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GEOLOGICAL SURVEY

ORIGINAL CONTAINS

COLOR ILLUSTRATIONS

INTERAGENCY REPORT NASA-18

EVALUATION OF NINE-FRAME ENHANCED MULTIBAND PHOTOGRAPHY

SAN ANDREAS FAULT ZONE, CARRIZO PLAIN, CALIFORNIA*

by

Robert E. Wallace**

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**U. S. Geological Survey, Menlo Park, California

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INTRODUCTION

Nine-frame multiband aerial photography of a sample area 4500 feet on a side was processed to enhance spectral contrasts. The work was done by the Itek Corporation on contract with the U. S. Geological Survey as part of a study of remote sensing techniques sponsored by the National Aeronautics and Space Administration. The area concerned is in the Carrizo Plain, 45 miles west of Bakersfield, California, in sec. 29, T. 31 S., R. 21 E., as shown on the Panorama Hills quadrangle topographic map published by the U. S. Geological Survey.

The accompanying illustrations include figure 1, an index map showing the location of the Carrizo Plain area; figure 2, a geologic map of the area based on field studies and examination of black and white aerial photographs; figure 3A, an enhanced multiband aerial photograph; figure 3B, an Aero Ektachrome photograph; figures 4A and 4B, black and white aerial photographs; and figure 5, infrared image in the 8-13μ band.

DISCUSSION

A comparison of the images and the geologic map show that a few geologic units are more clearly displayed in the enhanced multiband image than the color photograph, black and white photographs, or the infrared image. In addition to geologic units, the contrast between grass-covered land and bare land is greater in the enhanced image than in black and white or color photography, but is comparable to the contrast obtained on an infrared image.

The spectral differences to be enhanced, unfortunately, were not chosen for their geologic significance, but rather for spectral contrasts alone. The colors in which to display the spectral contrasts also were chosen somewhat arbitrarily to provide ease of visual recognition of the spectral contrasts. Other spectral differences as well as other color displays of the differences could have been chosen, and very likely spectral differences that represent significant geologic features might have been possible.

In the following description of the color differences displayed on the enhanced image, the colors of the original enhanced image will be referred to, but because of the difficulty of precise color reproduction the colors described may appear slightly different in the final published form.

The highest contrast between two geologic units produced by enhancement is between two types of alluvium indicated on the geologic map as Qm and Qa_3. Both are generally similar, possibly of early Recent or late Pleistocene age; both contain sand, silt and gravel; and both have mound topography developed. In the original enhanced image the older unit Qm, on which large mounds are developed, appears as yellow spots, the mounds, on a reddish background representing the brown soil surrounding the mounds. In contrast, unit Qa_3 appears as a bluish-green color. Interestingly, both units have been plowed for farming and because of this they appear on infrared imagery (8-13μ band) (figure 5) as almost identical gray levels, that is relatively cool in predawn hours when the imagery was taken in June 1965.

The color or spectral differences between Qm and Qa_3 that were enhanced apparently represent a difference in the stage of soil development; Qm is generally browner overall than Qa units. The brown hues of the soil in Qm, however, are mimicked by a thin strand of brown grass in the triangular unplowed area, and thus the unplowed area shows up in the enhanced image very similar to some areas of Qm.

The triangular patch of unplowed ground (see figure 2) also shows up as a light area in the infrared image because of the difference between the thermal inertia of the plowed and unplowed ground. The unplowed ground has a higher thermal inertia and thus its surface did not cool off as much in early morning hours as did the surface of the plowed ground.

Alluvium deposited in 1965 appears near the center of the image as a deep purple in the enhanced image. This unit is also conspicuous in the color photograph as a pale blue gray and on one black and white photograph as a pale gray. The infrared image was obtained before the flash flood that deposited Qa_1.

At least one major lithologic contrast identified on the ground, between gravel and sand of granitic debris in unit Qa_3 and fine silts, clays, and sand of Qa_2, is not apparent in the enhanced image nor in the Aero Ektachrome photograph.

The two different black and white photographs show different tonal values for the different geologic units. Figure 4A was made on Kodak Aerographic super XX film with a minus-blue (light yellow) filter. Kodak Plus X film was used for figure 4B, but the filter used is unknown. Note that figure 4A displays a contrast between units Qm and Qa_3 very similar to the enhanced multiband photograph. Although this contrast was achieved accidentally, it illustrates that if the spectral signatures of geologic units were known, contrasts could be considerably enhanced in black and white values.

