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ERTS MULTISPECTRAL IMAGE TRANSFORMATIONS FOR GEOLOGICAL LINEAMENT ENHANCEMENT

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16. Abstract

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Introduction

A study was conducted to investigate the edge enhancement potential of Gradient and Laplacian transformations on ERTS-1 multispectral scanner data. The requirement for enhancement came about from researchers interested in mapping geological lineaments from ERTS-1 satellite imagery. This high altitude (940 km) and large area (160 km square) imagery offers a greatly improved synoptic view of the earth as compared to lower altitude photomosaics. This report describes initial efforts to enhance linear features by application of two-dimensional derivative operators to the ERTS imagery. The enhancements also have direct applications to image registration by providing a means of enhancing temporarily invariant objects in the scene. The work was done as part of the evaluation of image transforms task under the NASA grants cited. Preliminary results are presented here.

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Image Gradient Transformation

Edges of relatively homogeneous features in remote sensor **images are characterized by step-like changes in the radiometric** values observed. The gradient or vector derivative can be used to enhance edges and suppress more homogeneous areas in the image. The gradient image for a continous real function f(x,y) of two real variables (x,y) is defined as:

$$\vec{\nabla} f = \vec{i}\,\frac{\partial f(x,y)}{\partial x} + \vec{j}\,\frac{\partial f(x,y)}{\partial y} \qquad (1)$$

where:

$\frac{\partial f}{\partial x,y}$ are the partial derivaties of the function with respect to x and y

$\vec{i},\vec{j}$ unit vectors in the two orthogonal image dimensions

$\vec{\nabla} f$ Vector Gradient

An approximation of the gradient for discrete images can be computed by differencing adjacent pixels[2].

$$\vec{\nabla} f = \vec{i}(f_{i,j+1} - f_{ij}) + \vec{j}(f_{i+1,j} - f_{ij}) \qquad (2)$$

where: f_{ij} is the image value at row i and column j

The gradient is most useful as a magnitude value which can be used to generate a positive gradient image. The magnitude of the discrete gradient is:

$$|\nabla f| = \sqrt{(f_{i,j+1} - f_{ij})^2 + (f_{i+1,j} - f_{ij})^2} \qquad (3)$$

The gradient is the derivative of a two-dimensional surface in the direction of the maximum rate of change. The direction of the gradient vector is

$$\Theta = \tan^{-1} \left[\frac{\frac{\partial f(x,y)}{\partial x}}{\frac{\partial f(x,y)}{\partial y}} \right] \qquad (4)$$

The coordinate systems are not specified here so this is a general expression for discussion only. The derivative of the image in any direction can be computed by taking the appropriate combination of the orthogonal derivatives:

$$\frac{df}{dr(\Theta)} = \vec{i}\frac{\partial f}{\partial x} \cos\theta + \vec{j}\frac{\partial f}{\partial y} \sin\Theta \qquad (5)$$

Where: $\gamma(\theta)$ is the radial direction of the derivative as defined by θ

Laplacian-Transformation

The Laplacian or second derivative magnitude for a discrete image is:

$$\begin{aligned} \nabla^2 f &= \left[(f_{ij} - f_{i-1,j}) - (f_{i+1,j} - f_{ij})\right] \\ &+ \left[(f_{ij} - f_{i',j-1}) - (f_{i,j+1} - F_{ij})\right] \\ &= 4f_{ij} - \left[f_{i-1,j} + f_{i+1,j} + f_{i,j-1} + f_{i,j+1}\right] \end{aligned} \qquad (6)$$

Note that the Laplacian is a scalar whereas the Gradient is a vector (see [2] pg. 387.) The scalar gradient magnitude and Laplacian were implemented via FORTRAN programs and applied to a portion of an ERTS-1 multispectral scanner covering an area in central Nevada.

Description of Test Data

The test data chosen for evaluation of the derivative operators was ERTS-1 MSS data from Frame 1010-17592 taken over central Nevada on August 10, 1974. The subframe analysed is shown in Figure 1. This is the same data analysed in reference 1 and this study is intended as a continuation of lineament analysis research described there. The area shown is represented by the first 768 columns and the first 570 lines from this frame. The ground area covered is approximately 27 miles wide and 28 miles vertically.

