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ANALYSIS OF PSEUDOCOLOR TRANSFORMATIONS OF ERTS-1 IMAGES OF SOUTHERN CALIFORNIA AREA

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ABSTRACT

Representative faults and lineaments, natural features on the Mojave Desert and cultural features of the southern California area were studied on ERTS images. The relative appearances of the features were compared on a Band 4 and 5 subtraction image, its pseudocolor transformation, and pseudocolor images of Bands 4, 5, and 7. Selected features were also evaluated in a test given students at the University of California, Los Angeles. Our observations and the test revealed no significant improvement in the ability to detect and locate faults and lineaments on the pseudocolor transformations. With the exception of dry lake surfaces, no enhancement of the features studied was observed on the Bands 4 and 5 subtraction images. Geologic and geographic features characterized by minor tonal differences on relatively flat surfaces were enhanced on some of the pseudocolor images.

PREFACE

Research on the application of ERTS-1 imagery to analysis of fault tectonics and earthquake hazards in California is being accomplished by California Earth Science Corporation under contract to the Earth Resources Observation Systems Program (EROS) Office, U.S. Geological Survey. Pseudo-color transformations of selected ERTS images have been prepared under a subcontract to The Rand Corporation. The purpose is to determine whether such transformations enhance the appearance of faults. Several of these transformations and a discussion of their usefulness in the detection and recognition of faults and other features are presented in this report.

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Note: Because of the expense of color photographic reproduction, 35 mm slides of the individual microfiche images and plates 1-3 are only included in copies submitted to the Technical Officer and the U.S. Geological Survey EROS office, Reston, Virginia.

INTRODUCTION

The perspective afforded by ERTS images enables viewing and comparison of major faults in southern California on a regional scale which is not possible on larger scale photography. Fig. 1 shows principal faults and major geographic features overlain on ERTS-1 image 1090-18012 of Band 7, which covers a portion of southern California. This particular image was chosen for enhancement because it shows a number of faults with a wide range of characteristics. The San Andreas fault, the principal active fault in California, crosses the central portion of the image and intersects the prominent northeast trending Garlock fault. The San Andreas and Garlock faults border the Mojave Desert Province. A number of other faults, as well as diverse geologic, geographic and cultural features, can be seen, for example, the San Gabriel and Tehachapi Mountains, several dry lakes and alluvial fans in the Mojave Desert, and the street pattern and density of urban development in the Los Angeles Basin.

One objective of the research is to evaluate the usefulness of pseudocolor transformations in recognizing and locating faults and other geologic, geographic, and cultural features. Several different types of pseudocolor transformations of Bands 4, 5 and 7 of the ERTS image presented in Fig. 1 were prepared and analyzed. Images of Band 6 were not included in our investigation because little new information of geological value is provided by this band. Using the digital tapes, we have generated images of all bands and have found that Band 6 and Band 7 are similar, but geologic structure is somewhat better displayed on Band 7.

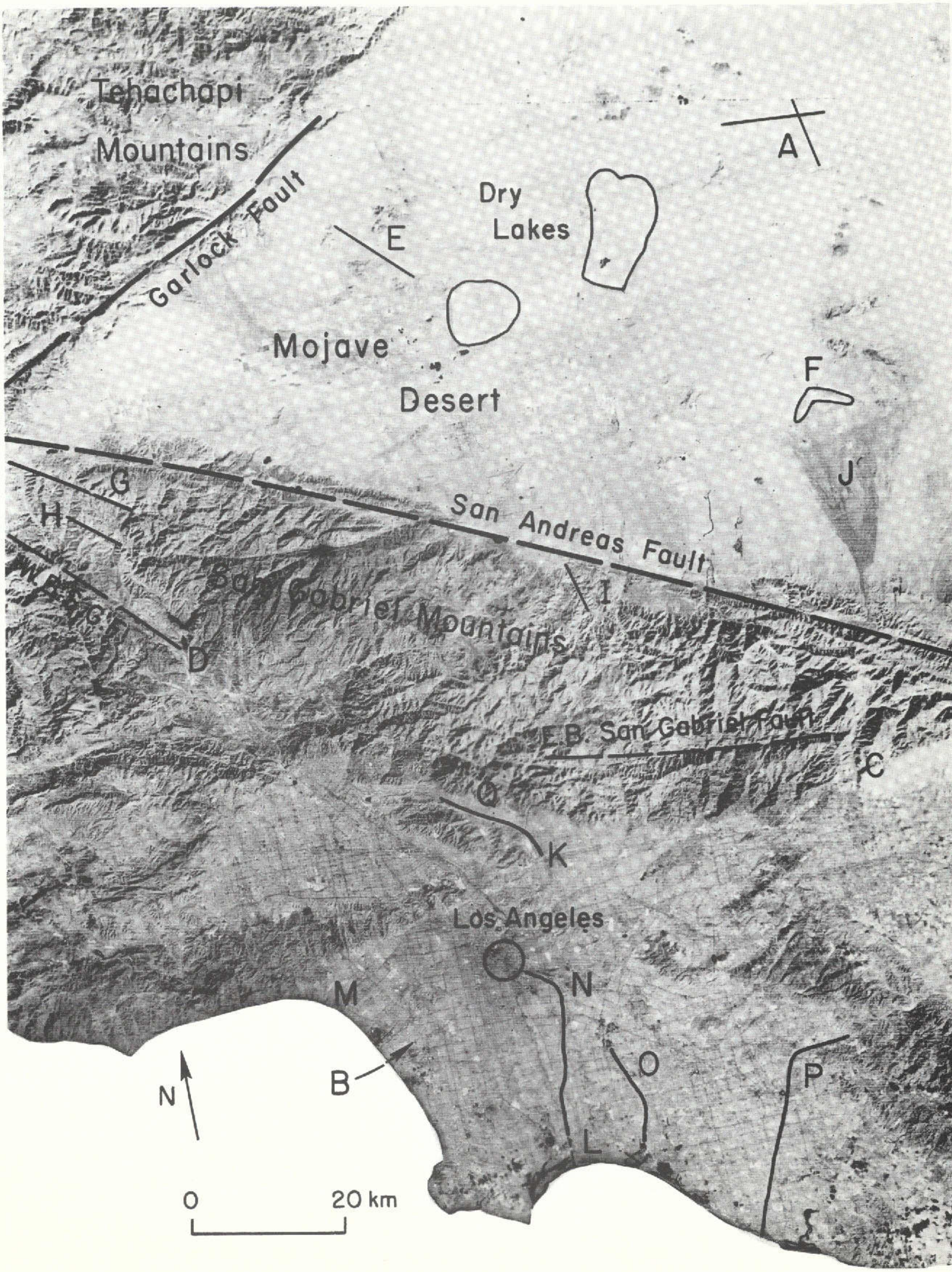

Figure 1 - ERTS-1, Band 7 image 1090-18012 of a portion of southern California. W.B.S.G.F: west branch San Gabriel fault; E.B.: east branch. See text for key to letters.

