated with the aid of aerial photography, yet extensive ground exploration is still required for positive analysis of the terrain. These costs can be reduced as photo-interpreters gain a higher confidence level in their interpretation of ground detail from aerial photographs.

Interpreters have become accustomed to working with panchromatic black-and-white aerial photography which has attained a high degree of development in reproducing ground detail in shadings of gray. Previous training and experience has conditioned the interpreters' optical reflexes to translate automatically the sixty-four shades of gray into approximations of typical rock, soil, swamp, vegetation, urban patterns and other terrain detail. If all of the variegated hues that appear in nature were presented to the interpreter, instead of the gray shades, then the interpreter would have an almost infinite number of chroma variations for interpretation. The use of the present three layer emulsion of color aerial photography presents a more-readily understood spectral relationship for the location and identification of soils and rocks than can be obtained from panchromatic black and white aerial photography. In essence, many degrees of contrast in photographic imagery are presented by color aerial photography; therefore it becomes a useful tool to the soils engineer.

The American Society of Photogrammetry Color Aerial Photography Committee was organized to plan and supervise tests of the capabilities for information extraction from color aerial photography. Excellent cooperation was obtained from interested government agencies and private industry. The Defense Intelligence Agency, U. S. Air Force, Army Map Service, U. S. Army Engineer Topographic Laboratories, (formerly GIMRADA), Coast and Geodetic Survey, U. S. Geological Survey, in addition to Eastman Kod ': Company, General Aniline and Film Corporation, Data Analysis Center, Itek Corporation, Fairchild Camera and Instru-

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ment Company and the Wild Heerbrugg Instruments Company, all contributed toward the successful accomplishment of the tests.

The primary purpose of the tests was to obtain quantitative and qualitative data regarding the role of color, panchromatic black-and-white and false color (Ektachrome Infrared) films in photogrammetric application to the extraction of terrain information. As planned, several precision cartographic cameras, each equipped with different emulsions, would be operated simultaneously over terrain for which detailed ground information would be obtained during the flights. In practice, coordination of the diverse organizations supplying vehicles, cameras, ground detail, and the weather proved difficult. This paper reports on several tests; one test over the Eastern Coastal Plain near Bennettsville, South Carolina, June 8-22, 1964; a Multiband Photographic Test as part of a GIMRADA contract in Yosemite and Davis, California, June 15-17, 1965; and another ASP aerial photographic test in the Western Desert near Phoenix, Arizona, June 22-July 2, 1966.

ABSTRACT: *A specialized area of interpretation of soils and rocks can be obtained from aerial photography in color. Several controlled tests include the Eastern Coastal Plain Bennettsville, South Carolina, and the western desert near Phoenix, Arizona. In using aerial color film, the three-layer emulsion presents a more readily understood spectral relationship than can be obtained from black-and-white film; the reconnaissance of inaccessible areas with their rock structures can be more rapidly analyzed with the aid of the distant view of aerial photographs than solely by ground exploration. Geologists never having visitied the ground site could analyzed soil conditions using 1:20,000-scale aerial color photographs and infrared with sparse generalized ground information. A highly skilled soils engineer interpretating the Arizona test photographs reached a valid conclusion as to the type of soils in the desert area when he was halfway through the study of the 1:40,000-scale aerial color photographs along with infrared color photographs.*

BENNETTSVILLE, SOUTH CAROLINA, TEST

A detailed report on the Bennettsville, South Carolina, Test is given in Reference 1. The test plan prepared by the American Society of Photogrammetry Color Aerial Photography Committee was implemented by using an RC-130 aircraft equipped with a pair of cartographic cameras; an RC-8 Wild Camera equipped with an Aviogon six inch focal length lens and a Fairchild KC-4 Camera equipped with a Geocon six-inch focal-length lens. Both cameras have a 9×9-inch format and are corrected for color. The films employed, panchromatic black-and-white, Ektachrome, and Ektachrome Infrared (false color) as well as Anscochrome were alternated in the cameras. The test site, approximately thirty square miles, included the city of Bennettsville, South Carolina (Figure 1). Army Map Service Engineers obtained ground truth data for 42 selected points scattered throughout the area.