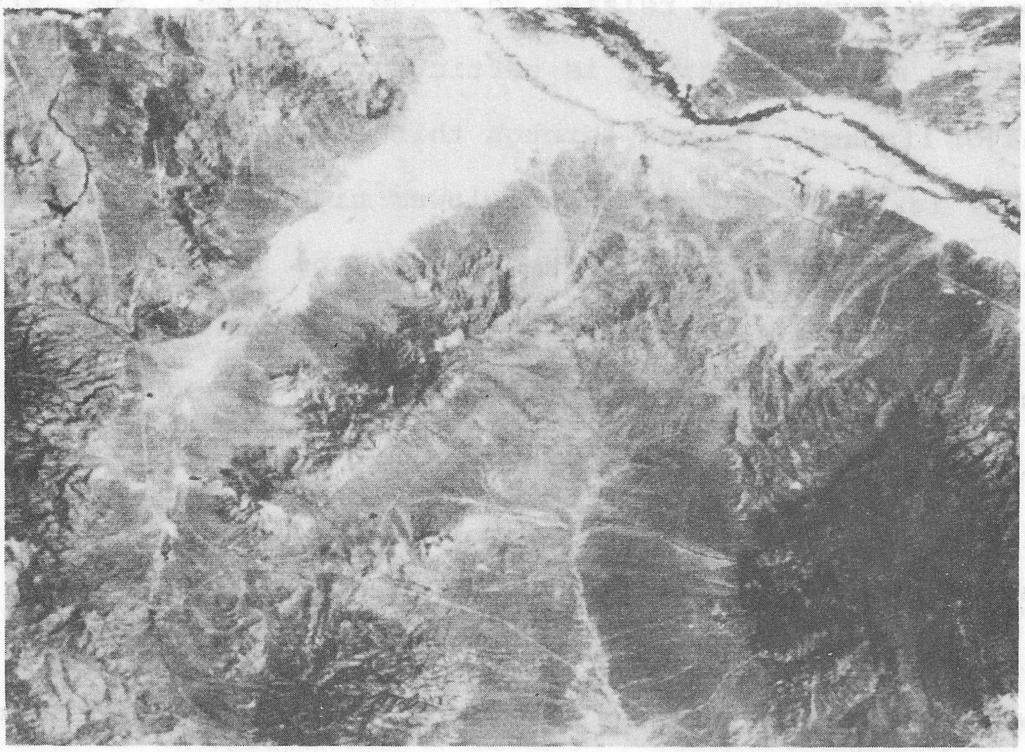


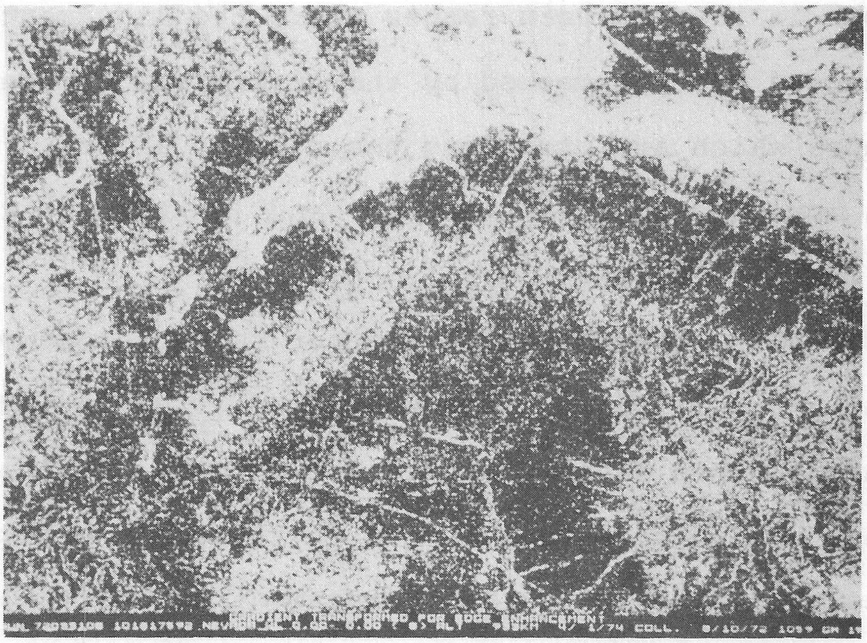
Figure 1 Nevada ERTS -1 test site used for lineament enhancement tests. Frame 1018-17592, Band 5 shown, obtained August 10, 1972. Center location: 40°, 2' North, 116°, 36' West. The Humbolt River crosses the image in the upper right corner with the Reese River joining it in the top center in the very bright area running southeast to northeast. The town of Battle Mountain lies at the junction of the two rivers. Interstate 80 parallels the Humbolt River as does the Southern Pacific and Western Pacific Railways. Mt. Lewis (El. 9688) rises in the range in the center of the picture.

The area is rich in mineral deposits and numerous lineaments have been mapped and related to these deposits. The Battle Mountain mining district is particularly rich in deposits and a major **lineament** passes through this area. Battle Mountain itself is the dark area in the lower right corner of Figure 1. The Humbolt River crosses the area in the upper right corner. This small area was chosen to test the enhancement techniques. Much larger areas will be processed based on any favorable results from this investigation.