CONCLUSIONS

The present experiment clearly demonstrates that certain geologic units can be made to stand out very conspicuously by enhancement of multiband photography, and thus this technique is potentially useful for geologic mapping. For example, in the sample tested the conspicuousness of unit Qm could be helpful in interpreting offsets along the San Andreas fault, thus contributing to the earthquake prediction problem. Very possibly if regional coverage were obtained, it would be possible to relate patches of the unit on oposite sides of the fault.

Two very different types of geological problems exist, however, which require somewhat different approaches. The first consists of discriminating between two or a few units which are involved in a limited problem that can be clearly defined. The second, and probably the most common type of problem, consists of exploration for interrelations of geologic units for which neither the geologic units nor the possible interrelations are identifiable before the study. The second type of problem has been approached primarily by black and white photogeology and field examination. Color photography adds color hues as additional signatures for different geologic units, and thus should be considerably more effective than black and white photography, provided color control, and thus the identy of the signatures, can be maintained. A procedure suggested is to perform reconnaissance or exploration studies with color photographs; then when specific problems of discrimination are identified, the spectral difference can be enhanced either by black and white or multiband techniques, whichever is most suitable to the particular problem.

By comparison to black and white photography, there should be a great deal more retrievable data in multiband photography. Several points should be considered, however:

(a) Needless redundancy: For geologic mapping, if discrimination of two or more units can be accomplished in one part of the spectrum, little is gained by repeating the discrimination process over and over in various parts of the spectrum, and selected black and white images might suffice as well.

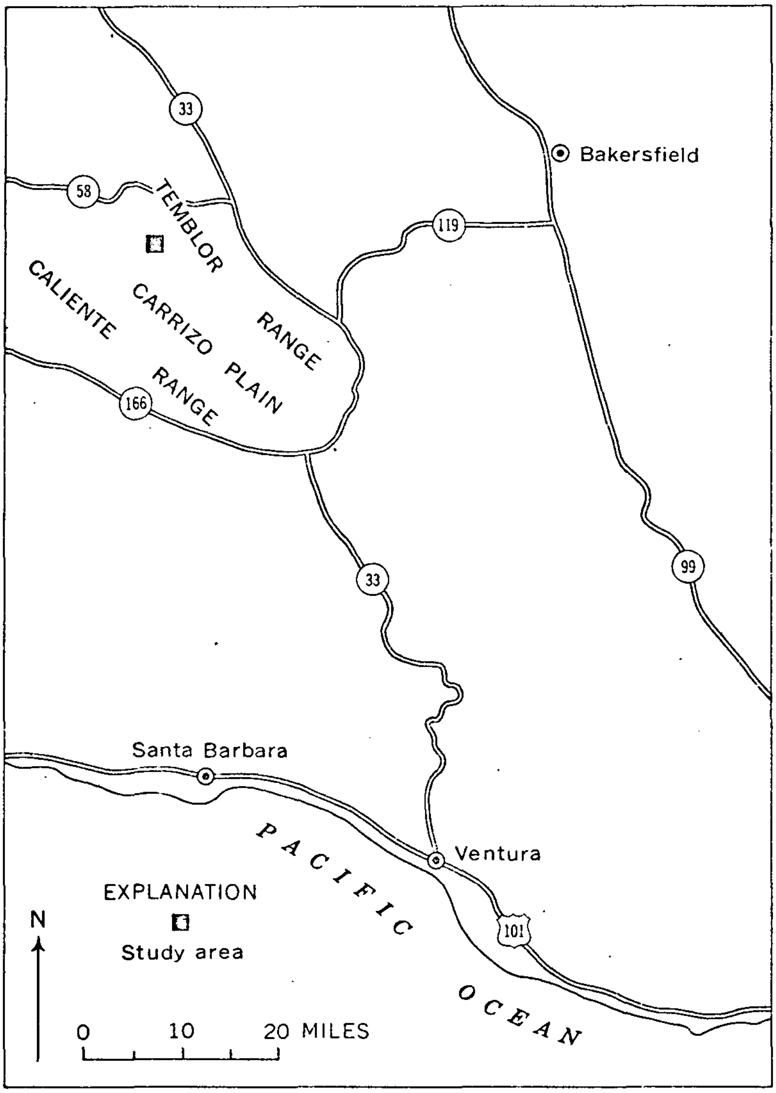
(b) Data processing: The mere presence of available data inherent in multiband photography does not insure its full use. Present processing techniques must be greatly simplified, automated or otherwise evolved before full value can be realized in solving geologic problems on the earth or planets by this technique. In this regard it is significant to note that largely because of costs, full utilization of black and white or standard color photographic techniques has never been realized by the geologic profession.