Interpretations were performed from 1:20,000 scale photography. The interpreters were not given ground truth, nor could they

FIG. 1. Bennettsville, South Carolina, Test Area.

PLATE 1. Ektachrome (Color) Film, no filter, Davis Test Site.

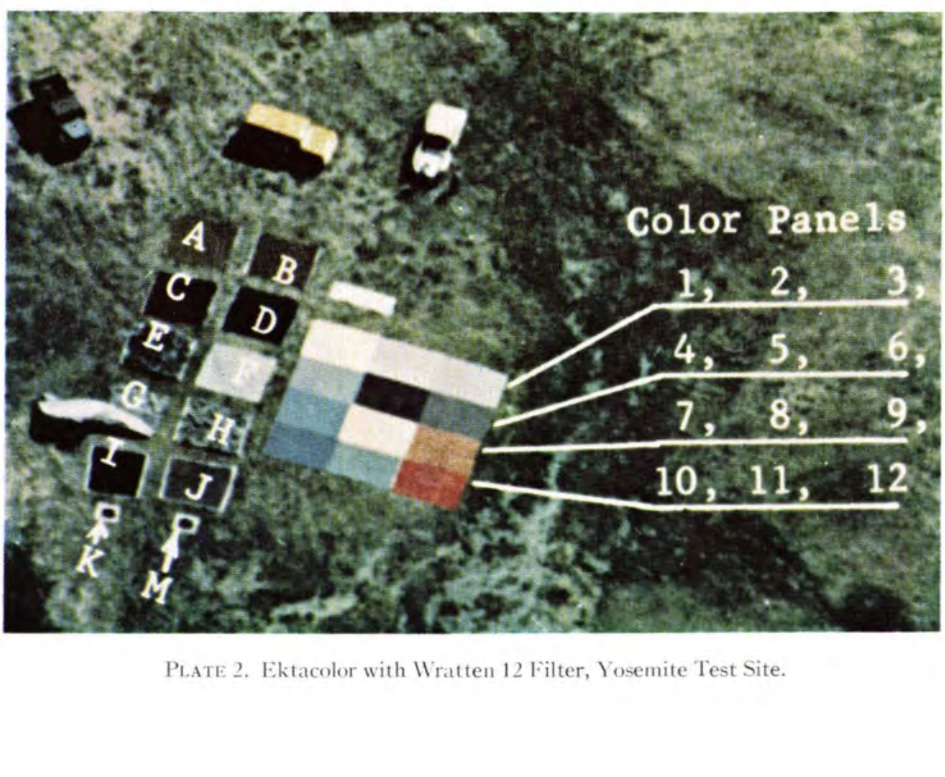

PLATE 2. Ektacolor with Wratten 12 Filter, Yosemite Test Site.