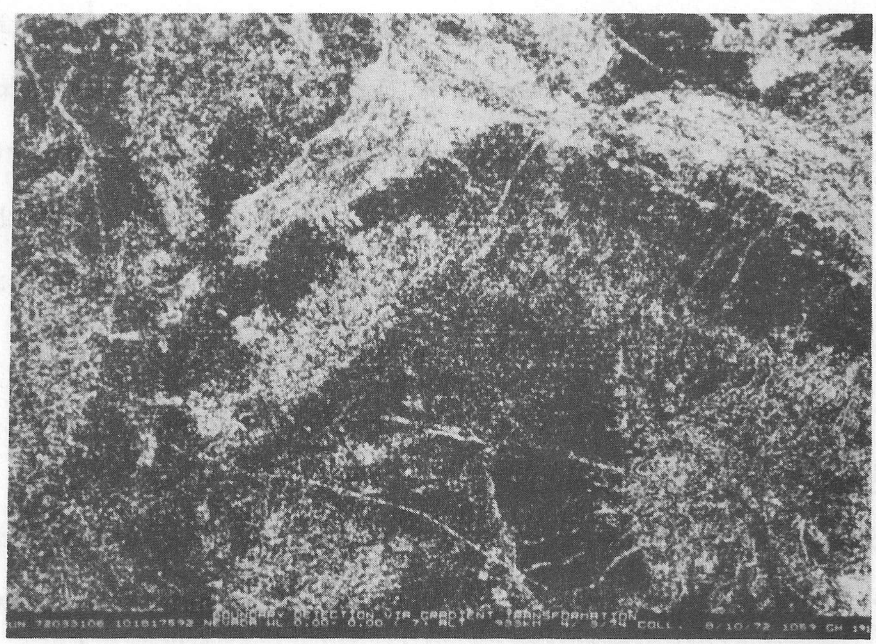
Evaluation of Gradient Transformation

The discrete gradient operation was applied to the data shown in Figure 1 for the four ERTS MSS bands. The results of these operations are portrayed by digital display images of the gradient reproduced in **gray** scale form. The gradient magnitude is a positive scalar with a range of values from zero where no edges are found to a maximum of five to twenty units for sharp edge phenomena. This range is expanded to cover most of the 0-255 dynamic range of the data system. The expanded gradient image was written on tape and reproduced using standard digital display histogramming and display procedures.

The gradient magnitude image is shown in Figure 2 for bands 5 and 6. Linear features in the image are enhanced quite well; however, the valley floors covered with highly reflective outwash material show very high gradient values indicating very rough surfaces in these areas. This result indicates a basic problem with the gradient in that



Band 5(.6-.7μm) Gradient Image



Band 6 (.7-8.μm) Gradient Image

Figure 2 Gradient magnitude transformation applied to the image data shown in Figure 1. Brighter areas are caused by larger gradient values.

both linear features and rough textured areas are enhanced producing a highly cluttered image. This is especially troublesome in the mountain ranges where the lineaments need to be enhanced and are masked by the clutter of the dense irregular shapes which are producing the clutter effect. This effect is more prominent in the red band (5) than in the infrared band (6) as seen in Figure 1.

The question remains as to whether the gradient makes geologically significant lineaments more visible. Most of the linear features seen in Figure 2 are roads, railroads, power lines and surface topographic features not related to lineaments of interest. A known lineament passes through the Battle Mountain area in a southeast northwest direction and it appears that this feature is evidenced by the faint line of brightness running in a straight line across the north edge of Battle Mountain. Another lineament can be recognized running southwest northeast at the east edge of a short mountain range just west of Battle Mountain in about the center of Figure 2. These lineaments are much more apparent in the gradient images than in the original image.

Threshold Gradient Analysis

Further manipulation was performed on the gradient images by thresholding the gradient at various gray levels. All gradient values below a threshold were set to a black level and all values above were set to white. The threshold was varied arbitrarily to observe the effect of thresholding. Figure 3 contains thresholded gradient images for band 5

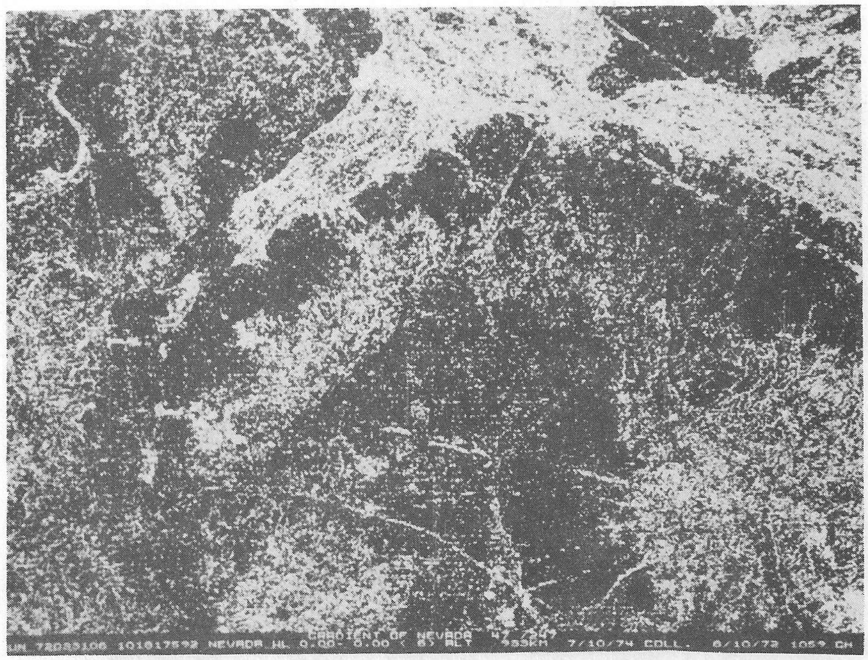


Figure 3a Thresholded gradient image of band 5 of Nevada Test site. Threshold = 47

