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Enhancement of Linear Features by Rotational Exposure*

The method, based on overlaying positive and negative films, resulted in enhancement of both man-made and geologic features on satellite acquired images.

Abstract: *A method for the photographic enhancement of linear features is presented which involves overlaid positive and negative films of the image to be enhanced. These films are held in perfect registration and through these a film is exposed by a low-angle light source. The results from two areas show significant enhancement of linear features due to urban and agricultural development, and to geologic structure or other phenomena.*

Introduction

The analysis of remotely sensed data commonly involves the search for linear and curvilinear features which may be related to deep or near surface geological phenomena (Reeves *et al.*, 1975). On a photograph such linear elements are usually of two types: (1) the linear feature is markedly different from the material on either side of it in texture, tone, or hue; or (2) the linear feature is defined by a contrast in the texture, tone, or hue of the areas on either side of it. While features of the first type are usually obvious, features of the second type may be very subtle in character making many lineaments controversial in that different observers often cannot agree on the existence let alone the meaning of such linear elements. A common method of enhancement of such linear features involves the use of two films which are overlaid with a slight offset. This offset doubles the width or number of linear elements in the photograph and makes them more obvious (Marrs, 1974). The technique suffers from a consistent observer bias in that only those linear features which are approximately at right angles to the direction of offset are enhanced. A method for converting a continuous tone image to one composed of linear elements was first developed by the Eastman Kodak Company (1966) and was later used by the Army Map Service as the "pictoline process" (1969). This paper presents this simple method of photographic enhancement of linear and curvilinear features based on the contrast of density of areas in the photograph. The system works well for linear elements of both the first and second type.

The system involves the use of two transparencies, one positive and one negative, which are maintained in perfect registration to eliminate the bias due to offsetting. The transparencies are placed together with the emulsion up on the top film and with the emulsion down on the lower film. The two transparencies will cut out virtually all light in the direction normal to the film, but allow a small line of light through the film by means of oblique illumination. The light will thus pass through only at the boundaries of light and dark areas. The registered pair of films is placed upon an unexposed negative film and, when illuminated from an angle, light passing between the emulsion of the transparencies exposes the film below (Figure 1).

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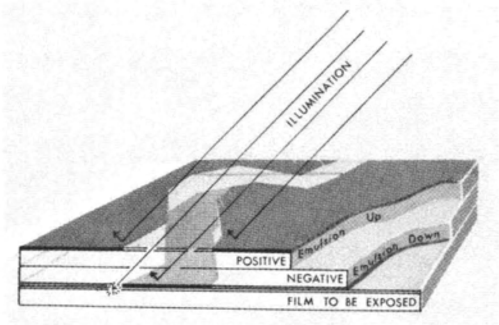

FIG. 1. Schematic diagram showing the enhancement process using a positive and negative transparency overlaid. While no light will pass through normal to the film surfaces, oblique illumination allows light through to expose the film underneath.

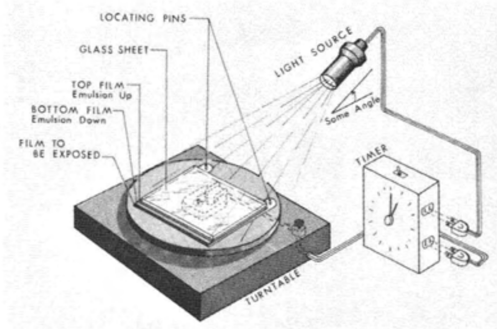

FIG. 2. Schematic drawing of the turntable and illumination system used in this study. The distance and angle of the light source from the turntable may be varied to obtain sharper and thinner or softer and wider lines in the resulting enhanced negative.

PROCEDURE

Our study uses Landsat photographs from two well-known areas in southern California. Positive and negative transparencies were carefully registered on a light table and held in place by the use of three registration pins and tabs. With the emulsions separated from each other, the pair was laid over a fine-grained high-contrast film and placed on a 78 rpm phonograph turntable. Rotation is introduced so that, whatever the direction of boundaries between light and dark areas, at some time they are aligned to expose the underlying film. Illumination was from an angle of 45 degrees with a tensor lamp located 3.5 feet from the turntable. Exposure times averaged 30 seconds, a time sufficient for good exposure and long enough to ensure a large number of turns of the turntable to eliminate unevenness in the exposure (Figure 2).