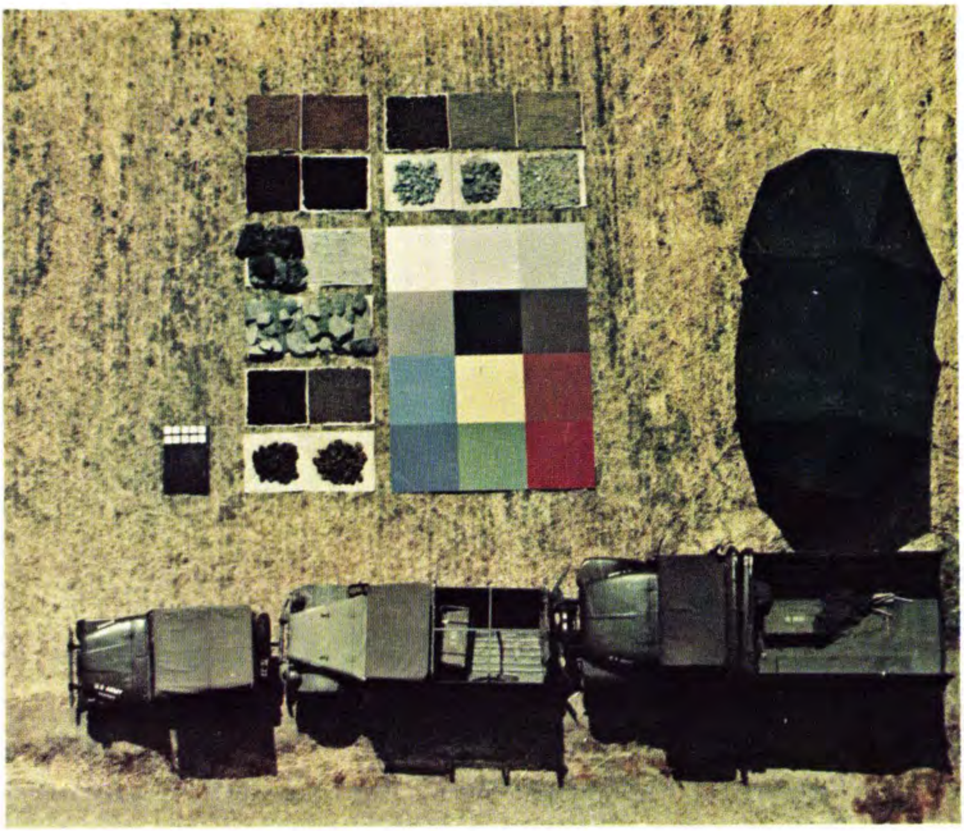

PLATE 3. Ektacolor with Wratten 12 Filter, Davis Test Site.

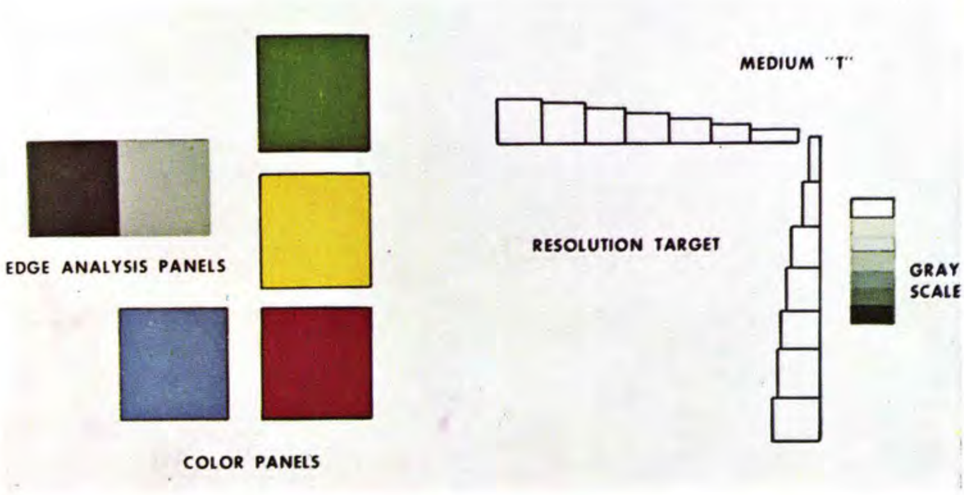

PLATE 4. Phoenix Photogrammetric Color Test Site.

PLATE 5. Ektachrome Aerial Photograph of Phoenix Test Site at 10,000 feet.

PLATE 6. Ektachrome Infrared Aerial Photograph of Phoenix Test Site at 10,000 feet.

FIG. 2. Drainage map prepared from Ektachrome infrared photographs, Bennettsville, S. C., Test Area.

compare one set of photos with the other two. In addition to preparing several 1:20,000 scale maps the interpreters were requested to make their analysis of each of 42 selected control points, supplying the same information as requested from the ground engineers.

A visual comparison of the overlay maps revealed an increasing amount of drainage density mapped from Panchromatic, color, and Ektachrome Infrared (false color) photographs in that order (Figure 2).

In the interpreters' opinion, Ektachrome Infrared film afforded a rapid and accurate means of mapping not only drainage, but also moist soils. Streams and ponds appeared black, dark brown, or blue depending on the amount of sediment in the water to reflect the infrared spectrum. Lack of sediment was indicated by the maximum absorption of infrared; silted waters registered as a lighter tone. Tertiary and intermittent drainage lines were readily observable since the presence of moisture contrasted with the highly reflective dry soil.

