N73- 43

Paper G 12

EXPLOITATION OF ERTS-1 IMAGERY UTILIZING SNOW ENHANCEMENT TECHNIQUES

Frank J. Wobber and Kenneth R. Martin, *Earth Satellite Corporation, Washington, D. C. 20006*

ABSTRACT

Photogeological analysis of ERTS-simulation and ERTS-1 imagery of snow-covered terrain within the ERAP Feather River site and within the New England (ERTS) test area provided new fracture detail which does not appear on available geological maps. Comparative analysis of snow-free ERTS-1 images has demonstrated that MSS Bands 5 and 7 supply the greatest amount of geological fracture detail.

Interpretation of the first snow-covered ERTS-1 images in correlation with ground snow depth data indicates that a heavy "blanket" of snow (e.g., > 9 inches) accentuates major structural features while a light "dusting", (e.g., < 1 inch) accentuates more subtle topographic expressions.

An effective mail-based method for acquiring timely ground-truth (snow-depth) information was established and provides a ready correlation of fracture detail with snow depth so as to establish the working limits of the technique. The method is both efficient and inexpensive compared with the cost of similarly scaled direct field observations.

The technique of snow enhancement appears to afford a simple [and no-cost] means of edge enhancement during the snow-covered periods. Increased tonal contrasts along the snow-covered/snow-free interface provide a form of natural edge enhancement for low resolution imagery. The investigators suggest that monitoring variation in snow melting and accumulation can supply unique fracture data unavailable during other seasons.

INTRODUCTION

Photogeological analysis has traditionally been conducted, whenever possible, using snow-free imagery on the assumption that snow-cover obscures geological features. This apparently results from a "no leaves and no snow" philosophy which has served as a criterion for successful aerial data acquisition and which may be extended to analysis of ERTS-2 imagery.

The principal investigator recently suggested that imagery of snow-covered terrain was a much under-utilized source of photogeological data. This report is an up-to-date review of the value and application of the technique for small-scale low resolution image analysis. It describes the spectral bands most useful for enhancing geological features in snow-covered terrain, presents a preliminary evaluation of supplemental image enhancement techniques and demonstrates snow enhancement as a photogeological technique.

It is anticipated that the early reporting of these results will both introduce scientists to a usable photogeological technique, and provide a useful forum for an interchange of ideas on the phenomena of snow enhancement.

BACKGROUND

That snow cover may actually be utilized as a photogeological tool to identify fracture traces and faults (particularly under conditions of low solar illumination) was proposed by the Principal Investigator following analysis of Gemini, Apollo and Nimbus photography. He suggested that monitoring snow cover variations in combination with low angle solar illumination may serve to accentuate subtle fracture traces and increase the detectability of topographically - expressed but subtle geological structure.

Seasonal snow cover served as a photogeological tool for Woloshin (1965) and Lowman (1967) to detect the extension of a fault in the East Sayan Mountains of the USSR. Recently, several previously unmapped fractures and faults in Alaska and western Canada were discovered utilizing heavily snow-covered Nimbus imagery.

The investigators noted from analysis of Apollo photography that fracture lineaments were frequently accentuated by the marked black and white tonal contrasts, i.e., between the dark-toned lineaments and the bright white tones of adjacent snow-capped rocks. Snow enhancement served as an especially useful technique for exploiting low resolution imagery. The technique has been made available to the mineral industry as a step leading to cost-benefit analysis of ERTS-1 technology.

Geological structure and lithology exert a strong influence on surface relief. Fractures (joints and faults) are usually more easily eroded than surrounding rock, producing linear to curvilinear surface depressions which are frequently imaged with dark-tones. Utilizing imagery with snow cover, fractures stand out in contrast to surrounding terrain because of (a) an absence of snow cover, (b) accentuaton of variations in vegetation cover, and/or (c) shadowing. The apparent absence of snow cover is attributed to accelerated melting rates induced by the higher moisture content of subsurface materials in fracture zones or, the obscuration of snow cover by vegetative overstory. Low angle solar illumination provides a pseudo-radar effect and produces shadows which emphasize subtle relief differences.

