ESC No. 141

E7.4-10.0.8.0.
CR-135969

FACILITATING THE EXPLOITATION OF ERTS-1 IMAGERY USING SNOW ENHANCEMENT TECHNIQUES

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November 1973
Type II Progress Report For Period: May 1,-October 31, 1973
Contract No. NAS5-21744

Prepared for

ERTS PROGRAM OFFICE
NASA GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. ESC #141-6	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle FACILITATING THE EXPLOITATION OF ERTS-1 IMAGERY USING SNOW ENHANCEMENT TECHNIQUES		5. Report Date November, 1973
		6. Performing Organization Code
7. Author(s) Dr. Frank J. Wobber, Kenneth R. Martin, Roger V. Amato and Thomas Leshendok		8. Performing Organization Report No.
9. Performing Organization Name and Address EARTH SATELLITE CORPORATION 1747 Pennsylvania Avenue, N.W. Washington, D.C. 20006		10. Work Unit No.
		11. Contract or Grant No. NAS 5-21744
		13. Type of Report and Period Covered Type II Report May 1 - October 31, 1973
12. Sponsoring Agency Name and Address ERTS Program Office Frederick Gordon, Technical Monitor		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The applications of ERTS imagery for geological fracture mapping regardless of season has been repeatedly confirmed. The enhancement provided by a differential cover of snow increases the number and length of fracture-lineaments which can be detected with ERTS data and accelerates the fracture mapping process for a variety of practical applications. The geological mapping benefits of the program will be realized in geographic areas where data are most needed - complex glaciated terrain and areas of deep residual soils.

ERTS-derived fracture-lineament maps which provide detail well in excess of existing geological maps is now available in the Massachusetts-Connecticut area. The large quantity of new data provided by ERTS may accelerate and improve field mapping now in progress in the area. Numerous other user groups have requested data on the techniques. This represents a major change in operating philosophy for groups who to date judged that snow obscured geological detail.

17. Key Words (Selected by Author(s)) Snow Enhancement, Fractures, Lineaments, Remote Sensing, Snow Cover Imagery		18. Distribution Statement	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 63	22. Price*

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

PREFACE

<u>The applications defined in this experiment have come from the utility of ERTS imagery as the primary data source and not from dependence upon large or small scale aircraft coverage.</u>

A detailed geological analysis has been conducted within two test sites (Great Barrington, Massachusetts and Canaan Mountain, Connecticut) utilizing available remote sensing records including snow-covered ERTS and snow-free ERTS which was validated using high altitude aerial CIR, SLAR and aeromagnetic data. These data have been analyzed and the results correlated with geological field measurements. Snow enhancement techniques that have been refined from these analyses will be documented in a Users Manual for NASA which will facilitate technique distribution to interested user groups.

An ERTS-derived fracture-lineament map, which greatly exceeds the detail present on existing geological maps, has now been prepared for the western Massachusetts-Connecticut area. This map was made available to potential users in the area, including U.S. Geological Survey personnel, Connecticut Geological Survey, and Massachusetts Geological Survey.

Benefits to the ERTS program in terms of future satellite needs for geology have been identified. ERTS wintertime imagery acquired in a systematic manner justifies repetitive ERTS coverage for geology in excess of the current 18-day schedule. Repetitive ERTS data acquired during successive winter seasons can be applied to a variety of multidisciplinary problems: for geological and environmental studies, the variable interactions of snow cover, moisture content, and dynamic snow melt/accumulation patterns will continue to provide new geological data for a substantial period of time.

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1.1 General Introduction

The investigators' studies confirm the value of snow enhancement for photogeological fracture analysis and present analytical results of ERTS snow-covered imagery. During this reporting period (May 1 - October 31, 1973), the last snow-covered imagery of the New England Test Area has been received and analyzed. A variety of viewing techniques to enhance lineament detection have been evaluated. The results of this evaluation are contained within this report.

Geological fracture data derived from analysis of ERTS (snow-covered) imagery has been compiled on a regional fracture-lineament map which was provided to various user groups within Massachusetts and Connecticut. It is anticipated that this data will benefit USGS - Massachusetts Geological Survey geological mapping which is currently being conducted in this area and also accelerate regional environmental programs for various planning agencies.

In addition to its value for fracture mapping, snow enhancement provides increased information which can be utilized for environmental geological studies. A number of application - benefits have been identified which serve to move this investigation from a research phase to the applied use of snow enhancement techniques. Efforts have been made to demonstrate practical applications of snow enhancement techniques. For example, snow-enhanced imagery will be utilized on an operational basis for the unique detection of mine subsidence features within the Northern Anthracite Basin in Pennsylvania. This program will be conducted by EarthSat, the Appalachian Regional Commission and the State of Pennsylvania. The program was specifically designed so that wintertime data could be utilized as a primary data source. An ERTS B program which will involve several states in environmental geology mapping has been submitted; snow enhancement techniques will provide a means of accelerating acquisitions of a variety of data.

1.2 Summary of Program Accomplishments and Benefits

A capsulized summary of principal accomplishments during this reporting period includes:

- A Photobase Map for Western Massachusetts and surrounding areas has been prepared to display fracture-lineament data as derived principally from the analysis of ERTS snow-enhanced imagery. The map has been sent to various operating agencies in the test area for evaluation.

- A comparative fracture-lineament analysis test of snow-free and snow-covered ERTS imagery within the New England Test Area have been completed. In three out of four sets of comparative snow-free and snow-covered imagery of the same area, a greater number and a greater total length of lineaments were interpreted from the snow-covered imagery (Table 1).

- Analysis of the second Test Site selected for a detailed multisensor analysis (Canaan Mountain, Connecticut) has been completed. ERTS snow-free, ERTS snow-covered, and SLAR imagery are being analyzed in combination with geological and aeromagnetic maps.

- All fracture-lineaments mapped from ERTS imagery have been validated by the Sequential Validation System developed by the investigators. (See progress report for September 1, 1972 - April 30, 1973). The system includes comparison of ERTS imagery interpretations with Radar Imagery, Aeromagnetic Maps, Geological Maps, Glacial Maps, Topographic Maps and ERTS Underflight Data.

- A portion of EarthSat's Ground Data Citizen Reporting Network has been re-activated to report leaf fall information (e.g. percentage of leaf canopy) on the dates of autumn ERTS overflights to more effectively analyze seasonal influences on fracture detectability.

- Evaluations of a wide variety of image viewing/enhancement techniques have been completed. Preliminary analyses are contained within this report. A full discussion of there results will be included within the Final Report.1/

- Automated enhancement of snow-free ERTS CCT's is continuing. Preliminary results have failed to show a significant increase in lineament detectability with directionally enhanced ERTS imagery.

1/ All sections and illustrations for the Final Report are being prepared as the experiment progresses.

TABLE 1: RESULTS OF ERTS-1 FRACTURE-LINEAMENT

SNOW-FREE VS. SNOW-COVER COMPARATIVE ANALYSIS TEST

Analyst A

Total Interpreted Lineaments	Comparative Set #1		Comparative Set #2	
	1096-15065 (SNOW FREE)	1204-15072 (SNOW COVER)	1096-15072 (SNOW FREE)	1204-15074 (SNOW COVER)
Number	287	312	336	267
Length(cm)	213	287	327	331

Analyst B

Total Interpreted Lineaments	Comparative Set #3		Comparative Set #4	
	1096-15065 (SNOW FREE)	1204-15072 (SNOW COVER	1096-15072 (SNOW FREE)	1204-15074 (SNOW COVER)
Number	137	175	167	216
Length(cm)	105	131	152	197

- The investigators have tested an additional enhancement technique - Agfacontour isodensity processing of snow-covered ERTS imagery. An evaluation of this technique suggests that it provides additional lineament detail.

- Numerous environmental applications of snow enhancement have been identified in such areas as mining and land use (See Figure 7); integrated geological and environmental applications will be tested during ERTS-B.

- A preliminary analysis of the influence of seasonal variations on fracture detectability has been completed. October 19, February 12, and April 7 ERTS imagery of an area in western Connecticut were comparatively analyzed (See Figure 8).

- Studies to evaluate snow cover as an aid for discriminating lithological differences have been initiated.

- A presentation of the results and benefits of this investigation was recently made to the Geology Review Panel at NASA GSFC. The application benefits derived from the use of snow enhancement techniques were emphasized by the investigators.

- A Structural Base Map for New England (1:1,000,000 scale) is being prepared to display all of the validated fractures and lineaments within the entire New England Test Area. The map can be utilized for updating of existing geological structure maps and determining the relationships between fracture-lineaments and regional tectonics.

2.0 BACKGROUND

2.1 General Background

Imagery of snow-covered terrains has rarely been consciously chosen for photogeological investigations when snow-free imagery was available. Snow cover has been widely assumed to obscure - rather than enhance - terrestrial features. This experiment hypothesized that imagery of snow-covered terrains was a much under-utilized source of photogeological data and that the technique could facilitate the analysis of relatively low resolution data collected by ERTS and other satellite systems.

Previous analyses by Wobber (1969) indicated that low angle solar illumination could have value in snow-covered glacial terrain. Woloshin (1965) and Lowman (1967) used Nimbus photography with snow cover to detect the extension of a fault in the East Sayan Mountains of the USSR. Reports by Sabatini and Sissala (1968) and Sabatini et al. (1970) included references to the fact that geological lineaments, hydrological features and outcrop patterns were enhanced by snow. The value of Nimbus imagery for detecting major structural features was recently noted by the U.S. Geological Survey; Lathram (1972) reported the discovery of several previously unmapped fractures and faults in Alaska and western Canada utilizing Nimbus imagery of heavily snow-covered terrain.

Using Gemini photographs, Wobber (unpublished research, 1970-1971) determined that snow cover proved useful for enhancing fracture lineaments, and accentuated lithological differences. Lowman (personal communication, 1972) also observed that the presence of snow cover enhanced structural features. Nicks (1970) noted from interpretations of Apollo photographs that snow sometimes enhanced fracture patterns.

