STATISTICAL PATTERN RECOGNITION AS AN AID IN GEOLOGIC INTERPRETATION OF MARTIAN TERRAINS

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Geological interpretation of imagery obtained from orbiting spacecraft is complicated for Earth by active erosion, vegetative cover, and a thick soil mantle. Fortunately, this is not the case for other planets where "ground-truth" is limited or non-existent. Instead, we must rely entirely on remotely sensed data. Traditionally, geologic mapping of the planets involves the delineation of materials units based largely on visual pattern recognition in the spatial domain and on a limited amount of spectral reflectance data, usually only albedo.

Many of the terrains on the planet Mars are especially amenable to analysis in the frequency domain through optical power spectra. First, available imagery is of high quality and good contrast; more importantly, many terrains are richly patterned as a result of tectonic forces, erosional or depositional processes, or some as yet undetermined mechanisms. In some cases, the terrains are extremely regular over thousands of square kilometers and yield optical diffraction patterns of a quality seldom obtained from terrestrial examples.

Optical diffraction patterns can be obtained easily with a simple optical bench set-up (Fig. 1). Basically, if an image transparency is placed in the front focal plane of a lens and illuminated by a beam of parallel, coherent light, the Fraunhofer diffraction pattern of the image will be formed at the back focal plane of the lens. The diffraction pattern is essentially the amplitude of the Fourier transform of the image. Phase information (the complex part of the transform) is lost. Unlike manual interpretation of images (which is subject to subjective selection or rejection of features), the optical diffraction pattern contains all spatial information found in the original image. This may be, at times, a hindrance as well as advantageous.

The frequency domain is better suited than the spatial domain to pattern recognition tasks because fewer samples are required to extract significant signatures - usually less than 100 as compared to thousands or millions. Furthermore, many features necessary to discriminate between terrains, for example, preferred orientations or particular spacings, appear naturally in the frequency domain.

Lendaris and Stanley (1970) first described the technique of diffraction plane sampling. Using a photodiode detector designed to take advantage of the centrosymmetry of optical diffraction patterns (Fig. 2), it is possible to obtain up to 32 samples of the spatial frequency distribution and 32 samples of azimuthal space. Algorithms have been developed for the complex tasks of pattern recognition based on such diffraction plane sampling (Kasdan, 1977). With these techniques, it is possible to differentiate and characterize terrains with precision and without subjective biases.

Some of our early tests indicated that these methods could distinguish diverse terrains with ease. Therefore, we have chosen as a more difficult test the several terrain facies comprising the Olympus Mons aureole. The several identified facies have been mapped (Morris and Dwornik, 1978) on the basis of differences, often subtle, among patterns that are generally quite similar. Where units are contiguous, the visual pattern recognition task is simple compared to that of classifying units occurring in isolated patches.

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Because available Viking Orbiter orthographic images are not each of the same scale and because their orientations are difficult to determine our first problem was to define a feature extractor that is independent of scale and orientation. For this, data from the wedge detectors (Fig. 2) were combined into groups of four measured clockwise from the detector exhibiting the largest value. Thus, the data for each image was reduced to eight values. A clustering algorithm employing a simple Euclidean distance measure was applied to these data and the results were plotted as a dendrograph (Fig. 3). In general, this procedure was successful with like units appearing together within the shaded clusters. Two dramatic examples of image pairs the same unit that were successfully classified are shown in Fig. 4.

Statistical pattern recognition in the spatial domain has the potential to aid the photogeologist in classification and characterization of planetary terrain units. Where units are contiguous, the visual pattern recognition task is relatively simple compared that of classifying units occurring in isolated patches. It is in the tasks of subdividing terrains that are subtly different and in the correlation of isolated patches of similar materials that the pattern recognition techniques described here may have their greatest potential.

References

Lendaris, G.G. and Stanley, G.L. (1970) Proc. IEEE, 58, pp. 198-216; Kasdan, H.L. (1977) Proc. SPIE, 117, pp. 67-74; Morris, E.C. and Dwornik, S.E. (1978) USGS Map I-1049.

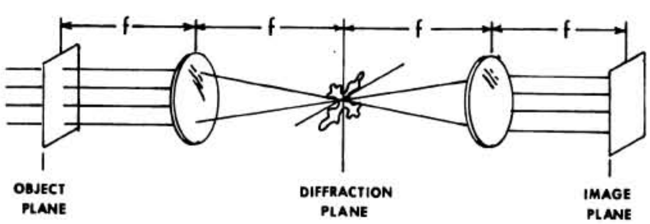

FIGURE 1. Diagram of optics for obtaining diffraction patterns.