PHOTOGRAPHIC ENHANCEMENT TECHNIQUES

A number of photographic techniques are available for enhancement of black-and-white imagery. Contrast enhancement is accomplished by expanding a selected narrow density range to cover the gray scale range that can be discriminated by the human eye. Contrast is increased in a limited density range; however, the "highs" and "lows" beyond the selected intensity range are lost in the black and white ends of the gray scale. Fig. 2 illustrates a density vs. log E curve for contrast enhancement; by varying exposure this curve can be shifted to the right or left. A number of contrast enhancements can be made to cover the entire intensity range of the original. Thus, the total information in the original can be enhanced and retained, but not in a single image.

Another technique is extended-range contrast enhancement, which is the increase of contrast over the entire density range of the original (Fig. 2). This is accomplished by use of film having a high maximum density. Although all of the original information may be retained in such an enhancement, the eye cannot discriminate densities over such an extended range; a portion of the highs and lows are lost at any level of illumination. By changing illumination, and hence the eye's adaption, different segments of the density scale can be viewed; thus, a single extended range contrast enhancement can serve as a succession of contrast enhancements.

Transparencies of positive and negative extended range contrast enhancements are used as separations in the pseudocolor process. Slides 2, 5, 8, 9, and 13 and Plate 2 are examples of extended range (high contrast) enhancements used to produce the pseudocolor transformations included in this report. The extreme range from very dark to white gives these images a "harsh" appearance, and no apparent improvement in the ability to discriminate features over the medium contrast originals can be detected. These images have been included to illustrate the individual steps in the production of pseudocolor transformations. Densities are transformed into colors in the pseudocolor images. Because of the eye's ability to discriminate hundreds of colors and only about 10 to 15 shades of gray, much more of the density information in the original should be discriminated in a pseudocolor transformation (Sheppard et al., 1969). Pseudocolor transformations of the Band 4, 5, and 7 images are presented in Slides 3, 6, and 10.

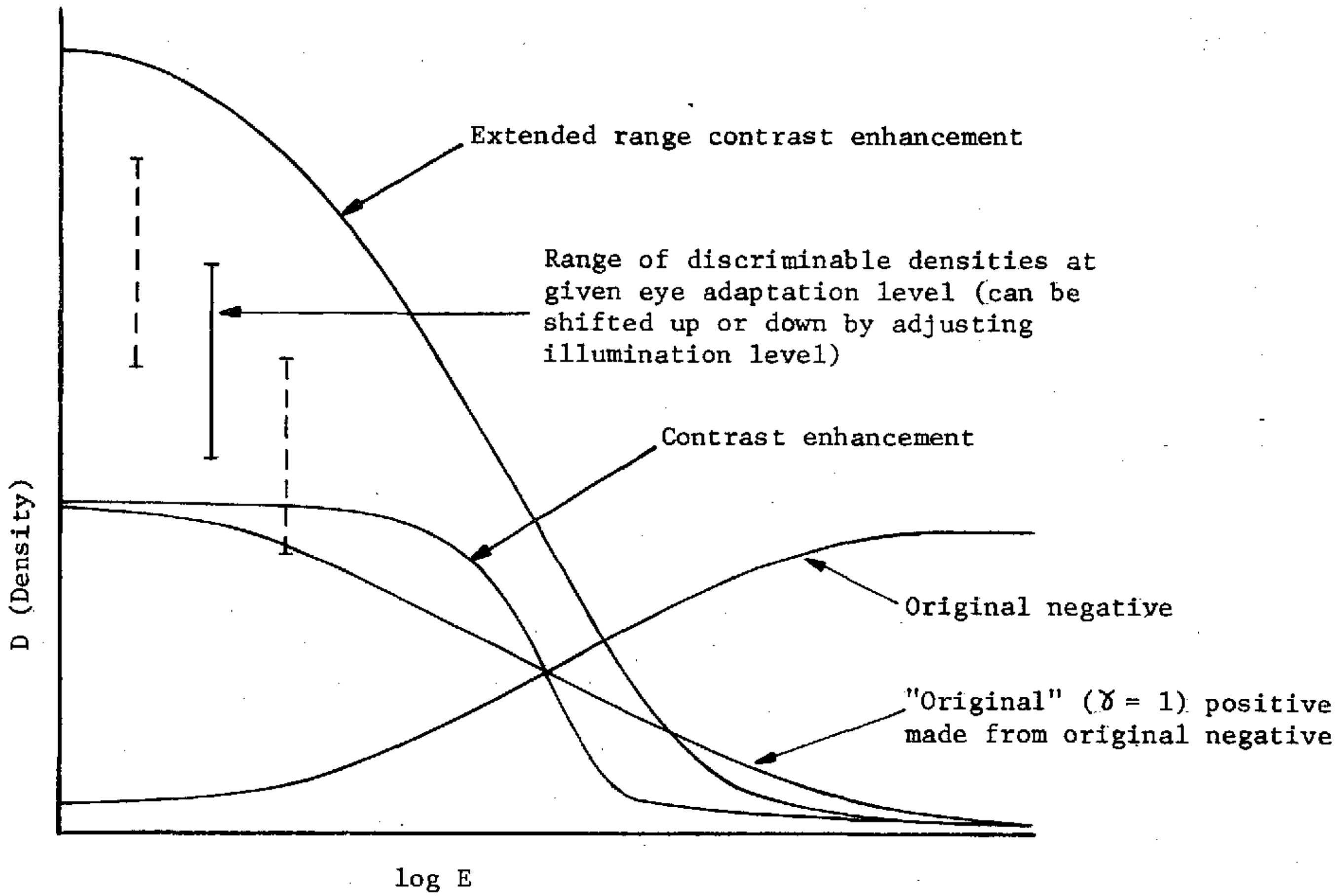

Figure 2 - Density versus log E (energy reaching film) curves for original positive and negative, contrast enhancement, and extended range contrast enhancement.