The investigators selectively analyzed available ERTS-analog (Mercury, Gemini, Apollo, Nimbus) and ERTS-simulation imagery of snow-covered terrain in preparation for ERTS-1. Particular attention was focused on the interpretation of ERTS-simulation imagery of snow-covered terrain in the Feather River/Lake Tahoe Basins of California. Techniques for analyzing ERTS-1 imagery of snow-covered terrains were developed during this effort.

2.2 Concept of Snow Enhancement

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) snow melt patterns to include an absence of snow cover, (b) accentuation of variations in vegetative cover, and/or (c) shadowing or reflectivity differences. The apparent absence of snow cover is attributed to accelerated melting rates induced by thermal transfer from 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 sublte relief differences.

Gray scale variances introduce unnecessary background detail reducing the effectiveness of 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, and increases the total number of identificable lineaments. Additionally, increased tonal (shadow) 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 porosity, permeability and thermal properties) of surface and subsurface materials. This is significant in that fracture zones commonly have a higher permeability and moisture content than surrounding areas.

The investigators have evaluated the contribution of low sun angle as a complement to snow enhancement to increase fracture detectability. Image analysts have long recognized that topographic changes can be detected when sun-facing slopes are illuminated and back slopes are in darkness. This situation is analogous to side-looking airborne radar (SLAR) imagery flown parallel or near parallel to structural trends. Slopes facing the aircraft give strong (bright) returns while far slopes produce a black radar shadow.

Low angle solar illumination contributes to discrimination of topographically-expressed structural lineaments, however, it is unlikely that low angle solar illumination alone will permit subtle linear or textural features (including faults in glaciated terrain) to be detected from low resolution imagery without additional enhancement. Snow cover when combined with low angle solar illumination, aids in the detection of subtle fractures with subdued surface expression by increasing the tonal (shadow) contrast of the topographically shadowed or vegetatively enhanced lineament against the highly illuminated snow-covered background. Snow melting is also accelerated in the moist zones within and above fractures creating a differential snow cover pattern in fracture zones. It is on this premise that snow enhancement as an interpretive technique for photogeological studies is based.

3.0 ERTS ANALYSIS PROCEDURES AND TECHNIQUES

3.1 Analysis Procedures

ERTS imagery is routinely received in both the 9.5 inch print and 70mm negative and positive transparency format. The prints serve as the primary base for ERTS reconnaissance analysis. 70mm negatives are utilized for producing enlargements of selected areas. 9.5 inch positive transparencies are additionally ordered for ERTS scenes of high interest and/or quality. The transparencies and prints are then used in combination for intensive analysis. Enlargements of selected areas were produced to facilitate detailed analyses of Test Sites.

3.2 Analysis Techniques

The applications value of snow-cover and low angle solar illumination as forms of antural enhancement have been confirmed by this investigation. Several additional viewing or processing techniques have also been found to increase fracture-lineament detail.

In the previous semi-annual progress report, the results of preliminary analyses using additive color presentations, density slicing and film sandwich (snow-free imagery) enhancement were reported. Testing of several other techniques was recently completed. The results are summarized below.

3.2.1 Agfacontour Isodensity Processing

A selected ERTS image of snow-covered terrain was processed using Agfacontour Isodensity colors with readings obtained by a snow depth reporting network, a correlation of certain colors to varying snow depths was identified. This correspondence suggested the utility of this film type for snow depth mapping. It should be recognized, however, that a surface network of snow depth observers is required to key various colors to actual snow depths. Additionally, ground spectral return is greatly influenced by vegetative overstory. Areas of coniferous vegetation obscure ground snow cover and affect spectral return. The reflectance of these areas and the resulting isodensity color rendition does not accurately represent snow depth conditions. This difficulty may be partially overcome by extrapolating ground snow depth data and increasing the density of surface stations within areas of coniferous cover.

The isodensity process also appears to have value for enhancement of geological structure. Fracture-lineaments were generally enhanced by the differential snow cover which existed on this date (February 12) and were further enhanced through isodensity processing. Lineaments representing topographic alignments were especially prominent.

3.2.2 Ronchi Grating

The capability of a Ronchi grating to enhance linear elements was evaluated through visual and photographic analysis of ERTS data. Positive and negative transparencies of snow-free and snow-covered terrain within the New England Test Area were examined; various combinations of these transparencies were tested.

The Ronchi grating was positioned between an illuminated transparency and a 35mm camera which was used to record the linear effects. The grating was then rotated slowly to find "primary" and "secondary" lineament alignment directions which were then photographically recorded. The results of the Ronchi analysis indicated that:

- few lineaments which were previously undetected utilizing standard analysis procedures were discovered through Ronchi enhancement.

- the Ronchi grating appeared to "connect" what were really series of unconnected linear trends. This was judged to have a potential value for recognizing macro-trends of structural linear elements.

- optimum enhancement occurs in accentuating linear elements with a high background contrast. This is most effective in (for example) areas of differential snow cover where lineaments are rendered in tones opposite to that of the surrounding materials. Another example is the accentuation of straight stream segments which appear in very dark tones on ERTS MSS Band 7.

In summary, the technique appears most effective for accentuating macro-trends, but was observed to have a limited applicability for more detailed ERTS fracture analysis.

3.2.3 Film Sandwich

In the previous semi-annual progress report, the results of an analysis utilizing a snow-free film sandwich were reported. Difficulty was encountered with the density of the transparencies which were too high for optimum fracture analysis.

Subsequently, medium density positive and negative transparencies of both snow-free and snow-cover ERTS scenes have been analyzed. Major linear trends and structural "grain," which correlated well with bedrock joint measurements recorded in the field, were accentuated by the snow-enhanced sandwich. Geological trends were not as apparent on the snow-free image apparently because of the lower surficial contrast.

The results of this analysis demonstrate that the film sandwich is a low-cost form of edge enhancement which can serve many user groups. The low-cost sandwich appears to be at least as effective as optical edge enhancement techniques for fracture mapping in snow-covered terrains.

3.3 Field Investigations

The investigators have employed a citizen reporting network to periodically supply snow depth information within the ERTS Test Areas. This network has now been re-activated to supply percentage of leaf canopy information for autumn ERTS overflights. Data supplied by this network has periodically been supplemented with direct field observations taken by the investigators to coincide with ERTS overflights.

A field trip to the New England Test Area is currently being planned to coincide with the November 27 ERTS overpass. The purpose of the trip is to investigate lineaments and other features of interest detected from ERTS analysis and to confirm their origin. Spot sampling of snow depth data and collection of bedrock joint measurements will be conducted.

Fracture-lineaments mapped from ERTS analysis have been selectively field-checked to confirm their structural origin. From previous field efforts, a large number of joint measurements have been acquired within the New England Test Area. The measurements are subsequently plotted on rose diagrams and compared with similar diagrams prepared from the compilation of ERTS fracture-lineaments. A high correlation of fracture-lineament trends supports the validity of ERTS-interpreted geological structure.

3.4 Test Site Selection

Two primary test sites within the New England Test Area are being used for detailed geological analysis - the Great Barrington, Massachusetts and Canaan Mountain, Connecticut test sites. The sites were chosen from areas with abundant snow cover, complex geological structure and subtle (not well-defined) bedrock jointing. Additionally, the limitations of existing geological data were evaluated in an effort to select areas where new geological data could be contributed.

A detailed geological analysis has been conducted within each test site utilizing available remote sensing records including snow-covered ERTS, snow-free ERTS, high altitude aircraft CIR, SLAR and aeromagnetic data. These data have been analyzed and the results correlated with geological field measurements. Techniques that have been refined from these analyses will be documented in the NDPF Users Manual.

The initial results of a photogeological analysis of the Great Barrington, Massachusetts Test Site (Test Site #1) were reported in the Semi-annual Progress Report for the period of September 1, 1972 - April 30, 1973. An analysis of Test Site #2 (Canaan Mountain, Connecticut) is now complete. The results are discussed in the following section.

4.0 MULTI-SENSOR DATA ANALYSIS OF TEST SITE #2 (Canaan Mountain, Connecticut)

4.1 Geographic Location and Site Selection Rationale

The Canaan Mountain area (Figure 1) is located in northwestern Connecticut and is bounded by coordinates 41°45'-42°00' and 73°15'-73°30'. The area includes portions of the western edge of the Berkshires (Housatonic Highlands) on the east, and segments of the Taconic Mountains on the west. The Canaan area was selected as a test site for the following reasons:

- It is located within the western Connecticut snow belt where opportunities to observe transient snow melt phenomena are maximized.
- It is a geologically complex area of varied rock types and structures, which allows evaluation of snow enhancement capabilities in diverse terrain and bedrock types.
- Geologic mapping has not been extensively conducted within this area providing a chance to contribute useful data.

4.2 General Geology

The major structural elements of the Canaan Mountain area include the Housatonic Highlands, the Canaan Mountain salient, and the Taconic Mountains and surrounding lowlands. The Housatonic Highlands are a southward continuation of the Berkshire Massif, a large anticlinal uplift exposing Precambrian rocks. The Housatonic Highlands consist primarily of Proterozoic granite-gneisses and interlayered metasedimentary rocks. Outliers of Cambrian Poughquag Quartzite are contiguous with the westward thrusted Proterozoic rocks and overlay slivers of middle Ordovician carbonates.

The Berkshire-Housatonic trend is interrupted by Canaan Mountain which is a salient of middle Ordovician schists of the Manhattan and Waloomsac formations. The Canaan Mountain salient has been variously interpreted as being in fault contact or conformable with the surrounding strata (Rodgers, 1959). The Berkshire-Housatonic rocks are bounded on the west by thrust faults indicating westward movement of the Berkshire trend over the rocks of the Taconic synclinorium. A thrust fault is also postulated along the eastern edge of the Housatonic Highlands, forming a fenster or structural window. The Taconic synclinorium consists of a series of Cambro-Ordovician schists and quartzites which have been thrust westward (probably from the eastern side of the Berkshire Massif) over marbles (Stockbridge marble) of similar age and downfolded into a complex series of synclines containing both autochthonous and allochthonous strata. Several large reverse faults also occur in the area.