Vegetation maps compiled from panchromatic lback-and-white photography which had less contrast than color photography, had less detail; and the vegetation amps compiled from the Ektachrome Infrared photography indicated more detail than the other two. The EK IR photography easily discriminated between deciduous and coniferous trees, crops, and grassland, based again upon the infrared reflectivity of the vegetation. Broad leaved trees radiated more reflectivity than the narrow needle coniferous variety. Merest beginnings of crop growth which showed as red traces against the blue soil, or as green against brown in color, could be more rapidly perceived than in tones of gray on the panchromatic film.

A comprehensive soils study would have required field trip by the photointerpreters; therefore they were requested to prepare their soils map by using a set of keys in which the soils were differentiated by area. The maps prepared from color and false coler photography provided the maximum number of detailed areas in which areas of similar soils were matched in symbol (Figure 3).

No geologic structures, folds or faults were observed in any of the three types of photography studied. The major landforms of the area were characterized by low relief, slightly hummocky, and much of the surface topography was probably deeply underlaid by unconsolidated sand and gravel as evidenced by the numerous excavations and pits throughout the area.

Each of the 42 preselected photo points were studied independently with the following results for 237 items requested:

The ratio of incorrect to correct was 69/136 for panchomatic.
The ratio of incorrect to correct was 47/163 for color.
The ratio of incorrect to correct was 45/165 for color IR.

The correct responses were approximately 20% greater for color film than for panchromatic and 22% greater for EK IR than panchromatic film. Conversely there were fewer errors for color photography than for items extracted from black and white photography. The speed of interpretation was higher for Ektachrome Infrared photographs.

To sum up the interpretive work performed on the three emulsions and the three sets of photography used in this test, color fidelity was one key to the interpretations, whereas color bias, which lent to some photos a predominantly green or blue tone because of exposure or processing, was another consideration. However, color bias is not as important

FIG. 3. Soils map prepared from Ektachrome infrared photographs, Bennettsville, S. C., Test Area.

as *color differentiation*, because the Ektachrome Infrared which is a color distorting medium, known as false color film, was equal, and in some cases better than color film for interpretations. To be more specific, if a patch of vegetation, rocks, soils, or a geological formation differs in hue and chroma from its surroundings, then it has its own specific spectral characteristics which facilitates discrimination and probable identification.

MULTISPECTRAL EXPERIMENTS

In the measurement of vertical color photography taken under field conditions there has been some question regarding the fall-off of color saturation at the edges of the camera field. In order to determine the fall-off in color densities from vertical color photography, several multispectral experiments were performed at the University of California with Professor R. N. Colwell, School of Forestry, Berkeley, California. The primary purpose of these experiments was to determine quantitatively the saturation of color at the edges of field of a wide-angle lens, by measuring the densities of color panels placed in the center of the field and at the edges of the field. It was assumed that data achieved by photographing with a lens of 45 degree field would be comparable to any wide angle lens as compared to narrow angle fields of one or two degrees. The experiments consisted of laying out three rows of 4×4-foot color panels painted with National Bureau of Standards coordinated paints whose spectral characteristics were known. Each row of eight panels was placed at the base of a 150 foot water tower at the University of California campus, Davis, California. One row was placed at the nadir, another row 12 degrees from the nadir and a third row 22 degrees from the nadir at the edge of the field of view. The colors of the panels were blue, chartreuse, green, brown, rust, yellow, red and black (cinders from Pisgah Crater)[2] (Plate 1). A 4×5-inch Format Speed Graphic Camera equipped with a 127 millimeter focal length Ektar lens was hand held to absorb random vibrations which could be transmitted by tower sway. It was considered that this arrangement would eliminate the bias of aircraft pitch, roll or yaw. The emulsions used were Tri-X Panchromatic, Orthochromatic, Ektachrome and Ektachrome-Infrared, in combination with narrow band pass filters—400, 440, 500, 540, 690 and 770 nanometers—as well as the regular broad band filters—Wratten 12, 25A, 47B, 61 and 90.

Approximately 1600 measurements were made by the author with a densitometer; the results of the measurements were tabulated and compared. It was concluded that photography exposed vertically through a wide angle lens suffers a slight loss of reflectivity of color, approximately 2 percent, when recorded in black and white or in color, except that the use of narrow band filters affect the transmission of the dominant wave length, as would be expected.