Another type of image enhancement can be used when two images, differing in time or wavelength, are available. A subtraction of two such images displays differences between the images; for example, a subtraction of two ERTS bands displays differences in the spectral characteristics of the scene. The subtraction, a black-and-white image, can be further enhanced by pseudocolor transformation. Slides 11 and 12 are original and pseudocolor images of a subtraction of the Band 4 and 5 images.

The details of the procedure to produce the pseudocolor transformations and subtraction images are presented in Appendix 1.

DISCUSSION OF IMAGES

Major structural features, such as the San Andreas and Garlock faults, are well displayed in images of all bands, and the enhancements offer no obvious advantages. In the case of less obvious geologic and geographic features, however, there are distinctions between the originals and pseudocolor transformations. In order to define these differences, a number of different types of features were compared in the originals and pseudocolor transformations. Admittedly, there is considerable subjectivity in this comparison. The pseudocolor may bring out a feature that was not seen in the original, but commonly it may be seen on re-inspection of the original after first being noticed on the pseudocolor.

As an independent evaluation of our comparisons, a test was devised and presented to 33 students in a field geology class at the University of California at Los Angeles. The results of the student test are included with our evaluations in Table 1.

The students were asked to indicate the relative appearance of six representative geologic and geographic features on 8 x 10-inch transparencies of originals and pseudocolor transformations of Bands 4, 5, and 7; the images were viewed on light tables. Hinged transparent overlays with letters A through F, shown as on Fig. 1, were provided to direct attention to the following individual features:

- A. Highways which radiate from Kramer Junction in the Mojave Desert.
- B. Street pattern in the Los Angeles Basin.
- C. East branch of San Gabriel fault, an alignment of saddles and straight canyons directly north of the San Gabriel River.
- D. West branch of San Gabriel fault, a lineament having a lighter tone than the background.
- E. Margin of light-toned area in the Mojave Desert.
- F. El Mirage Dry Lake, situated directly north of a prominent alluvial fan.

The students indicated the appearance of the above features on the following subjective scale:

- 1 Cannot be seen
- 2 Indistinct or difficult to see (poor)
- 3 Fairly easy to see (fair)

	BAND 4		BAND 5		BAND 7		BANDS 4-5 Subtractions	
	Orig.	P.C.	Orig.	P.C.	Orig.	P.C.	Orig.	P.C.
FAULTS AND LINEAMENTS								
West branch of San Gabriel fault (D)	3 (3.6)	4 (3.7)	4 (4.1)	5 (3.9)	4 (4.1)	5 (4.1)	3	2
East Branch of San Gabriel fault (C)	2 (3.1)	2 (3.1)	2 (3.8)	3 (3.6)	3 (4.1)	4 (3.9)	3	3
Libre Mountain fault (G)	3	3	4	3	4	3	1	1
Clearwater fault (H)	2	2	2	2	3	3	1	1
Little Rock lineation((I)	3	2	4	3	5	4	1	1
Average value for faults and lineaments	2.6	2.6	3.2	3.2	3.8	3.8	1.8	1.6
NATURAL FEATURES ON MOJAVE DESERT								
South margin of light toned area (E)	1 (1.2)	2 (1.7)	2 (1.4)	3 (2.2)	2 (1.5)	3 (2.4)	1	1
El Mirage Dry Lake (F)	5 (4.5)	5 (4.7)	4 (3.4)	4 (4.1)	2 (2.5)	1 (2.1)	4	5
Alluvial fan (J)	4	3	4	3	4	5	2	2
LAND USE AND CULTURAL FEATURES								
Highways which radiate from Kramer Junction (A)	1 (1.4)	2 (2.2)	2 (1.8)	3 (3.6)	3 (2.3)	4 (3.6)	1	1
Street pattern in the Los Angeles Basin (B)	1 (2.0)	2 (2.3)	2 (2.2)	3 (2.5)	4 (4.3)	5 (4.5)	1	1
Density of urban development in Los Angeles region (K-M)	1	1	1	1	4	5	1	1
Concrete-lined drainage channels and new, unplanted freeway routes (N-Q)	4	2	4	3	2	2	1-2	1-2
Cultivated fields in Mojave Desert	4	4	5	5	3	3	2	2

TABLE 1 - Summary of results of analysis of geologic and geographic features which appear on originals and pseudocolor transformations of ERTS images. Letters (A-F) refer to features on Fig. 1. Subjective scale of 1, (not seen) to 5, (very distinct) has been applied. The results of the student test analysis are included below the values assigned by the principal author . P.C.: pseudocolor image.

4 Distinct and easy to see (good)

5 Very distinct and extremely easy to see (excellent)

Additional information on the test is given in Appendix 2. The results are summarized on Figs. 3 to 5, in which the mean values and standard deviations of the observations are shown above the individual histograms. The student "t" distribution was used to test for differences in the mean values of observations of original black-and-white and pseudocolor images. In cases where the test revealed a difference in the mean values, the limits in the differences at 95% confidence level were calculated. The limits in the differences in the means, if any, are indicated between the histograms for the original and pseudocolor images.

The students taking the test felt that it was difficult to assign a subjective evaluation without comparing all of the images at once. This was not considered practical, and resulting discrepancies should have been averaged out by the number of students taking the test. The principal author of this report made a comparison of the images and applied the same subjective scale, except that all of the images were laid out and compared together. This method, while providing a more direct comparison of the value of images for detecting different kinds of features, makes it difficult to maintain a constant "feel" for the values of the subjective scale. The procedure was repeated and variations of 1 to 2 units in the subjective scale were obtained. This is comparable to the standard deviations of 0.5 to 1.1 obtained in the student test. In some cases the principal author's evaluation of the images differed significantly from the students; this can possibly be attributed to two factors: (1) the former observed the two images simultaneously, while the students viewed them sequentially, and (2) the senior author had had experience in evaluating pseudocolor transformations and the students had not. These factors were both found to be significant in a short series of tests conducted by the Rand group with medical images. It was found that the efficacy of pseudocolor transformations is increased if the familiar black-and-white original is also present and if the observer has had some experience in evaluating pseudocolor images.