Gray scale variances introduce unnecessary background detail which slows the photogeologist during his interpretive process. Snow-covered terrain tends to reduce background "noise", thereby simplifying the interpretation process. For example, grass covered areas present a uniform and homogeneous appearance when the ground is thickly snow-covered. The accompanying reduction in overall gray scale variance with snow cover reduces the threshold of lineament detection, increases the total number of identifiable lineaments, and reduces the number of "decisions" necessary for automated machine processing. Additionally, increased tonal contrasts along a given snow-covered/snow-free interface provide a form of natural edge enhancement for low resolution imagery.

New snowfall patterns or differential snow melting patterns within unfrozen materials are diagnostic of variations in the moisture content (and hence thermal properties) of surface and subsurface materials. This is significant in that fracture zones commonly have higher moisture contents than surrounding materials.

DESIGN AND ANALYSIS

The investigators are employing a low cost method for obtaining ground truth information. A somewhat low density snow depth reporting network was organized within western Massachusetts and Connecticut with assistance from the National Weather Service. A higher density newwork was subsequently developed by contacting newspapers within both the primary New England test area (Massachusetts and Connecticut) and the secondary test area in Maryland and Virginia to enlist public support. Newspapers in areas lacking snow depth observers were selected to feature an article briefly describing the ERTS Program, the Snow Enhancement Experiment and appeal for public support.

Significant public interest in the experiment and ERTS Program was found to exist. Readers have written to express a desire to participate as snow depth observers. These observers have supplemented the existing network (coordinated by EarthSat) which continues to report snow depth data on a weekly basis. Compilation of snow depth data on 1:250,000 scale photo base maps facilitates comparison of fracture data yield with snow depth for the purpose of defining the optimum conditions for snow enhancement.

In addition to manual analysis of snow-covered imagery, several viewing techniques are being utilized to speed acquisition of fracture data from ERTS-1 imagery of snow covered areas. The techniques include additive color presentations, film sandwiching, Ronchi grating and optical edge enhancement. Oblique imaging from light aircraft under integrated conditions of snow cover and low angle solar illumination, provided additional opportunities to detect subtle lineaments. Preliminary evaluations of these techniques are discussed in the following section.

RESULTS

Photogeologic analysis ERTS-simulation and ERTS-1 imagery of snow-covered terrain with the ERAP Feather River Site and within the New England (ERTS) test area provided new fracture detail which did not appear on available geological maps. Analysis of snow-free ERTS-1 images (1096-15065 and 1096-15072) indicates that numerous lineaments can be mapped; analysis of comparative ERTS-1 imagery during snow-covered periods allows for more rapid fracture analysis and provides additional fracture detail (Figure 1).

ERTS MSS/Bands 5 and 7 were determined (by comparative analytical tests) to supply the greatest quantity of fracture detail. MSS Band 4 supplied the least detail; MSS Band 6 closely approximated the data yield of Band 7. Considering these results in conjunction with analysis of ERTS-simulation imagery, it is suggested that the red region (approximately 580-700nm) is the optimum visible spectral region for fracture analysis. The infrared portion of the spectrum best suited for fracture mapping was the 800-1100nm (Band 7) spectral region which provided greater tonal contrast than the 700-800nm (band 6) region.

Additive (false) color viewing yielded unique information on fracture-related vegetative cover. Optical edge enhancement (Digicol), film sandwiching and use of a Ronchi grating have all been found to

FIGURE 1: ERTS-1 image (1132-15074-7) at 1:1,000,000 scale acquired on December 2, 1972. The imaged area is partially snow-covered and includes Connecticut, southwestern Massachusetts and the eastern edge of New York. The southern limitation of snow cover is indicated by a dashed line. Geographic reference points include Hartford, Connecticut (F), Springfield, Massachusetts (S), the Hudson River (H) and Mount Tom (D). Partial cloud cover (C) obscures ground detail, but can be distinguished from snow cover following careful image analysis. Based on field observations, snow depths vary from <1 inch just north of the line to 9 inches in the northwestern corner of the photo. Low angle solar illumination (22 degrees) accentuates subtle topographically expressed features (E) not as easily detected with a higher sun angle. Northwesterly trending thrust fault blocks (A) are accentuated by a thick (approximately 9 inches) snow cover. Light-toned (snow-enhanced) lineaments (B) approximate the direction of recorded glacial striations and are probably of glacial origin. Dark-toned (snow-free) lineaments (arrows) represent a small sampling of mappable lineaments within the snow-covered areas. A complete analysis is now in progress. Lineaments will be confirmed through subsequent geological validation procedures. Analysis was confined to the area of greatest snow visibility within the western portions of Connecticut and Massachusetts.

conditionally yield additional fracture information, but further study is needed to more completely define the utility of these techniques for fracture discrimination.