Further work in the area of multispectral and multiband photographic extraction techniques for the purpose of soil and rock discrimination was pre-formed under a contract between USAETL and the Aeronutronic Division of Philco-Ford, with the able assistance of Prof. R. N. Colwell who arranged for the target sites June 15-17, 1966, at Yosemite National Park and at Davis, California. Those tested were geared more closely to the specific discrimination of several kinds of soil and rock targets as well as a number of color panels and random targets. One test site was a clearing in Yosemite National Park, California, elevation 4,000 feet, at the base of Glacier Point, elevation 7,200 feet, upon which the cameras were mounted. The test panels, each 96 square feet, were composed of 7 colors, plus five shades of gray. Twelve rock and soil panels each 144 square feet contained representative soils from Buck's Lake, Pisgah Crater and Mono Crater (Plate 2). Several hundred exposures were made with a Curtis one shot color camera, 4×5-inch format, 150 mm. focal length, which takes three exposures simultaneously in black and white, one with a red filter, one with a blue filter and a third with a green filter. A second camera, a Printex, same format and focal length, was used to obtain color and Ektachrome infrared photography. A variety of filters was also used.

The same set of panels was transported to the Davis test site and photographed from the 150-foot tower, where each panel was reduced to sixteen square feet, employing the same cameras and films (Plate 3).

With a unique technique developed by Mr. Karl Heinz Lohse of Aeronutronic Corporation, each type of soil and rock as well as each color was discriminated from the other samples by laboratory photographic processes. These processes depended upon the spectral relationships of each sample. Although the particular technique is an involved laboratory process, the experiment proved that the unique spectral characteristics of each rock and soil sample facilitates its identification. The work conclusively demonstrated that any medium which yields the greatest information about the spectral characteristics of the targetted area enables the interpreter to identify it with more certainty.

Phoenix, Arizona, Test

A rigidly controlled color comparison test was devised by the American Society of Photogrammetry Color Photography Committee to be flown over the Arizona High Density Control Area which is part of the Phoenix, Arizona Test Range. The concept of the test plan was that greater emphasis would be placed on ground truth records to be made simultaneously with the aircraft flights, positive identification of ground control points in the photography, and large color panels whose spectral curves were known. The response of the desert soils, vegetation and rocks themselves would be compared with the color panels. Metric measurements to determine geometric distortion would be made and photo interpretations would be compared with the color panels. Three cartographic cameras would operate simultaneously, and test flights would be flown at three altitudes—10,000, 20,000 and 30,000 feet. All tests to be completed within one week after an initial test flight for exposure data.

In addition to the cooperation of the organizations mentioned previously—DIA USAF, AMS, USAETL, C&GS, USGS, Eastman Kodak, GAF, and Fairchild—the National Aeronautics and Space Administration supplied a pair of matched RC-8 Cartographic Cameras and USAETL furnished the KC-4 Fairchild Camera all three equipped as before with six-inch focal length, 9×9-inch format color corrected lenses. The Data Corporation under contract to the USAF prepared four 100×100-foot canvas panels painted in epoxy paint, in red, blue, green and yellow (Plate 4). Edge analysis panels 6,400 square feet each in gray and black were installed as well as a pair of *T*-bar resolution targets each 275 feet long. The High-Density Control Area is twenty miles south of Phoenix, in the Gila River Indian Reservation. The flights were made during June 25–July 2, 1966 at the maximum sun angle. While the three cameras were operating simultaneously in the RC-130 aircraft flying at the specified altitudes, ground truth data, such as temperature, humidity, light intensity and ground control photos of the control points, were being obtained. Horizontal and vertical control points in a thirty-five square mile area were recorded on all of the aerial photography by having the control points flagged with 12×12-foot sheets of white KaCel.

Numerous tests are being conducted on the resulting photography by several organizations including Army Map Service, Data corporation, Itek Corporation, U.S. Geological Survey, Coast & Geodetic Survey and USAETL. Olin Mintzer, Professor of Civil Engineering at Ohio State University, made a soils analysis of a small area.