Our evaluations are summarized on Table 1; the results for those features on the student test are included for comparison. The appearance of individual features on the images and comparison of the principal author's evaluation with the student test results are discussed below.

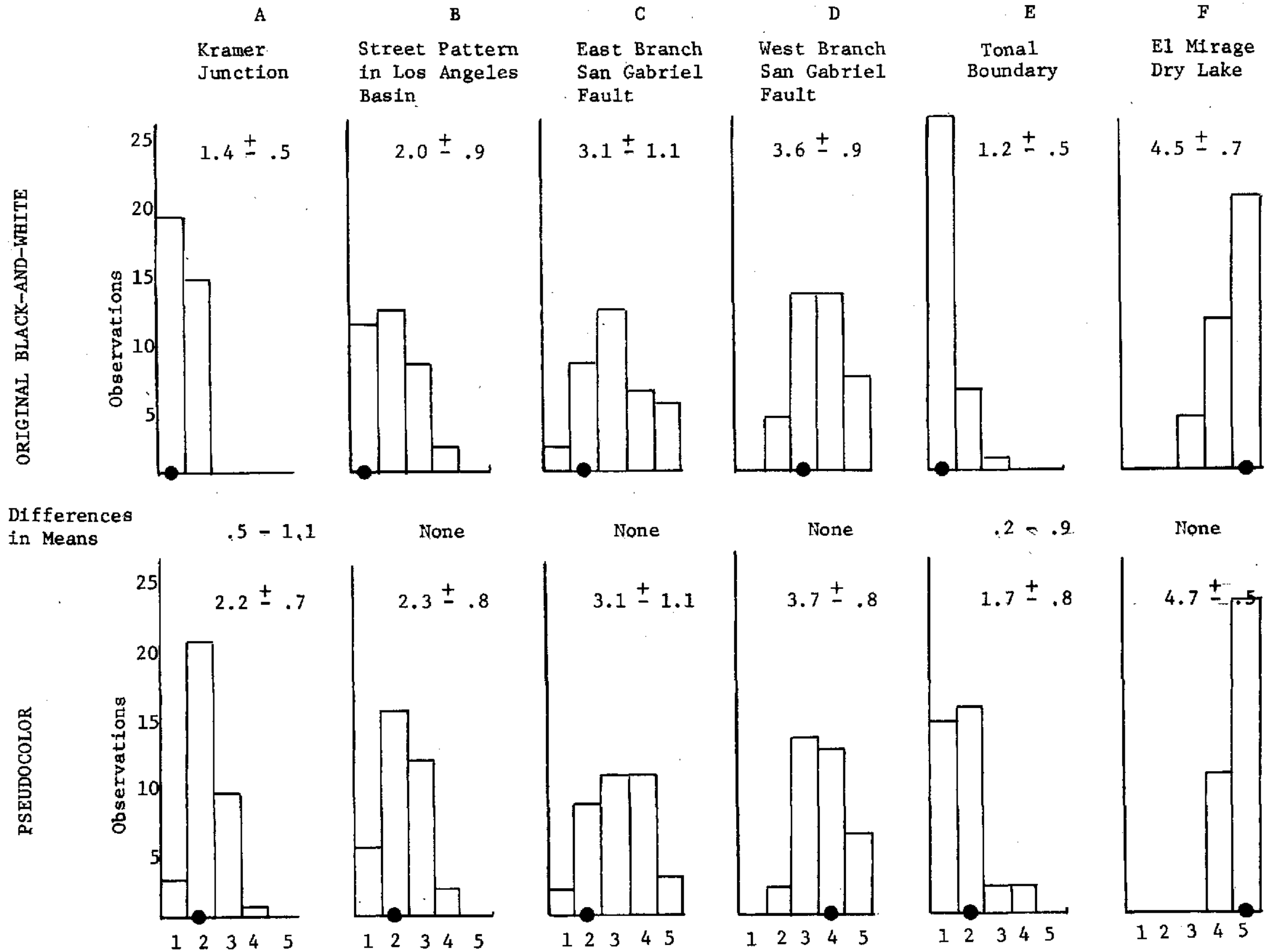

Figure 3 - Histograms showing results of student test comparing original and pseudocolor ERTS images of Band 4. Dots on histogram indicate principal author's evaluation.