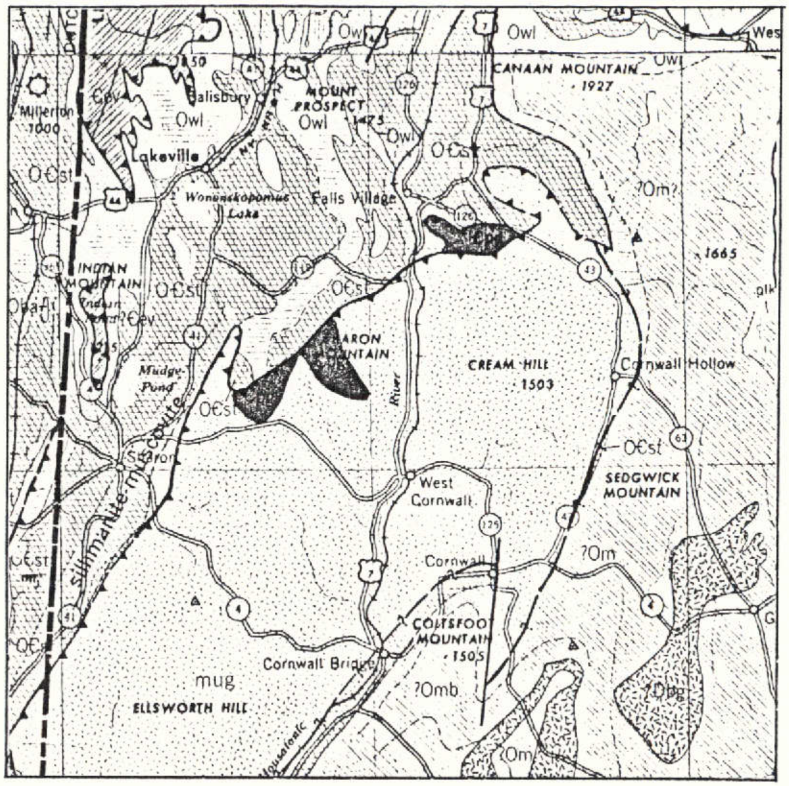
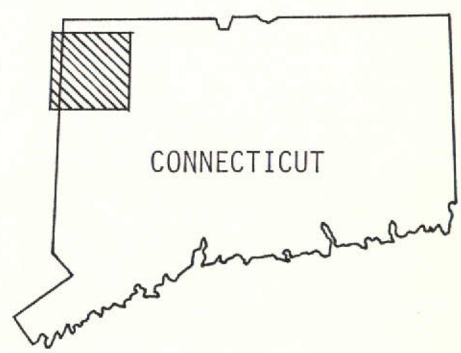


Figure 1: Geologic Map of the Canaan, Connecticut area. From Albany and Lower Hudson 1:250,000 scale geologic map sheets, New York Geological Survey. Location of area shown on map to the right.



EXPLANATION

Dbg	Biotite granite gneiss	Devonian
Owl	Walloomsac schist	Ordovician
Om?	Manhattan ? schist	Ordovician
OЄst	Stockbridge marble	Ordovician / Cambrian
Єpg	Poughquag quartzite	Cambrian
Єev	Everett schist	Cambrian
mug	Undivided mixed gneisses	Precambrian

Thrust fault, teeth on overthrust block

High-angle fault

Lithologic contact

In addition to the complex folding and faulting of this area, the rocks are also highly fractured. Numerous fracture-lineaments of various lengths cross the area; some traces may be unknown faults. The fractures tend to be concentrated mainly in the Housatonic Highlands and Canaan Mountain areas containing rocks which are highly deformed and where bedrock outcrops are relatively abundant. The origin of the fractures may be attributed to one or a combination of the following mechanisms a) formation in the basement rocks during the early Precambrian; b) formation during various periods of tectonic activity; and, c) formation through time by isostatic adjustment and tidal motion.

4.3 Multisensor Data Analysis

4.3.1 ERTS Imagery (Snow-Free)

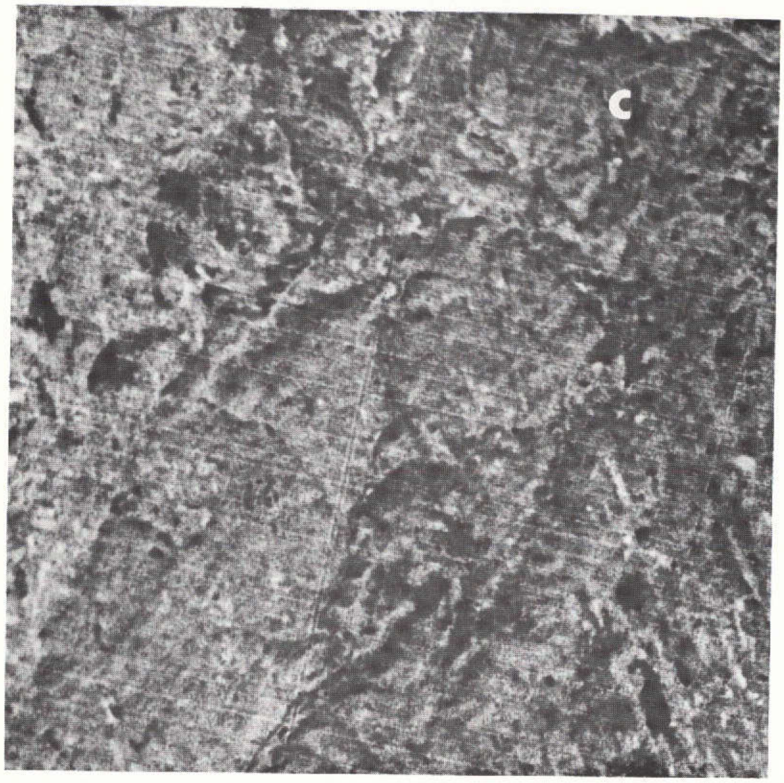
Analysis of a snow-free ERTS image (1096-15072-5) acquired on October 27, 1972, resulted in the detection of 104 fracture-lineaments. Major structural boundaries and faults could not be observed on the snow-free ERTS imagery (Figure 2), although sun angle was low (31°, azimuth 154°) and most deciduous vegetation bare. Predominant directions of the fracture-lineaments mapped from analysis of the snow-free image are between North and N30°W; N20° - 30°W is the primary orientation and N30° - 40°E is the secondary orientation.

4.3.2 ERTS Imagery (Snow-Covered)

An ERTS-1 snow-covered image (1204-15074-5) acquired on February 12, 1973, was analyzed for the same period of time as the snow-free ERTS and SLAR images (Figure 3). The sun angle (28°) and sun azimuth (146°) are similar to that of the snow-free image and are judged to have had only a minimal effect on data yield differences between the two images. Snow cover within the test site varied from 1 to 4 inches at the time of image acquisition.

The major structural boundaries of the area are prominent on the image. Snow cover has enhanced both topographically and non-topographically expressed features, especially in the Canaan Mountain and Housatonic Highlands areas. A total of 195 fractures-lineaments were mapped and plotted on a rose diagram for comparison with ground truth and data obtained from other sensor sources (Figure 6).

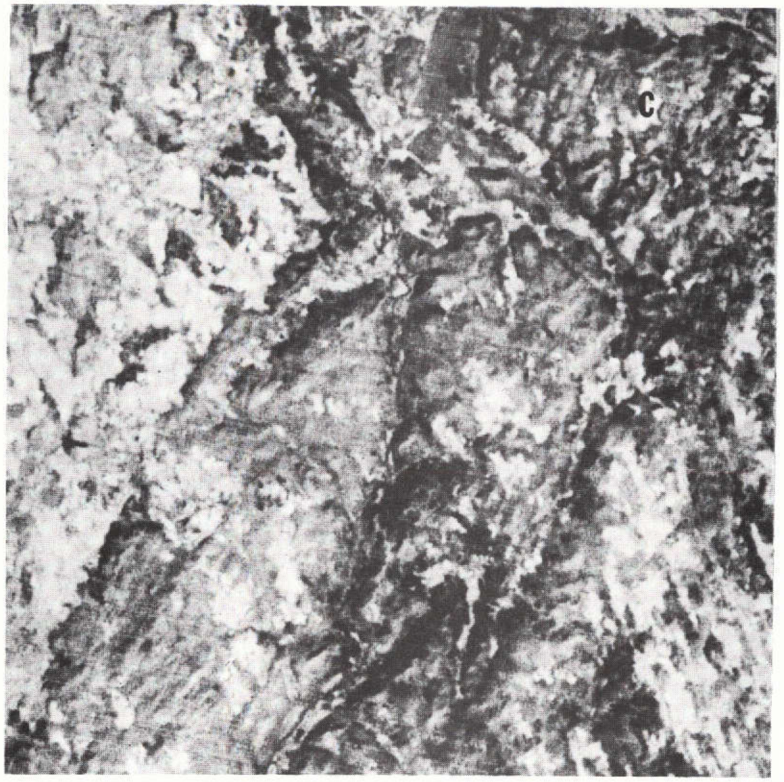
The snow cover enhanced both relief-expressed features and vegetative alignments enabling the investigators to detect nearly twice as many fractures as with the snow-free ERTS imagery.



A

B

FIGURE 2: ERTS-1 snow-free image (1096-15072-5) of the Canaan Mountain (c) Test Site in the northwestern corner of Connecticut. The image was acquired on October 27, 1972 and is reproduced at a scale of 1:250,000. Fracture-lineaments confirmed (———) and unconfirmed (-----) by a sequential validation system have been mapped on Image B.



A

B

FIGURE 3: ERTS-1 snow-enhanced image (1204-15074-5) of the Canaan Mountain (c) Test Site acquired on February 12, 1973. Fracture-lineaments confirmed (——) and unconfirmed (----) by a sequential validation system have been mapped on Image B. Snow cover within the test site was approximately 1-4 inches. The image is reproduced at a scale of 1:250,000.