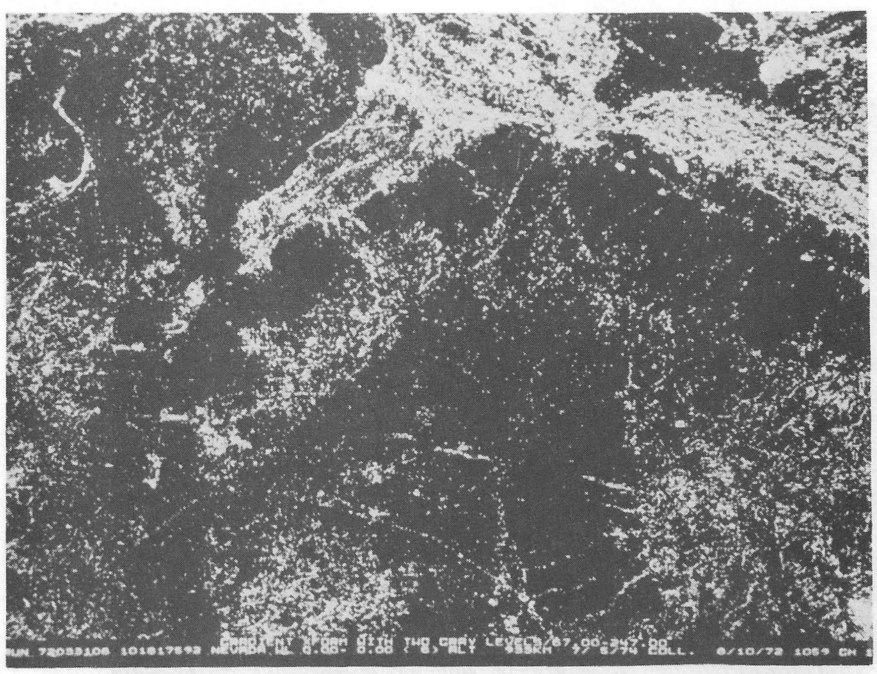


Figure 3b Same as (a) except for threshold = 67

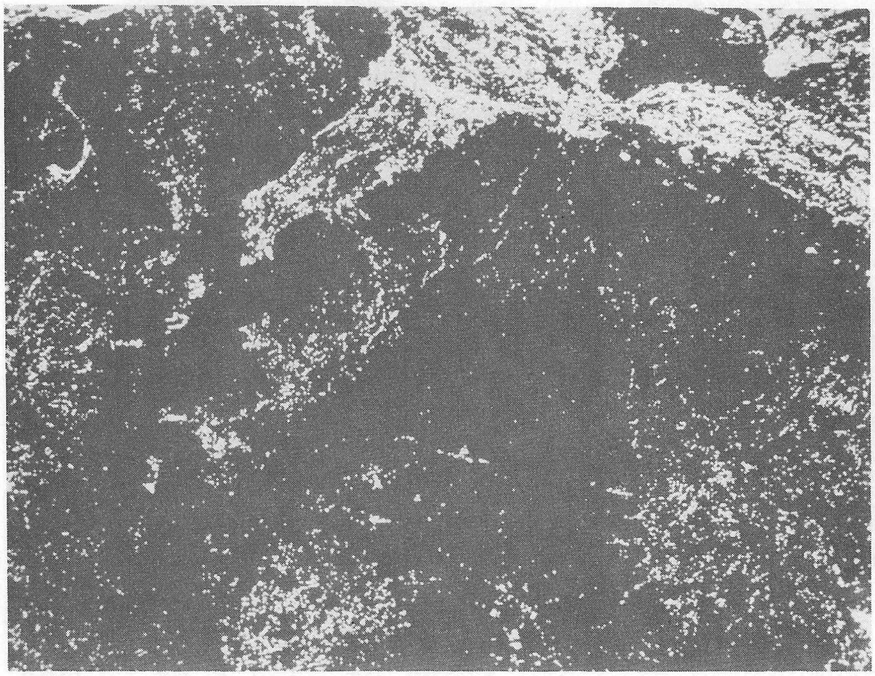


Figure 3c Thresholded gradient image of Nevada test site with threshold = 87.

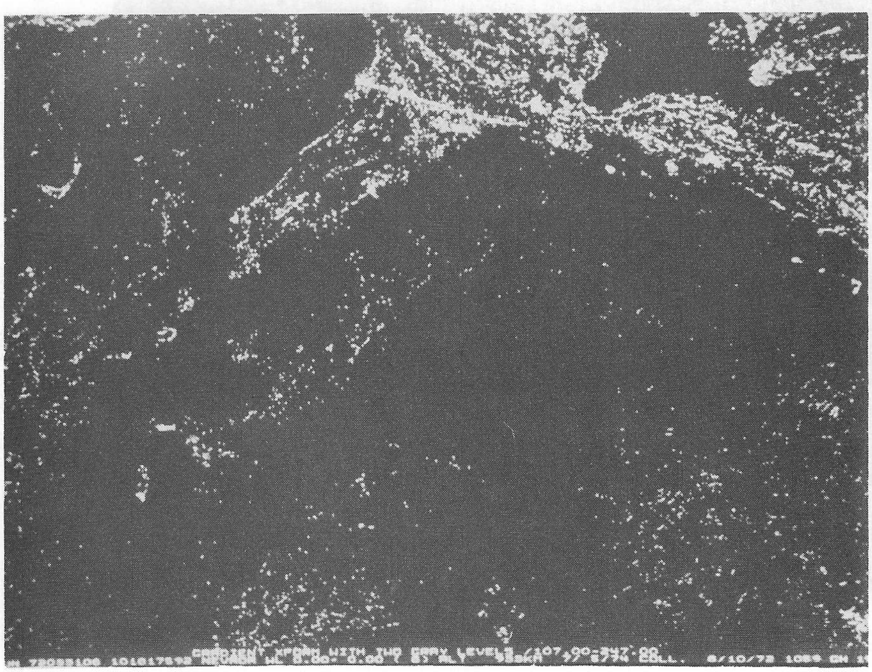


Figure 3d Same as (c) with threshold = 107.