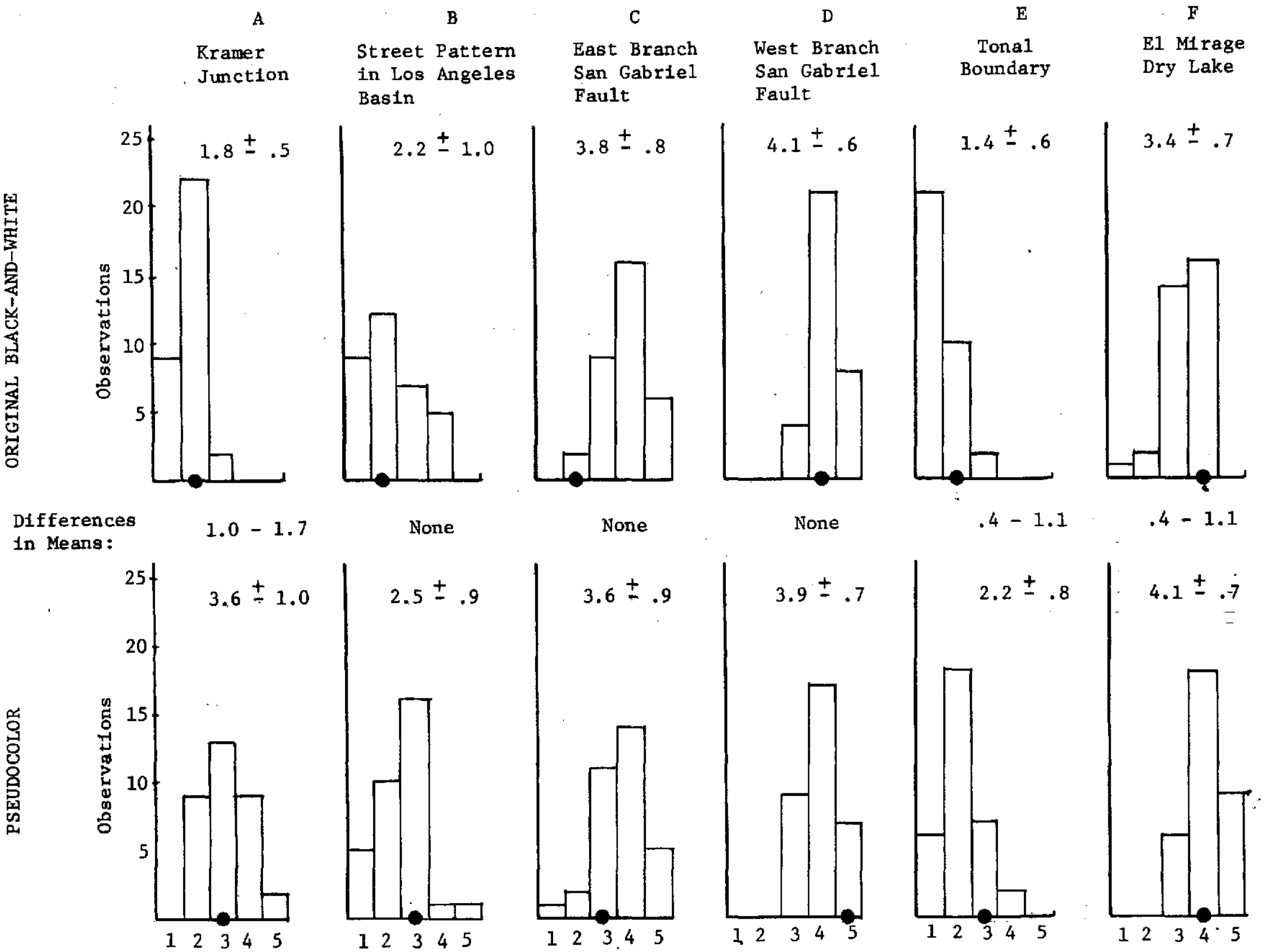

Figure 4 - Histograms showing results of student test comparing original and pseudocolor ERTS images of Band 5. Dots on histogram indicate principal author's evaluation.

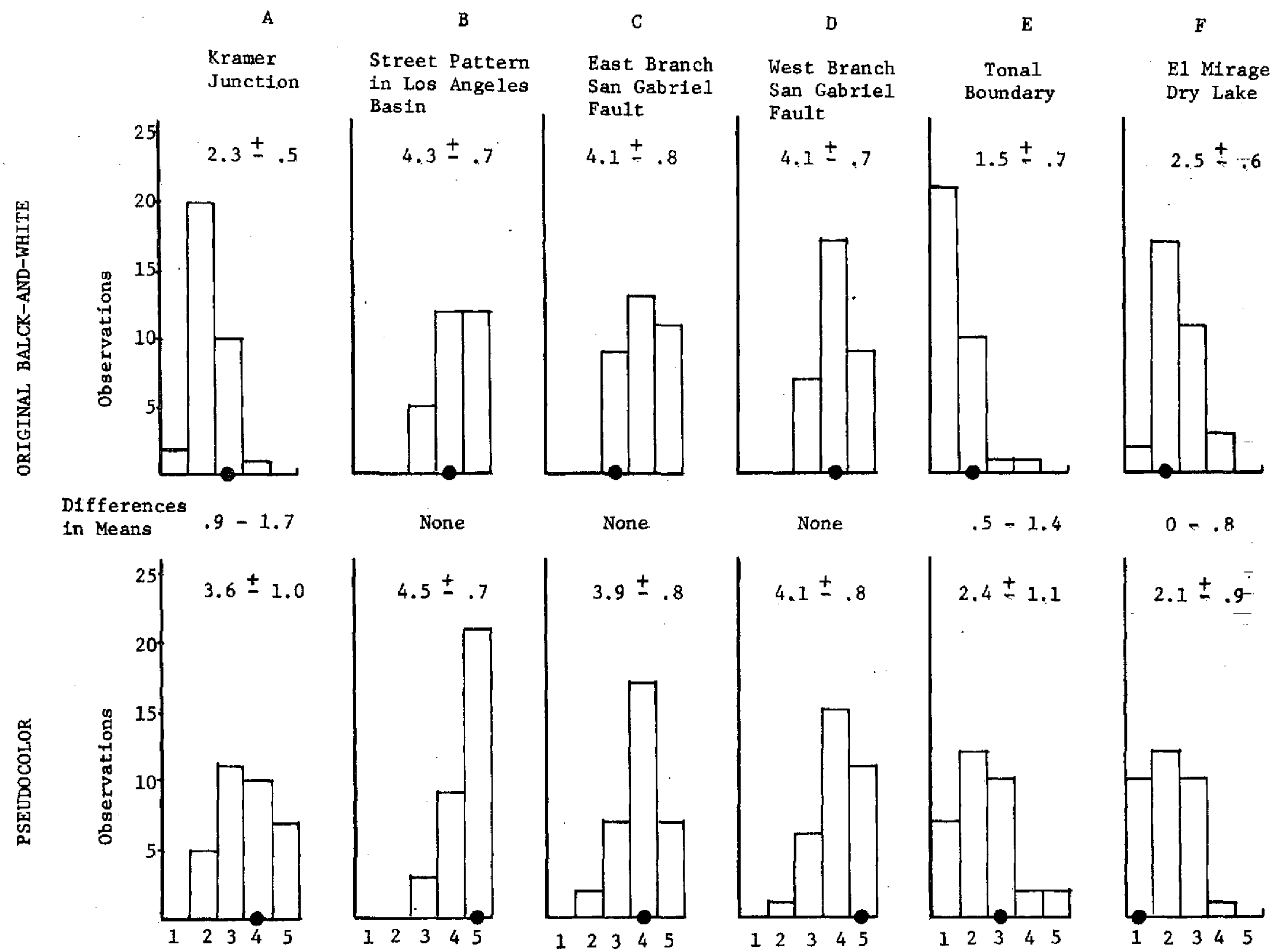

Figure 5 - Histograms showing results of student test comparing original and pseudocolor ERTS images of Band 7. Dots on histogram indicate principal author's evaluation.