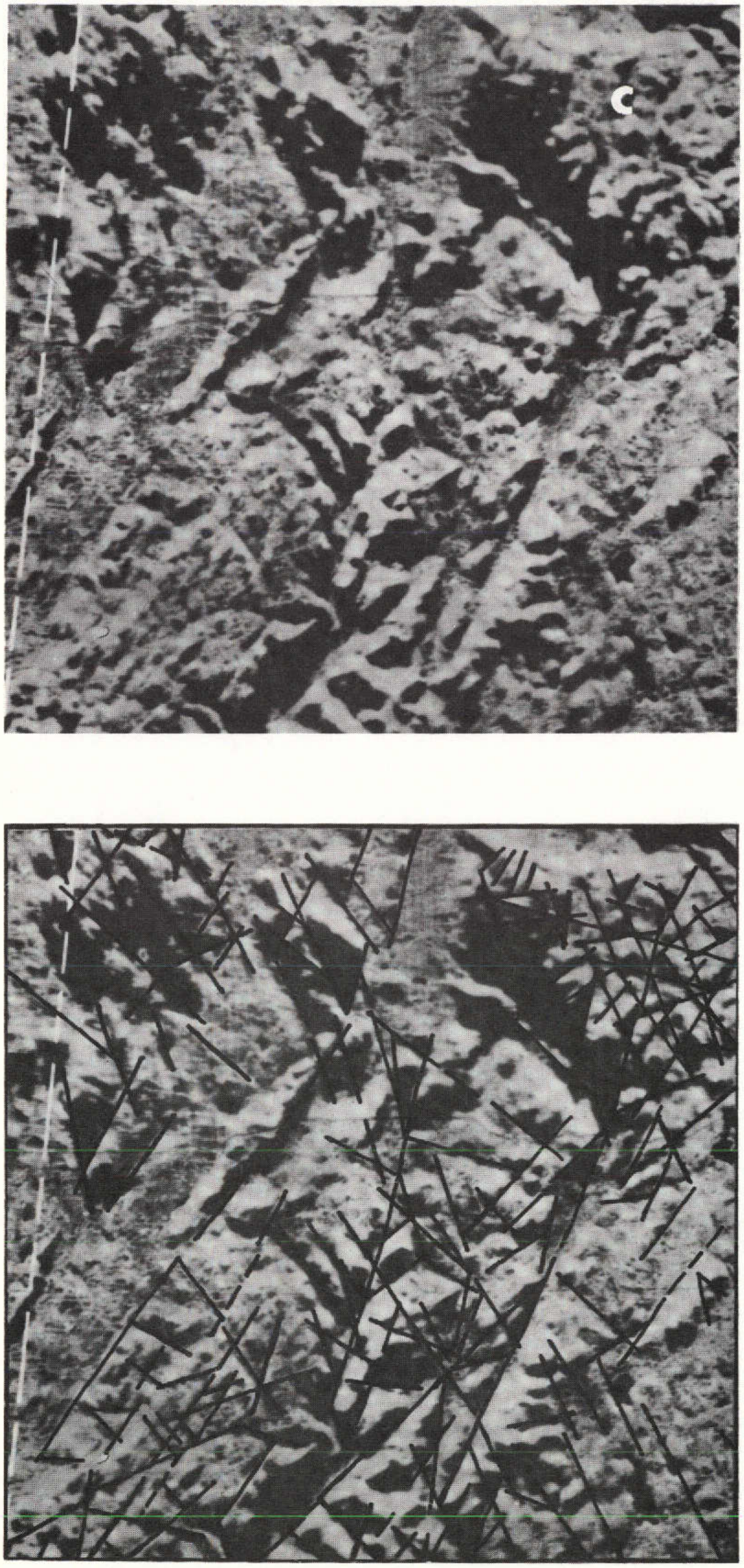
The major directions of N30° - 40°E and N20° - 30°W appear on the rose diagram for the snow-covered images however, the most prominent direction is N10° - 20°W. Directional variances are believed to be attributed to the "masking effect" which the snow cover provides by decreasing background "noise". Many additional and more subtle fracture-lineaments which are obscured by extraneous surficial detail, can then be detected on the snow-covered image.

4.3.3 Side-Looking Airborne Radar

SLAR imagery (Figure 4) acquired with an east-looking direction was also analyzed for the Canaan Mountain Test Site. Fracture-lineaments detected from SLAR analysis was recorded and used for substantiating the structural validity of fracture-lineaments mapped on ERTS imagery.1/ The SLAR imagery shows the thrust fault boundaries of the Housatonic Highlands, the Canaan Mountain salient, and the Taconic klippen which stand above the surrounding carbonate low-lands, and some of the high angle faults shown on the geological map (Figure 1). Numerous fracture-lineaments were interpreted from the imagery, especially in the older rocks of the Housatonics and Canaan Mountain.

A summary of the 150 fracture-lineament orientations (Figure 6) interpreted from the SLAR image indicates a major direction between N30° and N40°E, and a minor direction between N20° and N30°W. These directions correlate well with bedrock joint measurements obtained in the field (Figure 6). The directions also correlate well with the principal directions mapped from the snow-free ERTS imagery. The snow-covered ERTS image summary indicates a primary direction between N10° and N20°W, and it shows the N30° - N40° orientation as a minor direction. This result was believed to be due to the fact that the differential cover of snow accentuated subtle fractures with subdued topography which could not be detected using the snow-free ERTS or SLAR imagery. A similar result was observed in the analysis of the Great Barrington Test Site.

1/ NOTE: This can be accomplished in a general way, although the information content of ERTS snow covered imagery complements SLAR.



A

B

FIGURE 4: East-looking SLAR image of the Canaan Mountain (c) Test Site acquired May-June, 1970. Fracture-lineaments (———) have been mapped on Image B. SLAR imagery (both east and west looking) has been used as a geological information source to aid in the validation of fracture-lineaments interpreted from ERTS-1 imagery. The image is reproduced at a scale of 1:250,000.

4.3.4 USGS Aeromagnetic Maps

Aeromagnetic data of the Canaan Test Site was analyzed to define major magnetic lineaments (Figure 5). The marbles and schists of the Taconic synclinorium are of low magnetic intensity while Canaan Mountain and the Housatonic Highlands have relatively high magnetic intensities. A study of the correlation between the magnetic anomalies and major structural trends interpreted from ERTS and SLAR imagery indicates that major fracture-lineaments interpreted from the imagery correlate well with aeromagnetic lineaments. However, the shorter linear elements are not readily apparent on the aeromagnetic maps. Canaan Mountain is of special interest: it appears as a series of small aeromagnetic anomalies separated by linear spaces of low magnetic intensity. These linear "lows" correlate with fracture-lineaments which are best seen on the snow covered ERTS imagery and may indicate fracture zones which have been intruded by dikes or veins of non-magnetic mineral (s).

4.3.5. High Altitude CIR Photography

Underflight coverage was not acquired for the Canaan Mountain area.

4.4 Results and Conclusions

A Tectonic sketch map (Figure 5A) was prepared from the analysis of the snow-covered ERTS image (1204-15074-5) of the Canaan Mountain Test Site. All known thrust and high angle faults were detected on the image while numerous suspect faults were also observed. Major fracture systems have been annotated and foliation directions plotted on the sketch map. General lithologic contacts which aided the delineation of the structure of the area, were detected based on image tonal differences. The unique fracture pattern, image tone, and relief noted on the ERTS image add credence to the interpretation that the Canaan Mountain salient ("C" in Figure 2) is allochthonous, having been thrust westward over the Stockbridge marble in the Taconic synclinorium.

A comparison of the linear geological features (e.g., faults, fractures and lineaments) interpreted from multi-sensor data indicated a high degree of correlation between the interpretations. Comparison with other imagery showed that a majority of fractures and structural trends were not as evident on the ERTS snow-free image. This was attributed to the lack of contrasting medium (e.g., snow) which would accentuate structural features. This finding emphasizes the need for multi-seasonal, repetitive coverage in order to obtain the maximum yield of geological information from ERTS imagery.