Nine-by-nine-inch glass diapositives of the test area printed from panchromatic, color photography and Ektachrome IR photography were given to Professor Mintzer in that order. He was also supplied with a 1:100,000 scale photomosaic in black and white in addition to a topographic map. Never having visited the area, Professor Mintzer's knowledge was general; that landforms were developed as alluvial filled valleys, that the surface materials in grain size were anything from boulders to clay, and that only consoli-

FIG. 4. Plus-X aerial film of Phoenix Test Site at 10,000 feet. The color panels are shown in the lower center.

dated materials would be in the hills and buttes scattered throughout the test area. The colors of the test panels were well defined at all altitudes. The vegetation types to be expected were mesquite, salt bush, mustard grass, and cactus. No more information regarding soils or vegetation types was made available. Three stereo models of each of the flight heights (10,000, 20,000 and 30,000 feet) and three films were studied; first the panchromatic Plus-X, then the Ektachrome, and finally the Ektachrome IR (Figure 4, Plates 5 and 6).

The standard terrain data recording format was developed for information associated with soils. The record included: geologic information, origin, landform, drainage pattern, gully shape and gradient erosional features, phototone, landuse, vegetation and surface materials. Cultural features were also recorded.

The total time required to perform the photointerpretation and record the natural and cultural features was 48.5 hours; 22.5 hours for the 30,000-foot altitude, 13 hours for the 20,000-foot altitude; and 13 hours for the 10,000-foot altitude photography.

The interpreter was able to reach a conclusion as to the type of soils observed in the area when halfway through the study of the 1:40,000-scale photography. The predominant soil is silt with some sand ridges scattered throughout the test site. The conclusion that the soil is silt was reached through an analysis of the pattern elements recorded on the data format. The principal reason that the soil types were detected and recognized in the 20,000-foot photos is that the gully shapes, and important pattern elements were detectable in photos taken at that altitude. Work is continuing on this study by Professor Mintzer who should have a complete detailed analysis of the Arizona Test Range color photography within the next few months.

Conclusion

Although there is a substantial body of information on the subject of color aerial photography being developed at the present time (refer to Bibliography) this paper is a report on work in this field, in which the author has participated and has some personal knowledge.

Compared to panchromatic black and white photography:

- Color aerial photography yields a more accurate and rapid means of identifying culture and land use.
- Color aerial photography allows greater soils differentiation and crop identification.
- Color aerial photography gives the interpreter more confidence in his decisions.
- Etkachrome Infrared (False Color) photography is superior for the identification and delineation of water bodies, particularly in separating the silted areas.
- Ektachrome Infrared (False Color) photography is unexcelled for the differentiation of vegetation, broad leaved and narrow leaved species, bare soil and emerging crops.

From the above it is evident that the acquisition of color information is undeniably a major aid in the reconnaissance of soils, rocks, vegetation and stream information; the problems arise in the methods to be used in acquiring that information.

Aerial photography in both black-and-white and in color has been extensively employed in the past for soils analysis and geological exploration. According to Fischer (1958) differences in color allow certain geologic features to be traced more easily on color photographs than on black and white. In addition, experimental color filtering techniques during processing can also be employed to trace rock formations.

Minard (1960) reported that interpretation of color aerial photographs in the Piedmont Coastal Plain facilitated the mapping of two formational contacts which were extremely difficult to locate other than by extensive augering. Further work by Fischer (1962) indicated that color aerial photography was helpful in New Mexico in mapping the distribution of residual soils, recognition of relic sink-holes and in determining the origin of drifting sands on a limestone-capped mesa.

The state-of-the-art in the development of color emulsions, color sensitive black and white emulsions, filters, Apochromatic lenses, sensitometers and densitometers have provided many tools for the soils engineer to employ. The Bennettsville tests demonstrated the usefulness of color and false color films to discriminate terrain information, the multispectral tests presented evidence regarding the validity of photographic information on the color of rock and soil samples on vertical photography, and the Arizona tests have demonstrated that the higher altitude photography can yield useful information in particular regions. The time-consuming efforts of the field engineer can be reduced with the judicious employment of these tools.

Color aerial photography then is another tool which can be used to assist the soils engineers to determine the engineering character of soils and rocks, particularly in remote, inaccessible areas when color is employed to its full capability and within the limitations of the media.

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