Faults and Lineaments

The San Gabriel fault trends east-west to northwest across the central portion of the image shown in Fig. 1. This fault is presently inactive; the central portion of its trace cannot be seen on Fig. 1 because it is covered by younger, unbroken sediments (Ehlig, 1973). The western branch (D in Fig. 1) consists of two or more subparallel faults separating slivers of gneiss from sedimentary rocks to the east. A narrow band of breccia of Miocene to Pleistocene age occurs along the east side of the fault (Crowell, 1950); the breccia rapidly grades into finer grained rocks to the east. The trace of the west branch of the San Gabriel fault appears as a northwest trending light gray line on the ERTS image originals. In our opinion, the west branch of the San Gabriel fault is enhanced somewhat by the pseudocolor transformations, but the student test revealed no significant difference. The west branch of the San Gabriel fault can be seen (although not enhanced) on the Bands 4 and 5 subtraction images, but it is less obvious on the pseudocolor image than on the original.

The east branch of the San Gabriel fault (C on Fig. 1) trends east-west through pre-Cenozoic basement rocks of the San Gabriel Mountains. The prominent topographic expression of the fault trace is due to an alignment of deeply eroded canyons and low saddles. Alluvium shed from higher terrain to the north has displaced drainage channels, and canyon bottoms tend to lie south of the main fault zone (Ehlig, 1973). The topographic expression of the east branch of the San Gabriel fault (C on Fig. 1) is best illustrated on the pseudocolor image of Band 7; the sharpness of the topographic expression improves from west to east. We believe that the appearance is enhanced on the pseudocolor images of Bands 5 and 7, but the results of the student test do not support this conclusion. No significant difference in the appearance of the east branch of the San Gabriel fault can be seen on the Band 4 and 5 subtraction images.

The Libre Mountain fault appears as a northwest trending lineament between lighter and darker gray terrane on the ERTS image originals (G on Fig. 1). The light gray area to the north is underlain by granitic and metamorphic basement rocks, and the darker gray areas to the south are underlain by Pliocene sedimentary rocks (Jennings and Strand, 1969). The fault appears to be less obvious in the Bands 5 and 7 pseudocolor images; no significant difference can be detected between the Band 4 original and pseudocolor images. Neither this fault nor the following fault can be detected on the Bands 4 and 5 subtractions.

The northwest segment of the Clearwater fault (Jennings and Strand, 1959) is situated entirely in sedimentary rocks (H on Fig. 1). This feature is best displayed on the Band 7 image, and no enhancement of this feature is discernible on the pseudocolor image.

Segments of Little Rock Creek and Bare Mountain Canyon appear as a prominent lineament on the ERTS image (I on Fig. 1). Published geologic maps (Jennings and Strand, 1969) do not show a fault along this lineament. The lineament is situated in basement complex consisting of highly fractured and sheared granitic and metamorphic rocks which lack persistent foliation direction or prominent jointing. Considerable field work would be required to map the distribution of rock types and structure in sufficient detail to determine the nature of this lineation. Our reconnaissance examination was inconclusive and the existence of a fault could not be established. Regardless of its origin, it is typical of lineaments seen in ERTS images. Our analysis indicates that this lineament is more difficult to detect on the pseudocolor images than on the originals.

Natural Features on the Mojave Desert

Slight differences in tone appear in images of the Mojave Desert because of variations in vegetation, soil and rock type. The faint line at E (Fig. 1) corresponds to a vegetation change. South of the tonal boundary (darker region), vegetation consists mostly of brown sage brush spaced 0.6-2 m, but dark green Joshua trees and creosote bushes are interspersed throughout the sage. The lighter region to the north supports brown sage spaced 2-4 m; dark green Joshua trees and creosote bushes are rare to absent. In both areas the soil is light brown, fine-grained sand and silt with scattered granules and pebbles. The lighter tone is believed to result from the sparser sage and lack of dark green Joshua trees and creosote bushes.

This boundary is barely detectable on the originals, and our analysis indicates a consistent one step enhancement of its appearance in the pseudocolor transformations of all bands. The student test also indicated a .2 to 1.4 enhancement in the pseudocolor images. This feature is not visible in the Band 4 and 5 subtractions.

Large dry lakes appear as prominent light areas on Band 4 originals, and even more prominent on the Band 4 and 5 subtraction; they are somewhat less prominent on Band 5 and 7 images. El Mirage Dry Lake (F on Fig. 1) was included on the student test, and no significant improvement in the pseudocolor image over the Band 4 original was noted, but the student test shows a .4 to 1.1 improvement of the pseudocolor over the Band 5 original. The principal author did not believe that this lake could be differentiated on the Band 7 pseudocolor images, but it was seen by a majority of the students. The test results also indicate that it is more difficult to detect in pseudocolor than in the Band 7 original. On the other hand, El Mirage Dry Lake is further enhanced in the pseudocolor image of the Band 4 and 5 subtraction.

A prominent dark alluvial fan can be seen at the east edge of the image (J on Fig. 1). This feature is most prominent on the Band 7 pseudocolor image. It is less prominent on Bands 4 and 5 pseudocolor images than on the originals, and is barely detectable on the Band 4 and 5 subtraction images. The dark tone of the fan relative to the adjacent desert surface results from a thin veneer of dark gray Pelona schist debris deposited by mudflows, notably one of 1941 (Sharp and Nobles, 1953).