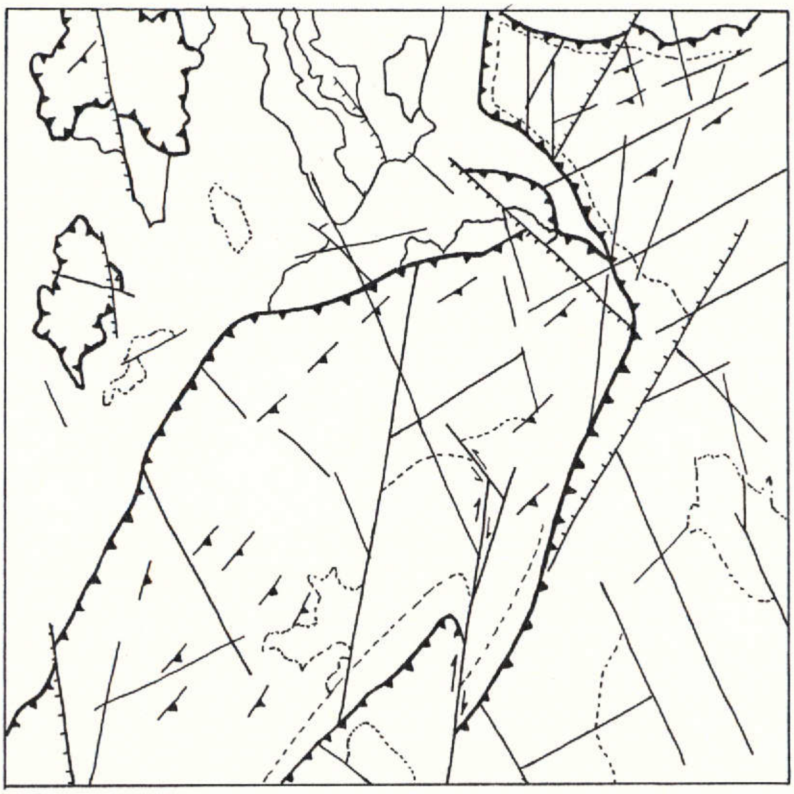
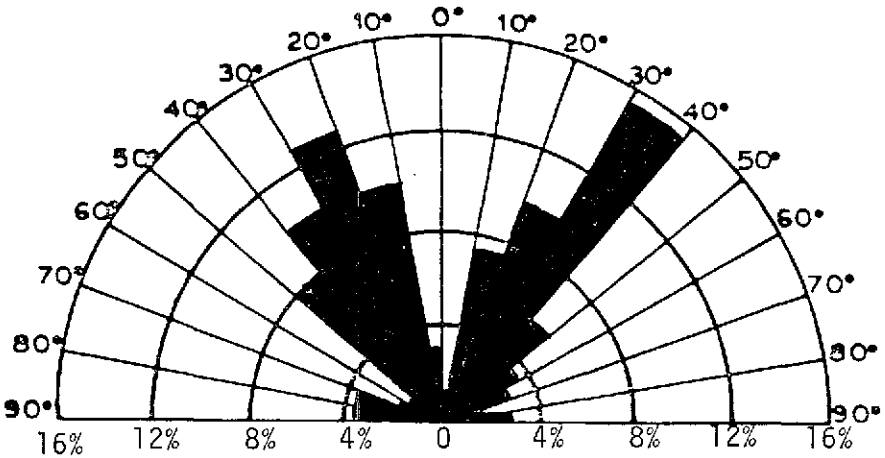
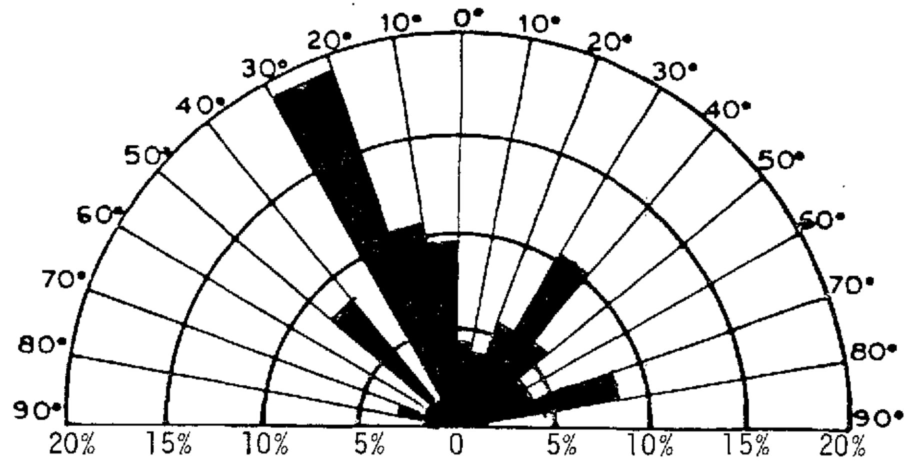


FIGURE 5A. Tectonic sketch map made from analysis of snow covered ERTS image in Figure 3 . All delineation is inferred and has not been field checked. [thrust fault symbol] = thrust faults, [high angle fault symbol] = high angle faults, [line symbol] = major fractures, [foliation symbol] = foliation direction, [lithologic contact symbol] = lithologic contacts.

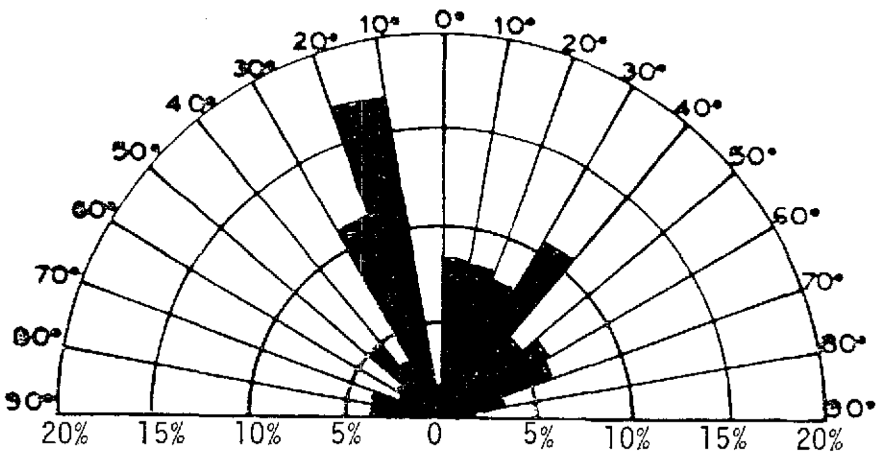
FIGURE 5B. U.S.G.S. aeromagnetic map at 1:250,000 scale of the Canaan, Connecticut test site. Arrows point to linear magnetic anomalies and anomaly separations which correlate with fractures mapped from ERTS-1 and SLAR imagery.



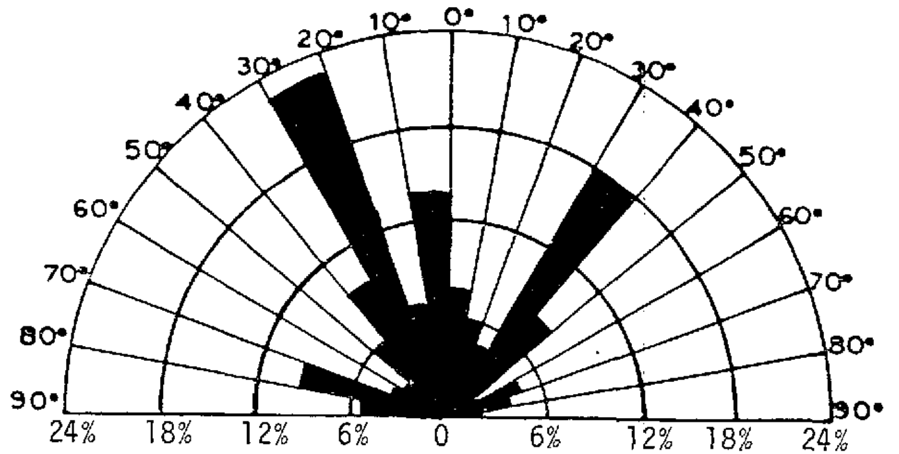
A. Measurement summary of fractures interpreted from SLAR imagery.



B. Measurement summary of fractures interpreted from ERTS-1 snow-free imagery.



C. Measurement summary of fractures interpreted from ERTS-1 snow-covered imagery.

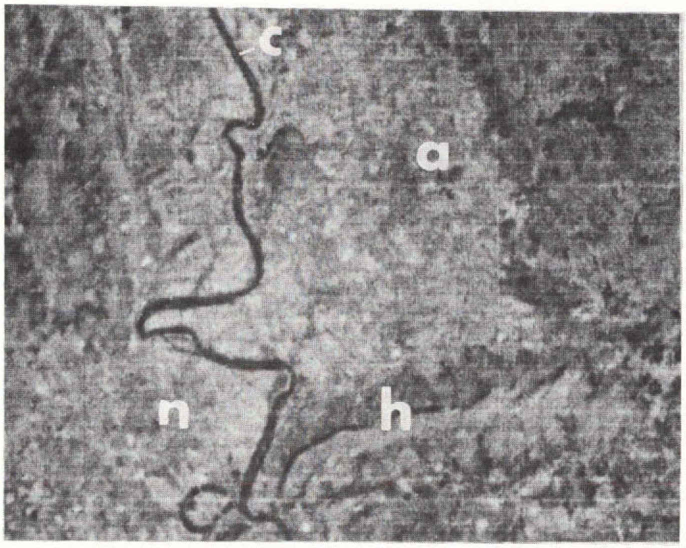


D. Measurement summary of bedrock joints obtained from field investigation.

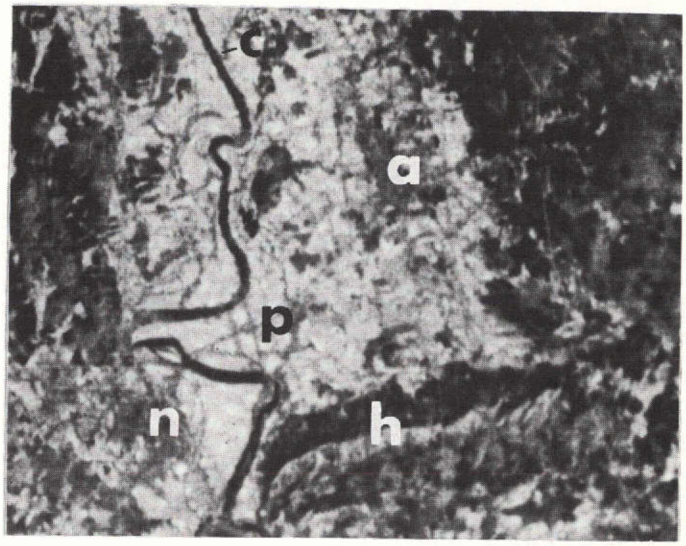
FIGURE 6. Rose diagram directional summaries of geologic fractures interpreted from multi-sensor imagery of the Canaan Mountain test site.

Sun angle, although an important factor in accentuating topographic relief, apparently did not effect the comparative snow-free versus snow-covered image data yields since sun angles were nearly the same (31° for snow-free, 28° for snow-covered). A total of 104 fractures were mapped from the snow-free image, 150 fractures from the SLAR image, while 195 were detected on the snow-covered image, indicating that snow enhancement can contribute significant amounts of information not available from other remote sensors.