(c) Other multiband approaches: The possibility of achieving the same end, that of enhancing spectral differences, by techniques other than the nine-frame technique employed in the present test should be considered. For example, analysis and reconstruction of color photography in various ways, or by selectively filtering for a specifically known spectral difference representing specific geologic problems may prove ultimately to be as effective or more effective approaches. It is not clear to the author at this stage which of numerous possibilities will ultimately prove most useful.

(d) Color reproduction: Color reproduction quality presents practical limitations. For example, a preliminary edition of this report was submitted in a Technical Letter in January 1966, including one of three sets of enhanced images prepared by Itek Corp. In June 1966 lithographic reproductions of the color figures were obtained so that wider distribution of the report would be possible, but the lithographed material displayed extremely poor color rendition of the original material and was unusable.

(e) Selection of contrasts to be enhanced: In addition to the above color-reproduction problem, a single enhanced image that was produced during trial runs by the Itek Corp. was far better enhanced from a geologic point of view than that which the nongeologist processors delivered as their final "best result" and which was submitted with the original Technical Letter and is reproduced here.

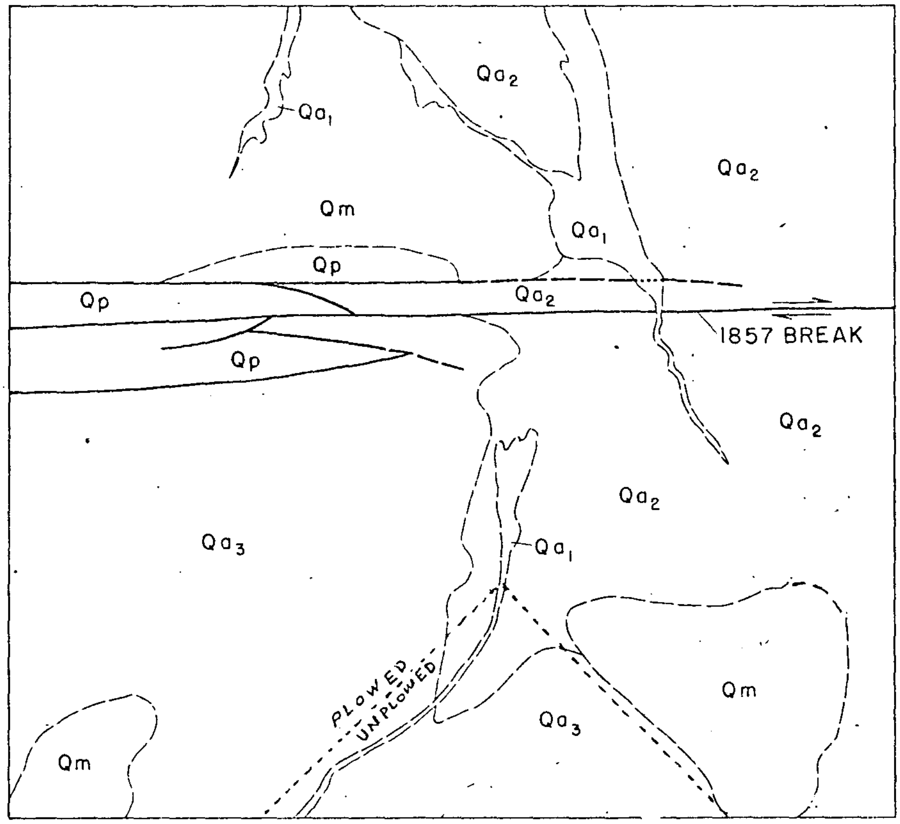
The most important consideration is that until the geologic vs. spectral color parameters are better known, the selection of parts of the spectrum to be enhanced cannot be intelligently selected. Finally, only the most highly controlled film processing techniques can hope to give meaningful results in multiband as well as other types of color photography.