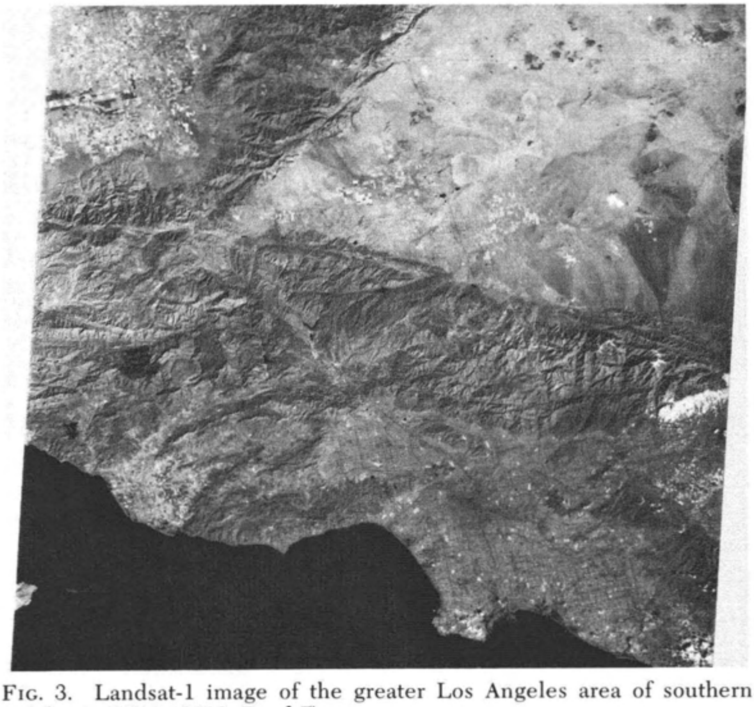

FIG. 3. Landsat-1 image of the greater Los Angeles area of southern California (1090-18012, Band 7).

Materials

Landsat photograph #1090-18012 of the Los Angeles area was selected due to the obvious linear geologic and cultural features in the region (Campbell, 1976) and Skylab photo 87-111 in the southern California batholith was chosen because of the excellent joint and fault patterns of many scales which occur there (Lamar and Merrifield, 1974a, 1974b).

Two types of film were used in the study. Kodak 6127 Professional film was used for general copy work due to its good reproductive character, fine grain, and negligible shrinkage. Kodak D-19 developer was used with this film to provide a favorable contrast with the negative. Kodak Kodalith film was used for its high contrast and the control it allows of the overall density of the negative. Standard Kodalith developer was used with this film. Copying and reproduction were done under an enlarger by standard procedures.

The turntable was a standard model variable speed phonograph run at 78 rpm and was illuminated by a high-intensity lamp connected to a timer.

Results

Figure 3 shows the area of the transverse ranges in southern California and includes areas of urban and agricultural interest as well as a number of major and well-known lineaments of geologic interest. The major faults are the San Andreas and the Garlock faults which are obvious, but many other lineaments are defined by differences in the texture or tone of the photograph. Figure 4 shows the same scene enhanced by the method described. Here linear features show up as dark on a white background or in a few places as light lines separating areas of texture. The most obvious enhancement lies in the drainage involving ridges and valleys which stand out well. Roads and agricultural plots show up strongly and directly on the photographs. Linear features of tectonic interest are characterized by light lines or by zones which separate areas of different texture in the enhanced photograph. In Figure 5, the major faults of the area are plotted for comparison with the enhanced photograph. In virtually every case these faults are more obvious on the enhanced photo than on the original (Figure 3).

The second study area involves an area east of San Diego in the southern California batholith (Skylab photo 87-111, Figure 6). The enhanced image (Figure 7) and its

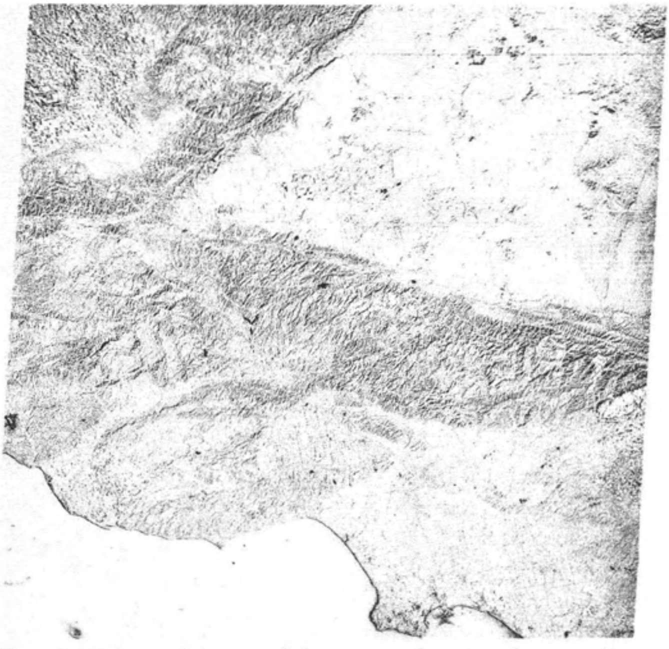

FIG. 4. Enhanced image of the greater Los Angeles area. Linear features associated with systems of highways and with agriculture generally stand out as lines of dark spots, and lineaments of geologic interest as light lines or as linear zones separating areas of different texture.