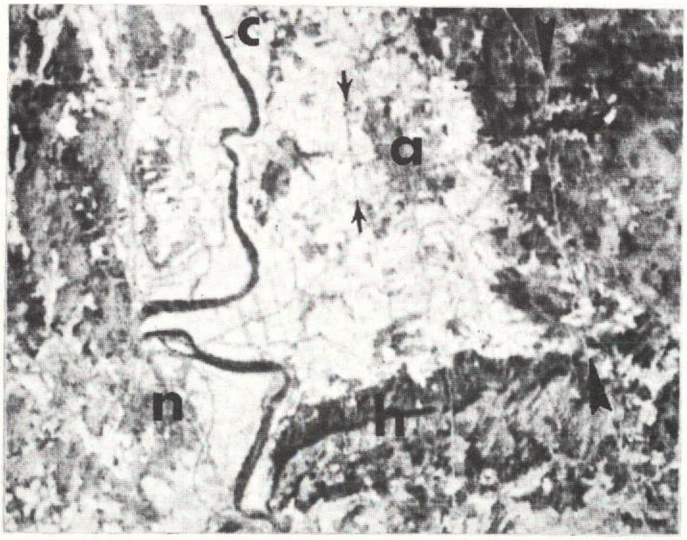
The difference in the numbers, spacing, and orientation of fractures mapped on the various types of bedrock is also significant. Fractures in the older thrust-faulted crystalline rocks of the Housatonic Highlands and Canaan Mountain are prevalent in at least four dominant directions and are much more numerous, and closely spaced than the fractures within the Cambrian and Ordovician metasedimentary rocks west of the Berkshire thrust zone. The metasedimentary rocks are less intensively fractured having only two dominant fracture directions. This suggests that the crystalline rocks underwent at least one more period of tensile stress. This deduction emphasizes the potential use of systematic fracture analysis (especially using snow-enhanced imagery) for determining multiple periods of tectonic activity, even in areas lacking widespread bedrock exposure.



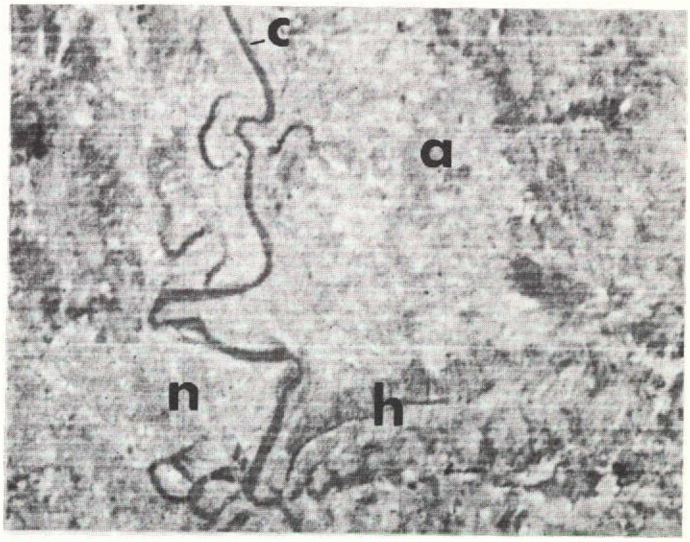
I



II



III



IV

FIGURE 7 The above images were acquired by ERTS-1 MSS band 5 over central Massachusetts. The 1:250,000 scale images illustrate the influences of seasonal variations on the comparative detectability of cultural features utilizing snow-free and snow-covered imagery. Image I (1096-15065) was acquired on October 27, 1972. The Connecticut River (c) flows north-south on the image. Mt. Holyoke, a large diabase dike, occurs at (h). The towns of Northampton (n) and Amherst (a), Massachusetts cannot be reliably identified. No highway detail is visible on this image. Image II (1168-15065) was acquired on January 7, 1973. The area shows a light cover of snow (approximately 2 inches). Street patterns (p) can be more easily discerned on this image than on Image I. The urbanized area of Amherst (a) and the University of Massachusetts can also be more easily located. This is attributed to the increased contrast between snow-cleared urban areas and snow-covered rural areas. Image III (1204-15072) was acquired on February 12, 1973 and shows a slightly deeper snow-cover (approximately 4 inches). Transmission lines (large arrows) and roadways (small arrows) are readily visible. Image IV (1258-15080) was acquired on April 7, 1973. Snow cover is not evident on this low contrast image. Land use cannot be as readily distinguished on this image as on the snow enhanced images (II and III).

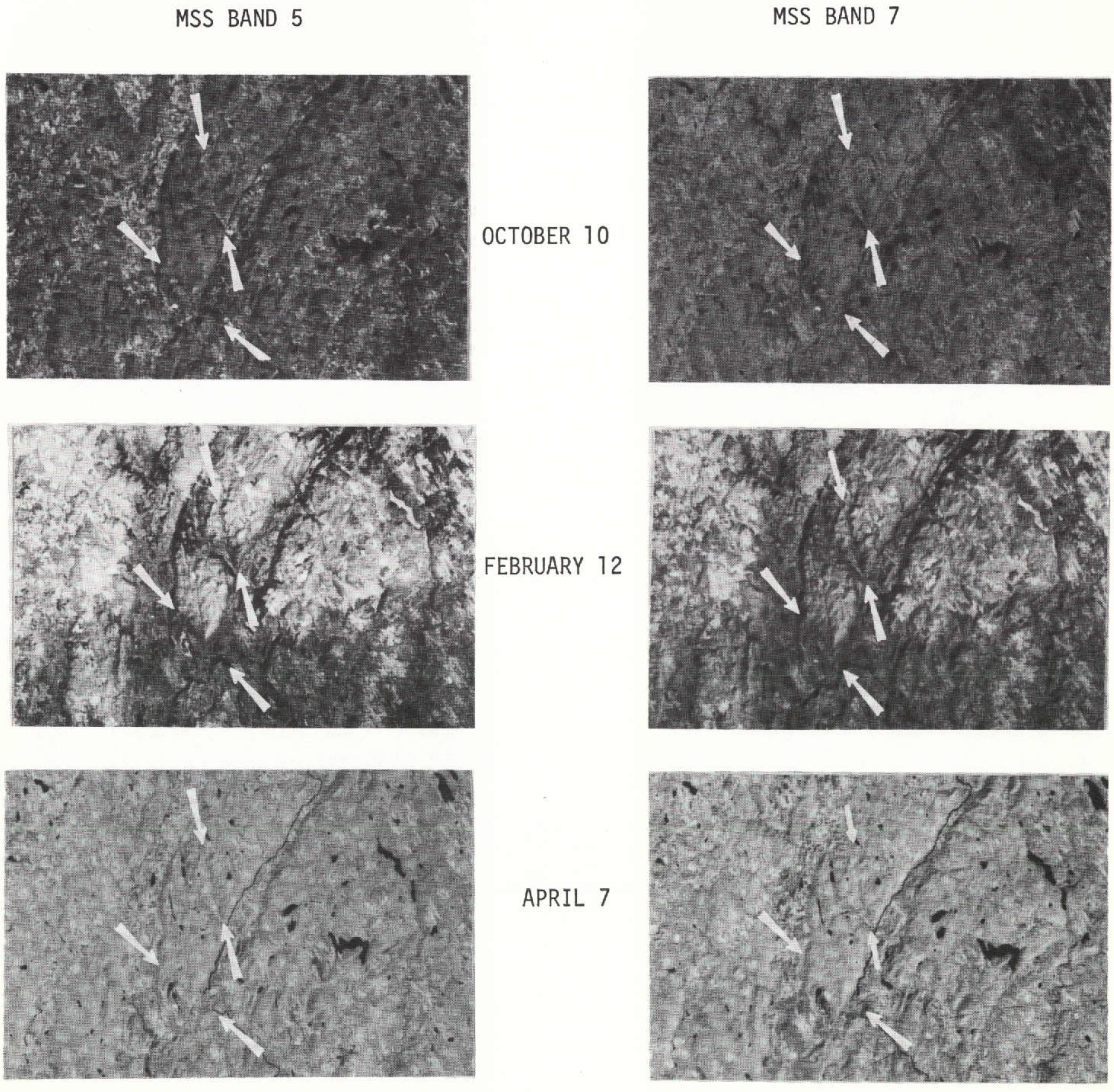


FIGURE 8: ERTS-1 imagery enlarged to a scale of 1:500,000 and acquired with MSS Bands 5 and 7 over the New York - Connecticut border. Macedonia Brook State Park is located near the center of the image area. The images demonstrate the influence of seasonal changes on fracture detectability. The February image contains a moderate snow cover (1-4 inches). The October and April images are snow free. Greater fracture detail was obtained from the snow-covered imagery during comparative analysis tests. This was attributed to the greater tonal contrast which a differential cover of snow provides. Several prominent fracture-lineaments (arrows) are indicated on the images. These features are difficult to detect on the snow-free images, particularly the April 7 imagery.

5.0 SIGNIFICANT RESULTS

5.1 Significant Results (Technical)

Detection and analysis of fracture systems can be more effectively conducted utilizing snow cover as an enhancement tool. From analysis within the Great Barrington Test Site it appears that the use of aeromagnetic data effectively supplements fracture-lineament data acquired from the analysis of ERTS imagery. Coincidence of lineaments derived from aeromagnetics with fracture-lineaments interpreted from ERTS imagery apparently indicate the presence of minearlized fracture systems and dikes. The combined use of both tools can increase the speed and efficiency of mineral exploration and geological mapping in areas where the bedrock is obscured by a thick unconsolidated sediment cover.

Comparative analysis of snow-free and snow-covered imagery of the New England Test Area has resulted in a larger number of lineaments mapped from snow-covered imagery in three out of four sets of comparative imagery. Analysts unfamiliar with the New England Test Area were utilized; the quality of imagery was independently judged to be uniform. In all comparative image sets, a greater total length of lineaments was mapped with the snow-covered imagery.

The value of this technique for fracture mapping in areas with thick soil cover is suggested. A number of potentially useful environmental applications of snow enhancement related to such areas as mining, land use and hydrology have been identified.

Snow-enhanced ERTS imagery often resembles SLAR imagery. ERTS imagery of snow-covered terrain without supporting aircraft coverage apparently complements SLAR imagery by providing fracture-lineament data in areas of relatively deep soil and subdued topography where SLAR is not as effective. SLAR does not replace the geological data yield of snow-enhanced ERTS imagery.

5.2 Applications Benefits

The applications defined in this experiment have come from the utility of ERTS imagery as the primary data source and not from the use of large or small scale aircraft coverage.

ERTS-derived fracture-lineaments maps, which greatly exceed the detail present on existing geological maps, have now been prepared for the western Massachusetts-Connecticut area. These maps were made available to potential users in the area, including the U.S. Geological Survey and Massachusetts Geological Survey.