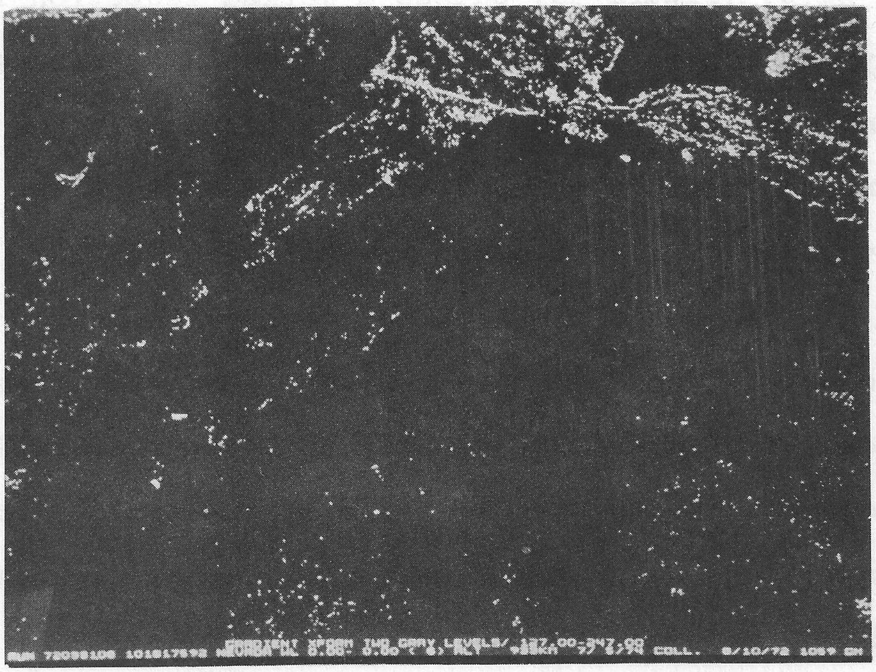


Figure 3e Same as c except threshold = 127.

for five values of threshold. The low threshold value of 47 produces an image very similar to the continuous gradient in Figure 2. The thresholded image is a little "cleaner" and more closely resembles the band 7 continuous gradient image. A threshold of 67 (Figure 3b) causes a marked reduction in edge density and causes the major Battle Mountain lineament to become unrecognizable. The sharp line feature in the central mountain range is quite clear and is enhanced by the raised threshold. Finer edge structure in the flat valley area now becomes visible, also. As the threshold is raised to 87, 107 and 127 more and more edge structure is elinimated. The interstate highway crossing the brilliant wash area becomes sharply visible for high threshold values whereas this feature was totally masked in the continuous and lower threshold value cases.

This experimentation indicates that thresholding may be a very valuable additional operation since linear features have various appearances in the gradient and can be further enhanced by using the correct threshold level. Beter evaluation of these operations must be carried out over much larger image areas. The present preliminary analysis was limited to the maximum single image data set size for every point display via the LARS digital display system. Display of the full frame will require an output device with at least a 2400 sample square digital image point capability. Mosaicing can be used to assemble the entire area photo but this was not done in this study.

Laplacian Transformation Evaluation

The Laplacian transformation was also applied to the same data set. The Laplacian is a scalar which can be negative or positive so a bias was added to produce a non-negative result. The Laplacian was applied to the test site data and the results for the .6-.7 μm band are shown in Figure 4. The "noisiness" of the image seems to be more uniform and edges are more subtle. Closer inspection reveals that edges are more distinct in areas of dense edges compared to the gradient. The road through the valley in the top center is visible in the Laplacian and not in the gradient.

The Laplacian was further explored by thresholding it also. Figure 5 contains the thresholded Laplacian for five cases. Here too the Laplacian shows less structure than the gradient although certain edges of lines are visible that do not show in the gradient. The Laplacian threshold of 35 seems to generate the most acceptable image since for higher values edges start to disappear as fast as the noise. An undesirable feature of thresholding is the subjective nature of the results making it difficult to analytically set threshold levels in an algorithm.

Summary and Conclusions

Experiments using the gradient and Laplacian operators on on ERTS-1 multispectral scanner imagery were performed to evaluate their lineament enhancement capability. Both unaltered and thresholded images were generated for a test site in Nevada. The work reported here was directed toward general evaluation of the transforms rather than specific