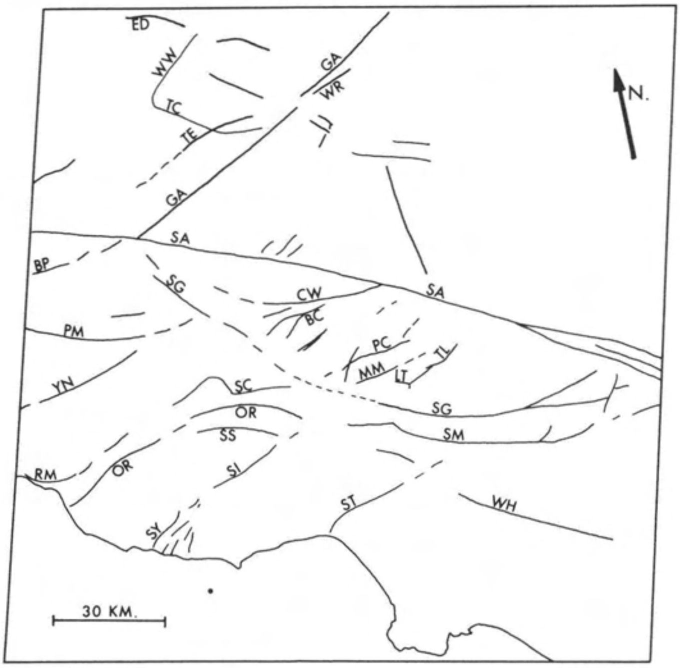

FIG. 5. Fault map of the greater Los Angeles area pictured in Figure 4. Faults include: BC Bee Canyon, BP Big Pine, CW Clearwater, ED Edison, GA Garlock, LT Lone Tree, MM Magic Mountain, OR Oak Ridge, PC Pole Canyon, PM Pine Mountain, RM Red Mountain Thrust, SA San Andreas, SC San Cayetano, SG San Gabriel, SI Simi, SM Sierra Madre, SS Santa Susana, ST Santa Monica, SY Sycamore, TC Tejon Canyon, TE Tehachapi, TL Transmission Line, WH Whittier, WR Warren, WW White Wolf, YN Santa Ynez; (Jahns, 1954).

negative (Figure 8) greatly emphasize the faults and joint patterns in the area (Figure 9).

In both test cases, the enhancement of linear features is significant, and the method may be useful to any investigators interested in the cheap and rapid enhancement of remotely sensed images using equipment available to almost everyone.

FIG. 6. NASA Skylab image number 87-111.

FIG. 7. Processed Skylab photo 87-111 shows significant enhancement of linear features related to faults and to joint sets within the southern California batholith.

FIG. 8. The negative of the enhanced image in Figure 7 shows the same features, but tends to emphasize the larger faults over joint related features.

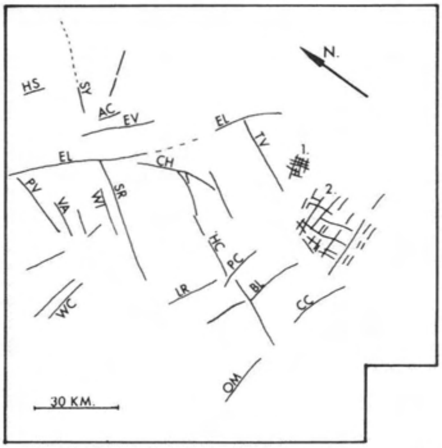

FIG. 9. Fault and joint map of part of the southern California batholith pictured in Figures 6, 7, and 8. Faults include: AC Agua Caliente, BL Barret Lake, CC Canyon City, CH Chariot Canyon, EL Elsinore, EV Earthquake Valley, HC Horsethief Canyon, HS Hot Springs, LR Loveland Reservoir, OM Otay Mountain, PC Pine Creek, PV Pamo Valley, SR San Diego River, SY San Ysidro, TV Thing Valley, VA Valle de Los Amigos, WC Warren Canyon, WI Witch Creek, WM Woodson Mountain; (Lamar and Merrifield, 1974a, 1974b). Numbers 1 and 2 indicate two areas of obvious jointing.

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