33
Bakersfield
58
TEMBLOR
119
CALIENTE
CARRIZO
RANGE
PLAIN
166
RANGE
33
99
Santa Barbara
PACIFIC
Ventura
EXPLANATION
N
Study area
101
OCEAN
0
10
20 MILES

Figure 1

Figure 2



Geology by R. E. Wallace
U. S. Geological Survey

NORTH

SAN ANDREAS FAULT ZONE
CARRIZO PLAIN, CALIF.

0 500 1000 FEET
APPROXIMATE SCALE

EXPLANATION

Recent — QUATERNARY

Qa1

Alluvial deposits of sand, silt and gravel; deposited during flash flood of Sept. 1965

Qa2

Alluvial deposits of sand, silt and gravel. Deposits of main fan-forming period

Qa3

Alluvial deposits of sand, silt and gravel, derived largely from Paso Robles and Panorama Hills Formations. Mound topography developed to fair degree

Pleistocene or Recent — QUATERNARY

Qm

Mounds of fine silty material underlain by interbedded sand, silt and gravel. Brownish, fine-grained soil in hollows surrounding mounds. Origin of mounds unknown, but now occupied by ground squirrels

Pleistocene

Qp

Paso Robles Formation

Gravel, sand and silt, granitic cobbles and boulders derived from conglomerate of the Santa Margarita Formation

Contact
Approximately located

Fault
Dashed where approximately located

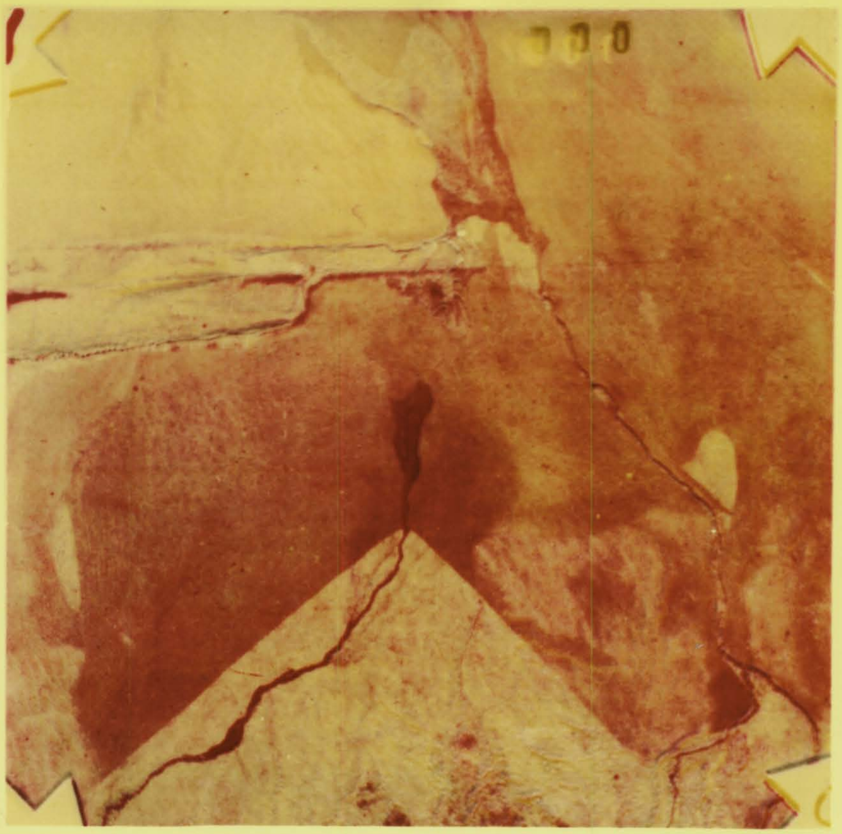


Figure 3A

Figure 3B

Approximate scale 1 inch 1000 feet

Approximate scale 1 inch 1000 feet.

Figure 4A

Approximate scale 1 inch 1000 feet.

Figure 4B

Figure 5