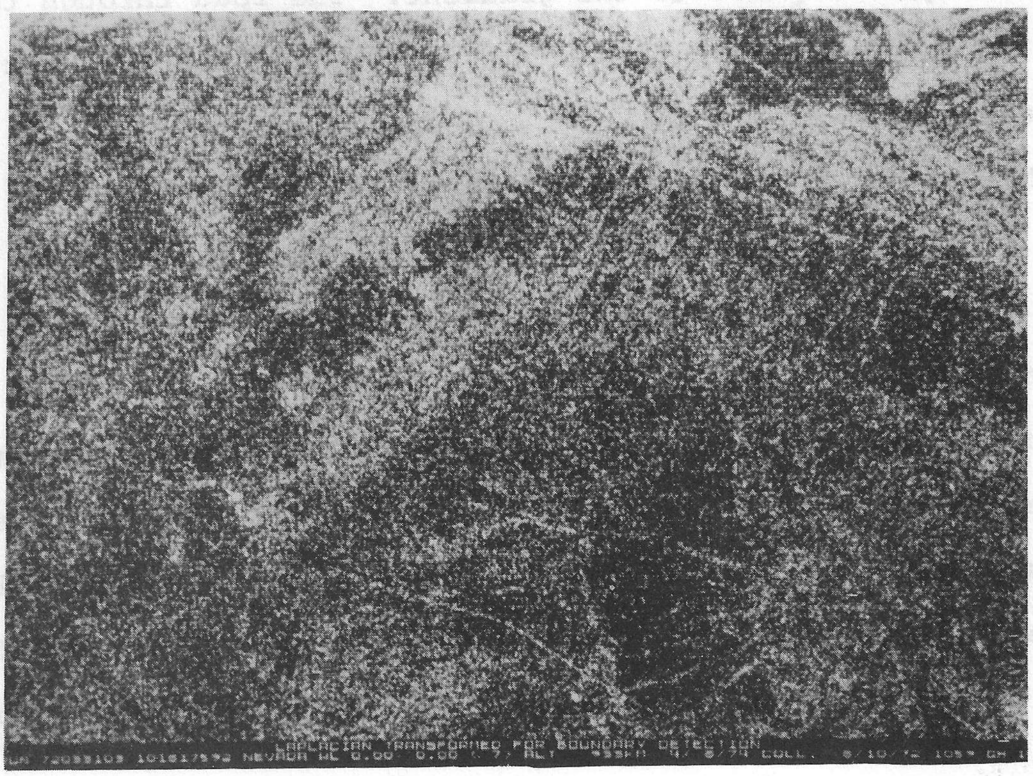


Figure 4 Laplacian Applied to Test Site Data ERTS Band 5, (.6-.7μm).

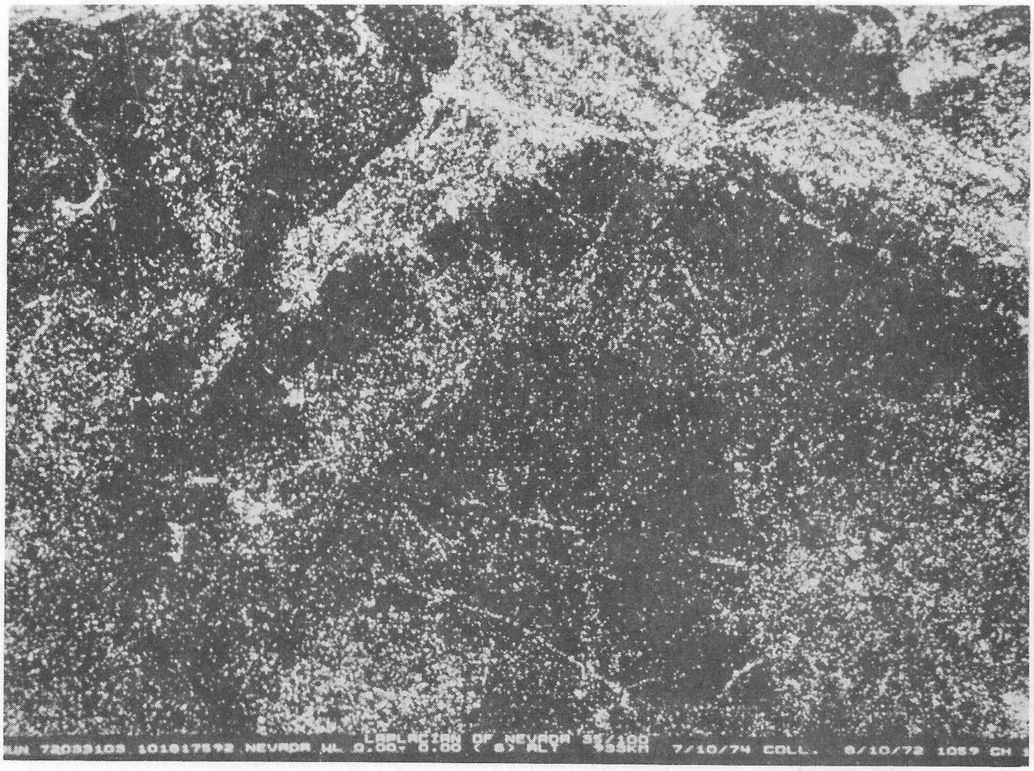


Figure 5a Thresholded Laplacian Image of band 5 (.6-.7μm) of Nevada site. Threshold = 35.