Benefits to the ERTS program in terms of future satellite needs for geology were identified (Figure 9). ERTS wintertime imagery acquired in a systematic manner justifies repretitive ERTS coverage for geology in excess of the current 18-day schedule. Repetitive ERTS data acquired during successive winter seasons can be applied to a variety of multi-disciplinary problems: for geological studies, the interactions of snow cover, moisture content, and dynamic snow melt/accumulation patterns may provide new geological data for a substantial period of time.

A summary of additional applications benefits is listed below:

- Rapid movement of investigation from experimental research (technique development) to applications. The technique will be applied to environmental geology, i.e., detecting fracture-related mine subsidence in the Northern Anthracite Basin.
- New concept of geological data acquisition available to commercial flying companies - economic benefits (extention of flying periods, etc.)
- Effort to encourage operational use of snow enhancement techniques (mining companies and commercial flying firms)

5.3 NASA (ERTS) Program Benefits

A variety of benefits to the ERTS program realized by applied use of snow enhancement techniques are suggested by the results of this investigation. These benefits are presented in capsule form below:

- Justification for continued repetitive ERTS-Type coverage for geological studies - increases in geological data with successive winter seasons.
- Recognition of merits of technique from foreign countries (norther latitudes) - inquiries on availability of NASA imagery and technique development from Canada and Norway.
- Extended resolution threshold for ERTS and other low resolution satellites.

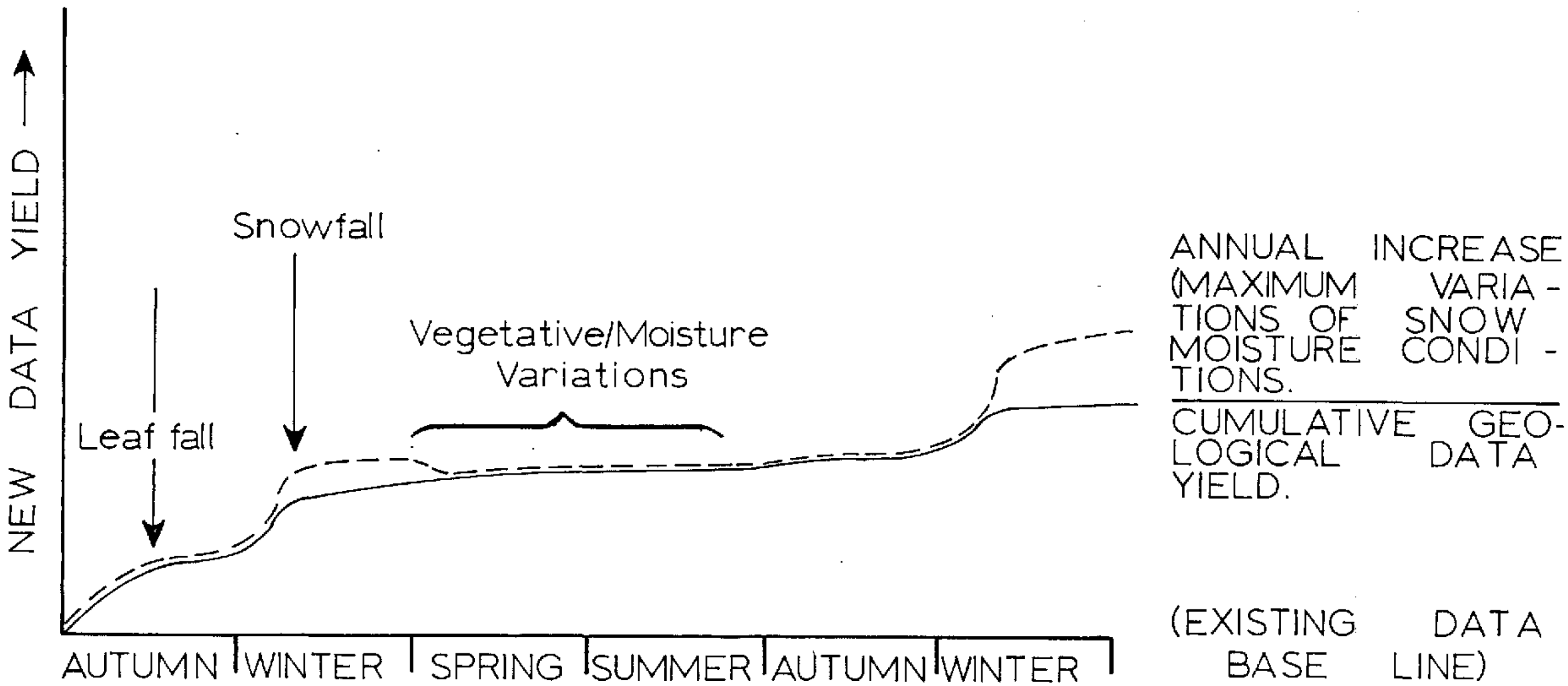


FIGURE 9: Seasonal contributions of new geological data. The geological data yield from ERTS analysis increases gradually over a period of time with major gains occurring during significant seasonal events including leaf fall, new snowfall, snow melt, etc. NOTE: Wintertime snowfall variations can increase geological data for an extended period of time.

6.0 PROGRAM FOR NEXT REPORTING PERIOD

6.1 Task Summary

A capsulized summary of the tasks which remain to be conducted within the final reporting period follows:

- Conduct several periods of field investigations in New England Test Area to examine fracture-lineaments and other selected features observed during ERTS analysis.
- Continue analysis of in-coming ERTS imagery.[1/]
- Evaluate snow cover as an aid for discriminating lithological differences.
- Document the detectability of a variety of geological features for areas of differing lithology, topography and vegetative cover under varying conditions of snow cover, i.e., light vs. heavy cover.
- Generate computer enhanced imagery of snow-free and/or snow-covered terrain within Test Site #1.
- Continue preparation of Snow-Enhancement User Manual.
- Complete and finalize Snow Enhancement Final Report.

6.2 Anticipated Principal Products

Principal products generated for the final reporting period are anticipated to include:

- New England Structural Base Map (1:1,000,000 scale) annotated with fracture-lineament detail obtained from ERTS analysis.

1/ Until December 17 cutoff.

- Comprehensive Final Report documenting the results of this investigation. Benefits realized from the application of snow enhancement and related techniques will be identified.

- Snow Enhancement Users Manual detailing the procedures to be utilized to obtain the maximum information from snow covered data.

7.0 CONCLUSIONS

The applications defined in this experiment have come from the utility of ERTS imagery as the primary data source and not from the use of large or small scale aircraft coverage.

The utility of ERTS imagery for fracture mapping regardless of season has been repeatedly confirmed. The enhancement provided by a differential cover of snow increases the number and length of fracture-lineaments which can be detected with ERTS data and accelerates the fracture mapping process. Snow enhanced ERTS imagery provides unique data which complements SLAR.

An ERTS-derived fracture-lineaments map which greatly exceeds the detail present on existing geological maps is now available in the Massachusetts-Connecticut area. This map was made available to potential users in the area, including the U.S. Geological Survey and Massachusetts Geological Survey. As a result of this experiment, the value of snow enhancement is increasingly recognized for multidisciplinary studies within the ERTS program. Snow cover enhances geological features including landforms, foliation and bedding as well as fracture-lineaments. For environmental geology applications, ERTS imagery of snow-covered terrain permits rapid discrimination of land use and hydrological detail, e.g., thermal outfalls, soil permeability variations and drainage patterns. Snow cover also increases the tonal contrast between differing vegetative densities or types (e.g., coniferous versus deciduous forest), thus aiding vegetation mapping. Areas of snow-clearing (e.g., airport runways, highways, urban areas, etc.) contrast readily with surrounding terrains, thus facilitating identification and mapping of such surface phenomena and in fact, increasing the effective working resolution of ERTS imagery.

Snow-enhanced ERTS imagery often resembles SLAR imagery. ERTS imagery of snow-covered terrain without supporting aircraft coverage apparently complements SLAR imagery by providing fracture-lineament data in areas of relatively deep soil and subdued topography where SLAR is not as effective. SLAR does not replace the geological data yield of snow-enhanced ERTS imagery.

8.0 RECOMMENDATIONS

Benefits to the ERTS program in terms of future satellite needs for geology were identified. ERTS wintertime imagery acquired in a systematic manner justifies repetitive ERTS coverage for geology in excess of the current 18-day schedule. Repetitive ERTS data acquired during successive winter seasons can be applied to a variety of multidisciplinary problems; for geological studies, the interactions of snow cover, moisture content, and dynamic snow melt/accumulation patterns will provide new geological data for a substantial period of time.

Add-on investigations have been submitted to NASA which would demonstrate operational applications of snow enhancement techniques. The investigators recommended the funding of these programs. They are summarized below:

- Application of Snow Enhancement Techniques to the preparation of Map Products in Environmental Geology.

  This investigation is an ERTS-B proposal which will be conducted using both ERTS-1 and ERTS-B imagery. Prototype maps will be prepared which display environmental geological information in a format usable by selected State planning agencies. Analyses conducted within the present investigation confirm that snow enhancement techniques will increase the usability of ERTS data for environmental geological studies. State agencies and development commissions have expressed an interest in this investigation.

- Preparation of an Excavation Hazards Map series for the Northeast Corridor Utilizing Snow Enhancement Techniques.

  The maps produced will be prepared in cooperation with the Department of Transportation and interested members of Congress who have requested to be kept advised of practical ERTS applications.

- Extension of Snow Enhancement Techniques to Unglaciated Terrains for Geological Studies

The objective of this investigation would be the development of unique fracture information in unglaciated terrains of moderate-to-deep soil cover. These are areas where the most limited quantities of fracture data are now available. Techniques to maximize fracture detection in complex geological terrains have been successfully developed from analysis of ERTS snow-covered imagery within the New England Test Area. The investigators believe that these techniques can be extended to facilitate the detection of fractures in areas of deeper, less permeable soils where fracture detail is difficult and usually impossible to obtain.