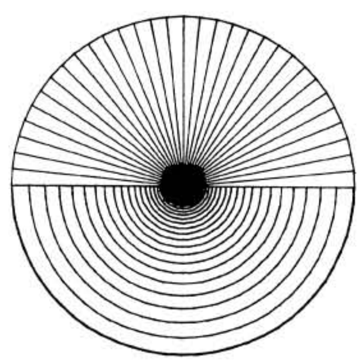

FIGURE 2. Diagram of the 64 element photodiode.

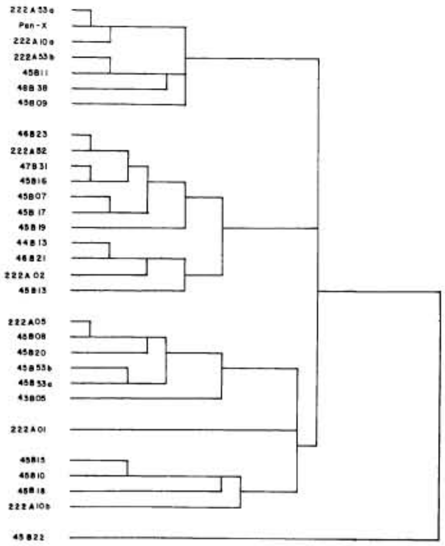

FIGURE 3. Classification of 29 images of the Olympus Mons Aureole. In this dendrogram, the connections nearer the left edge connect samples that are more alike.

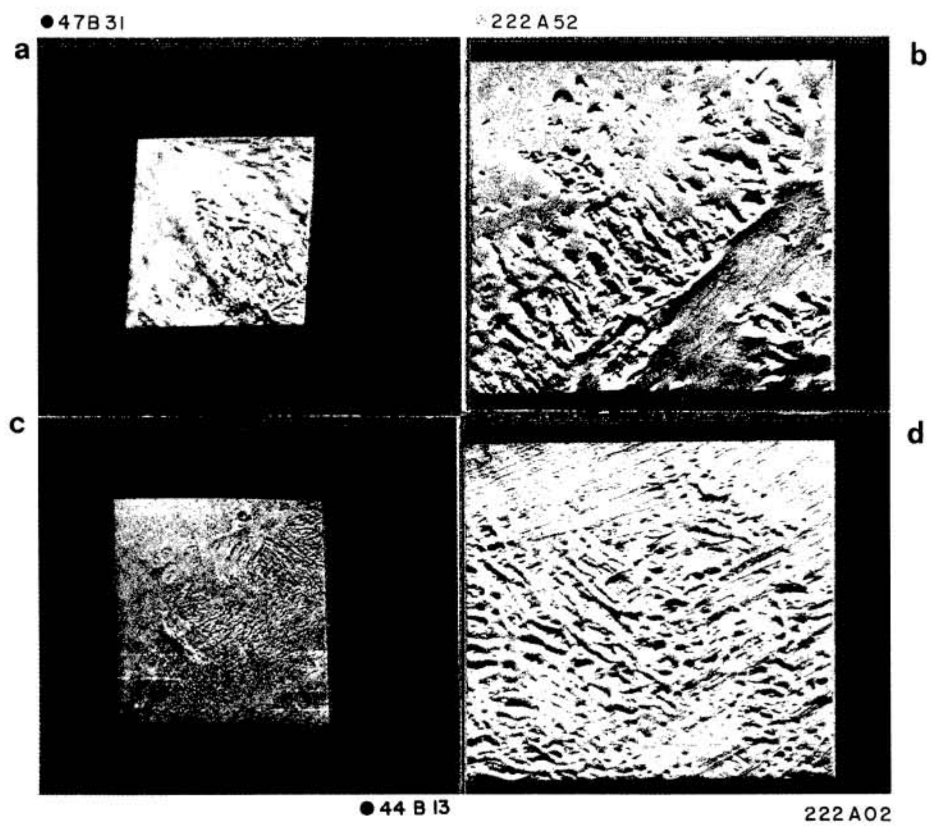

FIGURE 4. Pairs of images (a & b; c & d) showing two different facies of aureole material that were correctly classified by the feature extractor and clustering algorithm described.