Land Use and Cultural Features

Our study indicated a consistent one step enhancement in the appearance of highways which radiate from Kramer Junction (A on Fig. 1) on the pseudocolor transformations of all bands. The student test indicated a similar enhancement of .5 to 1.7. This feature appears most prominently on the pseudocolor transformation of Band 7. Similar results were obtained in our study of street patterns in the Los Angeles Basin (B on Fig. 1). In contrast, the student test revealed no significant difference in the appearance of street patterns on originals and pseudocolor images. Streets and roads are not visible on the original and pseudocolor transformation of the Band 4 and 5 subtraction.

The dense urban development of downtown Los Angeles appears as a darker gray area on the Band 7 original. Areas of less intensive development fade into lighter shades in the peripheral areas. Darker gray areas corresponding to outlying urban centers in Pasadena (K on Fig. 1), Long Beach (L), and Santa Monica (M) can also be differentiated and are most prominently displayed on the pseudocolor transformation of Band 7. These urban areas are not detectable on the originals and pseudocolor transformations of the other bands, or in the

Band 4 and 5 subtractions.

The concrete-lined channels of the Los Angeles (N on Fig. 1), San Gabriel (O), and Santa Ana (P) rivers appear as white lines on the originals of Bands 4 and 5. A recently completed segment of the Foothill Freeway (Q) has a similar appearance. Older segments of the freeway system do not appear as white lines because they become darker with use and originally barren land along the freeways is planted. These light-colored linear features are less well displayed on Band 7 and all the pseudocolor images. Only the new segment of the Foothill Freeway can be seen in the Band 4 and 5 subtractions.

Cultivated fields in the Mojave Desert appear as rectangles with varying shades of gray on the originals and as different hues on the pseudocolor images. These features are best displayed on Band 5 images; the pseudocolor images offer no obvious advantages in viewing these features.

CONCLUSIONS

Five representative faults and lineaments appearing on the ERTS images of the Los Angeles County area were studied. The faults appear on the originals as light lines in contrast to their surroundings, as contacts between areas of slightly different tone, and as topographic lineaments. Band 7 images were found to be the best for the detection of faults and lineaments. Some of the structural features appeared to be enhanced on the pseudocolor transformations, others were not. The average value on the subjective scale of appearance for the five faults and lineations is the same for the originals and pseudocolor transformations. In our analysis, two fault segments were believed to be enhanced, but no significant difference between the original and pseudocolor images was reported by the students. We conclude that the pseudocolor transformations offer no advantages over the original images in the recognition of faults and lineaments in the ERTS images studied.

With the exception of dry lake surfaces, the Bands 4 and 5 subtraction images were less satisfactory for the detection of the individual features considered. Some geographic and geologic features such as light-colored drainage channels, new freeway alignments, cultivated fields, dry lakes and alluvial fans are either unenhanced or more difficult to see on the pseudocolor transformations. In contrast, our observations, as well as the student test, indicate that the pseudocolor images provide significant enhancement of road intersections, street patterns, slight tonal differences and density of urban development. These results indicate that pseudocolor images enhance certain features characterized by minor tonal differences on relatively flat surfaces.

APPENDIX 1

Method of Producing Pseudocolor Transformations and Subtraction Images

A complete explanation of the method for producing a full spectral gamut of colors in Ektacolor using only two separations and a discussion of colorimetry, film calibration and sensitometry appears in Stratton and Gazley (1971). The method described by Stratton and Gazley has been improved to allow emulsion-to-emulsion printing in all steps of the process.

The current photographic technique for the production of a pseudocolor transformation of an image is shown in the schematic diagram (Fig. 6). With the exception of the originally supplied 70 mm positive, the films are 8 x 10-inch sheet; the 8 x 10 inch sheets are pre-punched and contact printed emulsion-to-emulsion in a pin-register vacuum frame to provide the required registration.

The details of the procedure are as follows:

1. The medium contrast black-and-white intermediate, 0_i, is made from the supplied 70 mm positive image by projection printing onto Kodak commercial film 4127 and developed in DK 50 diluted 1:1. Exposure and developing time are such as to yield a density range of approximately .50 to 1.50. Slides 1 and 4 are medium contrast originals of Bands 4 and 5; Slide 7 and Plate 1 are originals of Band 7.

2. The high contrast black-and-white positive separation, 0_p, is printed from 0_i on Kodak contrast process ortho film 4154 and developed in D-11 diluted 1:1. Exposure and developing time are such as to yield a density range of approximately .30 to 2.70. Plate 2 and Slide 8 are high contrast positive separations of Band 7; Slides 2 and 5 are high contrast positive separations of Bands 4 and 5.

3. The high contrast black-and-white negative separation, 0_n, is printed from 0_i on Kodak high speed duplicating film 4575 and developed in DK 50 diluted 1:1. Exposure and developing time are such that the density range is approximately the same as 0_p. Slide 9 is a high contrast negative separation of Band 7.

4. To obtain the final pseudocolor transformation, 0_n and 0_p are printed onto a single sheet of Kodak Ektacolor print film 4109. The 0_n exposure is accomplished with a red light source (tungsten lamp plus wratten 23A filter), and subsequently the 0_p exposure is accomplished with a blue light source