Preliminary correlation of selected fractures with snow depth ground data indicates that snow depth greater than was anticipated by the investigators (e.g. $>$ 9 inches) provides significant topographic enhancement. It now appears that thick cover of snow (e.g. $>$ 9 inches) accentuates major topographically expressed geological features e.g., thrust faults (Figure 1), while a light "dusting" (e.g., $<$1 inch) accentuates subtle fracture trends. The importance of snow depth in controlling the detectability of geological structures will be more fully defined following receipt and analysis of additional ERTS-1 data.

Low angle solar illumination produced topographic shadowing which emphasized subtle relief differences not as apparent on snow-free imagery collected during autumn. Factors such as density and type of vegetative cover and texture and permeability of surface materials influence the enhancement capabilities of snow cover and have yet to be studied in detail.

ANTICIPATED BENEFITS

The investigators are testing benefits that may be realized through practical application of snow enhancement techniques. For example, commercial flying firms may extend the period (from snow-free into snow-covered periods) during which satisfactory images for selected photogeological studies can be acquired. In geological reconaissance, bedrock outcrops may be more readily located under conditions of differential snow cover, i.e. increased snow free/snow cover tonal contrasts. Fracture data derived from the experiment will be provided to the Boston office of the U.S. Geological Survey who have been mapping the area for over 8 years.

The Principal Investigator suggests that snow enhancement is a simple and no-cost form of edge enhancement, i.e., it can be useful in place of costly electronic edge enhancement in some cases. It is also suggested (but not adequately tested) that snow enhancement will simplify automated recognition of other geological features. For example, the density (or absence) of overstory controls the amount of ground snow cover which can be aerially sensed and therefore the spectral return of geobotanical indicators of mineralization. Certain cultural features such as airport runways and highways could be identified on snow-cover imagery, but not on snow-free imagery of comparable resolution. This was attributed to the high contrast of the dark-toned snow free surfaces with the adjacent light-toned snow piles.

Navigational benefits have already been realized by the investigators in ERTS field checking.

Extension of snow enhancement techniques from temperate areas to areas of permanent snow cover for acquisition of geological data is likely. This seems particularly true since relatively deep snow (e.g. > 9 inches) was found to enhance certain topographic features indicative of geologic structure.

ACKNOWLEDGEMENTS

The Principal and Co-Investigator acknowledge the contributions of Dr. Paul Lowman, Scientific Monitor, and Mr. Arthur Fihelly, Technical Monitor for their continuing interest in the study. Mr. Roger Amato, Ms. Marge Kolar, and Mr. Luis DeMendoza of EarthSat are contributors to the study.

REFERENCES

Lowman, P., 1967. "Geologic Applications of Orbital Photography." NASA Technical Note D-4155. Goddard Space Flight Center. 25pp.

Wobber, F. J., 1969. "Environmental Studies using Earth Orbital Photography," Photogrammetria. Vol. 24, No 3/4, pp. 107-165.

Wobber, F. J., and Martin, K., 1972a. "Exploitation of Aircraft and Satellite Imagery Using Snow Enhancement Techniques." Presented to the International Geological Congress, Montreal, Canada. August, 1972.

Wobber, F. J., and Martin, K., 1972b. "Utilizing Snow Cover for Accentuating Geological Fracture Systems: A New Photogeological Technique," World Mining. Vol. 25, No 12. p. 55-89

Woloshin, A., 1965. "Notes on Geologic Interpretation of Nimbus AVCS Image of Southern California," in Multisensor Imagery Collection, U. S. Army Corps of Engineers for NASA Earth Resources Survey Program, pp. 189-191.