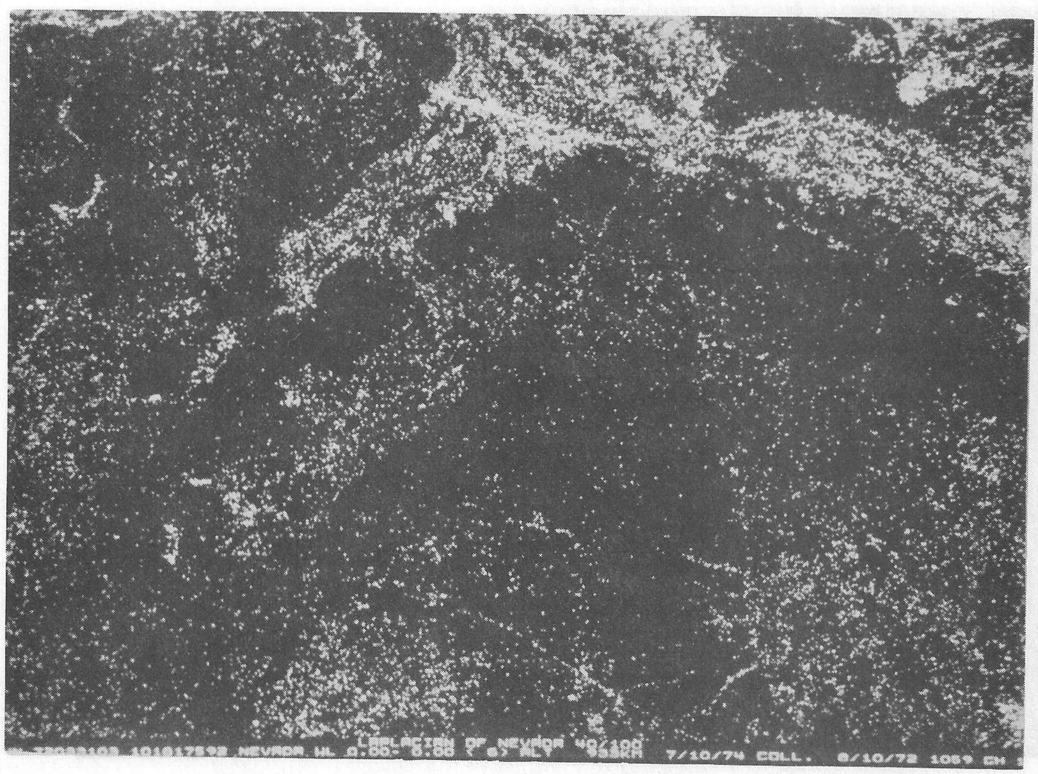


Figure 5b Thresholded Laplacian Image with threshold = 40.

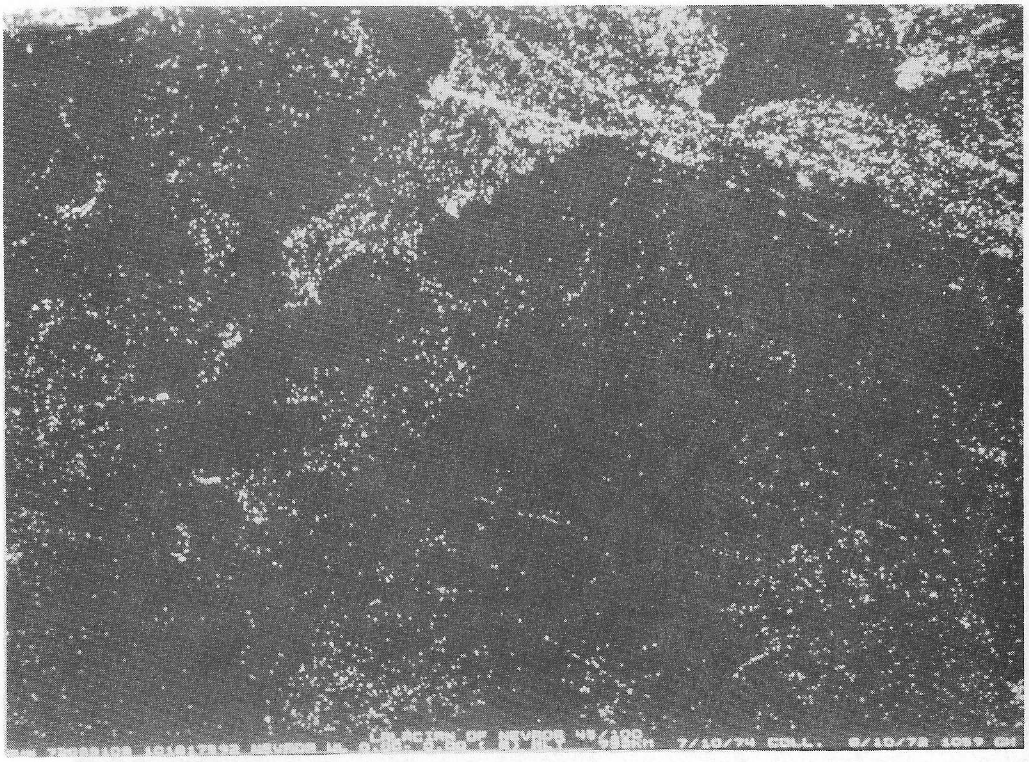


Figure 5c Thresholded Laplacian Image Threshold = 45.