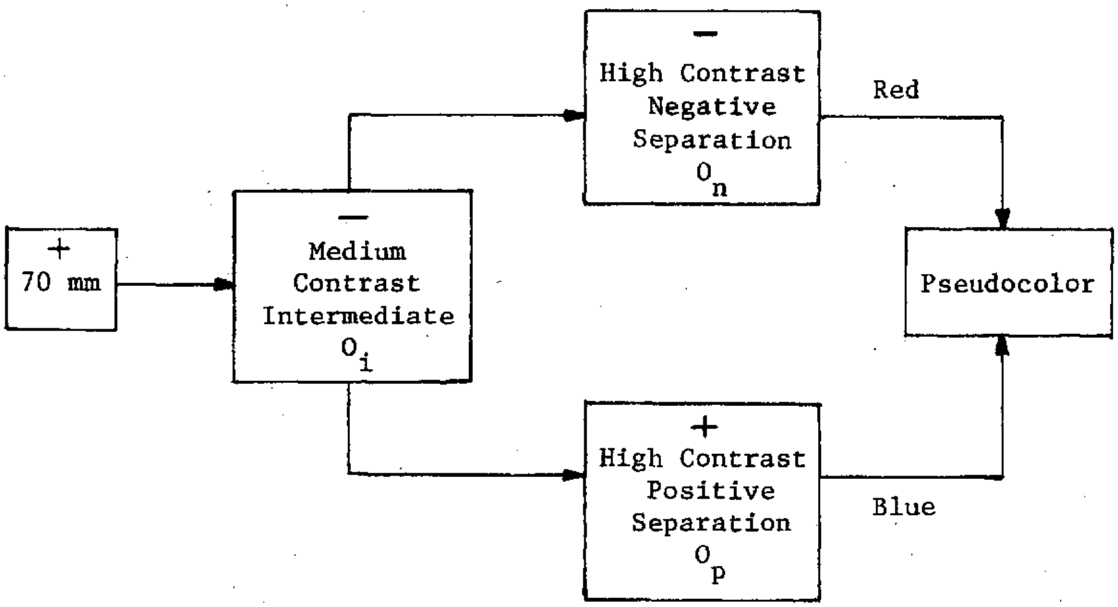

Figure 6 - Diagram of two separation pesudocolor transformation process.

(tungsten lamp plus wratten 47A filter). The exposures of each separation are controlled to yield a transformation which contains all the spectral hues. The light areas in the original 70 mm positive black-and-white image appear as red, the medium areas as yellow-green, and the dark areas as blue. The Ektacolor film is developed in unmodified Kodak C-22. Plate 3 and Slide 10 are pseudocolor transformations of Band 7; Slides 3 and 6 are pseudocolor transformations of Bands 4 and 5.

The intermediate 0_i required for a pseudocolor transformation of subtraction of two different spectral bands of the same image is produced as follows:

1. A positive image is printed on 8 x 10 inch commercial black-and-white film from one band and a negative image is printed from the other band. The film is exposed and developed to a gamma of approximately one.

2. These 8 x 10 images are positioned in register with rear illumination and copied photographically (not by contact), and developed to produce the medium black-and-white intermediate 0_i with a nominal density range of .50 to 1.50. Slide 11 is a medium contrast separation of a Band 4 and 5 subtraction.

3. The pseudocolor transformation is produced from the 8 x 10 intermediate 0_i following the method outlined above in steps 2, 3, and 4. Slide 13 is a high contrast separation for a Band 4 and 5 subtraction, and Slide 12 is the pseudocolor transformation for the Band 4 and 5 subtraction.

APPENDIX 2

Details of Student Test

Transparencies were placed at 12 stations on two rows of light tables. Station numbers and corresponding numbers of slides and plates in this report are as follows:

Station Numbers	Slide Numbers	Plate Numbers	Band	Description
1, 10	1	-	4	Original
2, 7	3	-	4	Pseudocolor
3, 11	4	-	5	Original
4, 8	6	-	5	Pseudocolor
5, 12	7	1	7	Original
6, 9	10	3	7	Pseudocolor

Twelve students were assembled, one at each station, and the following written instructions were given:

A number of stations with ERTS images of a portion of southern California have been made up. The purpose is to test your ability to detect different features on different types of images. It is important that you visit the stations in the order indicated on the answer sheet; do not go out of turn or look at adjacent stations. You will be allowed 2 minutes at each station. Do not waste time looking for features which are difficult to see on some images. Lettered overlays have been prepared to direct your attention to the particular features.

Indicate your impression of how well these features can be seen on the images by placing numbers 1 to 5 in the appropriate boxes for each image and feature. Use the following subjective scale:

1 Cannot be seen
2 Indistinct or difficult to see (poor)
3 Fairly easy to see (fair)
4 Distinct and easy to see (good)
5 Very distinct and extremely easy to see (excellent)

It was found that more than two minutes were required for each of the first few images; however, as the students became more familiar with the test, less time was required.

The sequence of viewing individual images could have influenced the student's opinion of the appearance of individual features. To avoid this bias, the students visited the stations in different sequences. The different sequences of stations and the number of students who visited each sequence are tabulated as follows:

Number of Students	Station Sequences						Number of Students	Station Sequences					
4	1	2	3	4	5	6	1	6	5	4	3	2	1
1	2	3	4	5	6	1	1	5	4	3	2	1	6
1	3	4	5	6	1	2	1	4	3	2	1	6	5
1	4	5	6	1	2	3	1	3	2	1	6	5	4
1	5	6	1	2	3	4	1	2	1	6	5	4	3
1	6	1	2	3	4	5	1	1	6	5	4	3	2
2	7	8	9	10	11	12	1	12	11	10	9	8	7
2	8	9	10	11	12	7	1	11	10	9	8	7	12
2	9	10	11	12	7	8	1	10	9	8	7	12	11
2	10	11	12	7	8	9	1	9	8	7	12	11	10
2	11	12	7	8	9	10	1	8	7	12	11	10	9
2	12	7	8	9	10	11	1	7	12	11	10	9	8

It is believed that the sequence of visiting stations was sufficiently random to eliminate any "learning bias" in favor of the pseudocolor images.

Each of the students was given a standard color blindness test; no evidence of color blindness was detected.

REFERENCES

Crowell, J.C. (1950) Geology of Hungry Valley Area, Southern California; Amer. Assoc. Petrol. Geol., Bull., V. 34, p. 1623-1646.

Ehlig, P.L. (1973) History, Seismicity and Engineering Geology of the San Gabriel Fault; in Geology, Seismicity, and Environmental Impact, Assoc. of Engineering Geologists Special Publication, p. 247-251.

Jennings, C.W. and Strand, R.G. (1969) Los Angeles Sheet of Geologic Map of California; Calif. Div. Mines and Geology.

Sharp, R.P. and Nobles, L.H. (1953) Mudflow of 1941 at Wrightwood, Southern California; Geol. Soc. Am. Bull., V. 64, p. 547-560.

Sheppard, J.J., Stratton, R.H. and Gazley, C. Jr. (1969) Pseudocolor as a Means of Image Enhancement; The Rand Corporation, Santa Monica, California, P-3988.

Stratton, R. and Gazley, C. Jr. (1971) A Photographic Technique for Image Enhancement; Pseudocolor Two Separation Process; The Rand Corporation, Santa Monica, California, R-597-PR, 36 p.