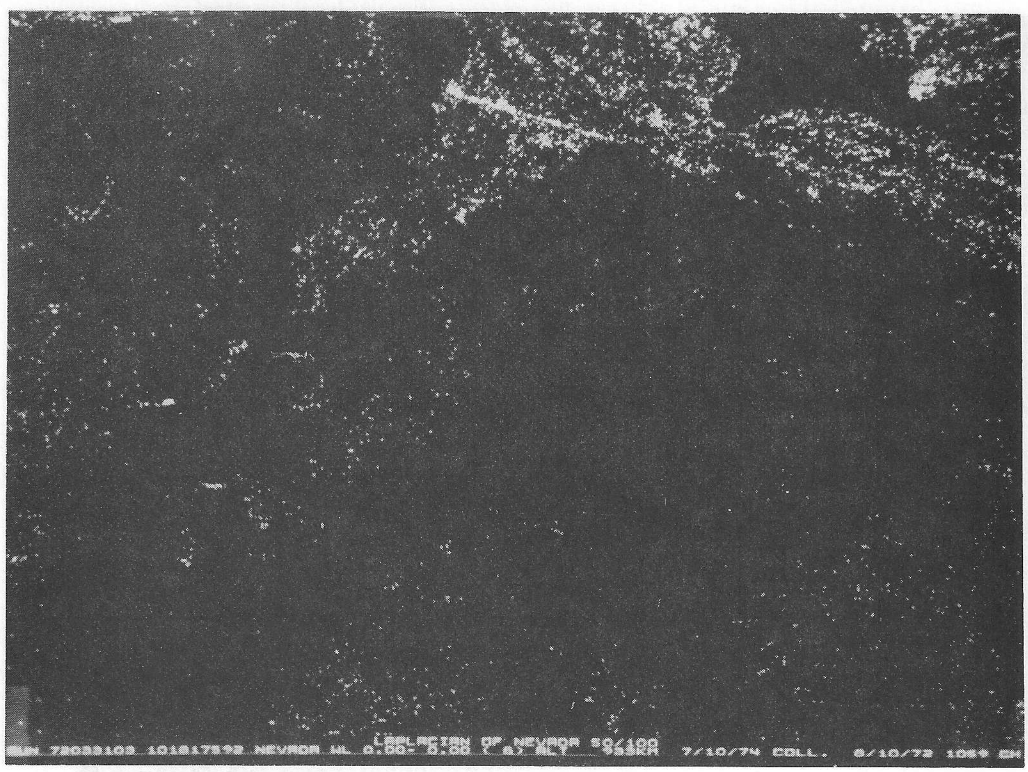


Figure 5d Thresholded Laplacian Image, Threshold = 50.

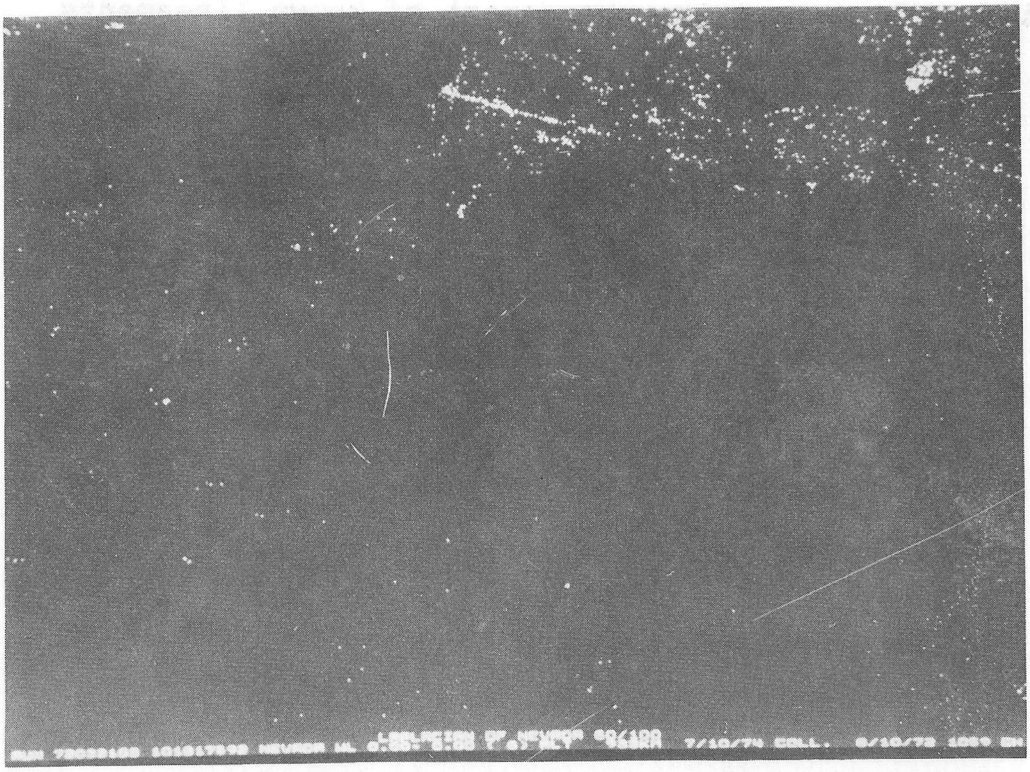


Figure 5e Thresholded Laplacian Image, Threshold = 60.

lineament detection. Only a small area of the frame was studied. Further work will be required to define an acceptable transform then the entire frame should be enhanced and studied with respect to enhancement of known lineaments.

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