APPENDICES

APPENDIX A

PROGRESS REPORT SUMMARY

Reporting Period: May 1, 1973 - October 31, 1973

CATEGORY: 8-Interpretation Techniques Development

SUB-CATEGORY: C-General

TITLE: Facilitating the Exploitation of ERTS-Imagery Using Snow Enhancement Techniques - SR #141: NAS 5-21744

PRINCIPAL INVESTIGATOR: Dr. Frank J. Wobber (P-511)

CO-INVESTIGATOR: Mr. Kenneth R. Martin

SUMMARY:

The applications of ERTS imagery for geological fracture mapping regardless of season has been repeatedly confirmed. The enhancement provided by a differential cover of snow increases the number and length of fracture-lineaments which can be detected with ERTS data and accelerates the fracture mapping process for a variety of practical applications. The geological mapping benefits of the program will be realized in geographic areas where data are most needed - complex glaciated terrain and areas of deep residual soils.

ERTS-derived fracture-lineament maps, which provide detail well in excess of present geological maps, are now available for the Massachusetts-Connecticut area. The large quantity of new data provided by ERTS may accelerate and improve field mapping now in progress in the area. Numerous user groups have requested data on the techniques which represent a major change in operating philosophy for groups who to date judged that snow obscured geological detail.

Snow-enhanced ERTS imagery complements SLAR imagery in deep soil areas of subdued topography. It is in these areas where SLAR imagery is least effective for fracture analysis. Snow enhanced ERTS imagery will now provide geo-environmental data unavailable from other sources; it has particular value for facilitating discrimination of bedding contacts, lithological variations, fracture systems and variation in permeability.

Use of snow enhancement techniques will accelerate acquisition of a variety of data used for environmental geology map preparation for operating planning agencies at the State, county and municipal levels. This will be pursued in ERTS-B.

APPENDIX B

APPENDIX B

TASK STATUS REPORT

	TASK	STATUS	COMMENTS
PHASE I			
1.0	Establish Technical Interface with NDPF	Completed 6/30/72	Meetings held with the scientific monitor: ERTS-simulation U-2 aircraft imagery analyzed.
2.0	Assemble Geological Maps and Snow Cover Data	Completed 10/31/72	Subscription to New England Climatological Data: State geological maps of Massachusetts, Connecticut, Vermont, New Hampshire, and geological quadrangle maps for western Massachusetts purchased and analyzed.
3.0	Select and Establish Snow Points	Completed 2/28/73	A comprehensive net of weather stations has been organized. Physical ground points for light aircraft survey have been minimized.
4.0	Base Map & Underflight Preparation	Completed 10/31/72	Base map scale determined: Other New England investigators contacted.
5.0	Lineament Map Pre-Preparation	Completed 8/30/72	Radar imagery of Massachusetts, Connecticut, and Rhode Island was intensively analyzed to prepare geological lineament maps of the test area.
6.0	Snow Cover and Snow Melt Survey	Completed 12/31/72	Survey package designed and sent to newspapers in low density snow depth reporting areas. Readers indicating interest have been supplied with snow-depth reporting materials.
PHASE II			
7.0	Select & Analyze Snow Free ERTS Imagery	Completed 2/28/73	All ERTS-1 imagery of the test area analyzed upon receipt. Images 1096-15072-5 & 7 and 1096-15065-5 & 7 of the New England Test area and 1062-15190-5 & 7 of the Maryland Test area are being enlarged to a 1:250,000 scale to serve as a photo base map.

TASK	HEADING	STATUS	COMMENTS
2.0	Analyze Snow-Covered Imagery	Completed 8/31/73	All ERTS-1 snow-covered of the test area analyzed. Intensive analysis of frames 1132-15074, 1168-15065, 1204-15072,1204-15074, 1258-15073 and 1258-15080 has been conducted. U-2 snow-covered imagery also analyzed.
3.0	Prepare & Submit A Preliminary Data Analysis Plan	Completed 12/31/72	A Data Analysis Plan has been submitted and approved by the ERTS Contracting Officer.
		PHASE III	
1.0	Modify Manual Optical & ADP Enhancement Techniques.	Completed 2/28/73	A re-evaluation of techniques and approach has been conducted. No major changes were necessary - minor modifications have been integrated.
2.0	Process ERTS Imagery Though Last Snow-Covered Period.	Underway	Automatic processing of ERTS CCT's is underway. Seasonal influence on fracture detectability is being studied.
3.0	Prepare Final Report	Underway	The Final Report is being written as the experiment progresses. Sections I, II and III (Introduction, Background and Design) complete in draft form. Subsections in Section IV and V (Analytical Procedures) are being prepared.
4.0	Prepare NDPF User Manual	Pending Completion of Final Report	Processing of a variety of candidate illustrations for the Manual is underway.

▨ - Completed Tasks

APPENDIX C

The Commonwealth of Massachusetts

Executive Office of Transportation and Construction

Department of Public Works

100 Nashua Street, Boston 02114

October 23, 1973

Mr. Frank J. Wobber
Director Geosciences Div.
Earth Satellite Corp.
1747 Pennsylvania Ave., N.W.
Washington, D.C. 20006

Re: SR#141 ERTS Snow Enhancement Map

Dear Mr. Wobber:

Please be advised that we have received and reviewed your project map which arrived with your letter of September 26, 1973.

The map is of professional quality and attempts to test a hypothesis concerning Earth Lineaments as detected from space.

Since all mapping in Massachusetts is done in Coöp programs with the U.S.G.S., I feel that their critical analysis should weigh much more heavily than any comment I might make. Personally, I feel that a combination of all mapping methods available to us should be considered and evaluated before we produce a quadrangle or State bedrock and structure map.

We presently have available aeromagnetic maps as well as gravimeter and aero radiometer maps with which this map will have to be correlated before we know whether the information is valid. In the long run we should form a much better impression.

It would be interesting to compare the appearance of a known major structure which has previously been mapped in order that we might adjust our thinking to known length, width, displacement and appearance of classic structures. Sorry, I can not be of more help at this time.

I wish to make one more request for infra-red heat sensitive imagery from N.A.S.A. in order to help us work with the pressing environmental problems that we encounter each day. I would rather solve one practical problem than complete all the esoteric studies ever proposed.

Very truly yours,

Joseph R. Sinnott
State Geologist, Mass.

JRS/sp

Alyeska pipeline
SERVICE COMPANY

2100 TRAVIS STREET, HOUSTON, TEXAS 77002, TELEPHONE (713) 222-2647, TELEX 762-3

October 6, 1972

Dr. Frank J. Wobber, Director
Geosciences and Environmental
Applications Division
Earth Satellite Corporation
1771 N. Street, N. W.
Washington, D. C. 20036

Dear Dr. Wobber:

Thank you for your letter describing ESC's enhancement experiment. We at Alyeska are interested in remote sensing for several reasons --expected snow depths and drainage patterns and possible monitoring of construction activities if resolution permits. (I am trying to build a mile-by-mile/day-by-day model of conditions we would encounter in the construction phase of our project. This objective will not justify much expense; it is to be done as much as possible on available information.) If you feel your experiment has potential in this area, please contact me and we will investigate in more detail.

Sincerely,

David F. Sicks

Oslo , April 12. 1973

Dr. Frank Wobber
Earth Satellite Corp.
Washington, D.C.
U S A

Dear Sir:

I met you at the Earth Observation Satellite Summerschool in July 1969 in Cambridge, England.I have read abaut your ERTS I project,and to your information, Iam cooinvestigator in two Norwegian ERTS I project approved by NASA.

My thoughts came to you when looking at one ERTS image of Norway with a low sun angle,21 degrees aND WITH A THIN LAYER OG SNOW IN PARTS OF THE MOUNTAINS. This really accentuated the geometry impression of the land. However I have yet no ERTS images of this area with high sun angle, so it is impossible to determine exactly the degree of accentuation. I am working in the field of snowmapping,geomorphology and structutal geology. It would be interesting to know if you have any report and information available for me.

Sincerely yours,

Johnny Skorve

Johnny Skorve

Kirkeveien 127 III
Oslo 3
Norway

The Commonwealth of Massachusetts
Water Resources Commission
Leverett Saltonstall Building, Government Center
100 Cambridge Street, Boston 02202

OFFICE OF THE DIRECTOR
DIVISION OF WATER RESOURCES

May 16, 1973

Frank J. Wobber, Director
Geosciences and Environmental
Application Division
Earth Satellite Corp.
1747 Pennsylvania Avenue, N.W.
Washington, D.C. 20006

Dear Mr. Wobber:

I have recently read your correspondence of April 25, 1973 to Mr. Beshara. I was quite impressed by the information available on the ERTS images.

As the staff geologist, I am in the process of preparing a geological library to be used for the purposes of water resource investigation and planning. I am interested in knowing what services, publications and imagery your office has available for purchase by a state agency. I am especially interested in the results of your snow-covered terrain study.

I am in complete agreement regarding the gains to be made in the use of this data and I would sincerely appreciate any information that you could provide.

Mr. Beshara extends his regards.

Very truly yours,

Sheldon Shapiro

Sheldon Shapiro
Principal Civil Engineer

SS:eb

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Cornell University

HOLLISTER HALL, ITHACA, N.Y. 14850

August 20, 1973

Dr. Frank J. Wobber
Earth Satellite Corp.
1747 Pennsylvania Avenue
N.W. Washington, D.C. 20006

Dear Dr. Wobber:

I am a graduate student in Civil and Environmental Engineering majoring in Aerial Photographic Studies. I am doing research on remote sensing of snow and have seen abstracts of your work dealing with "Exploitation of ERTS-1 Imagery Utilizing Snow Enhancement Techniques." Would it be possible to obtain a copy of this report? Thank you for your consideration in this matter.

Respectfully yours,

Frederick C. Voigt

Frederick Voigt
Graduate Research Assistant

FV/js

CAPE COD PLANNING AND ECONOMIC DEVELOPMENT COMMISSION
1st DISTRICT COURT HOUSE, BARNSTABLE, MASSACHUSETTS 02630
TELEPHONE: 617-362-2511

August 15, 1973

Earth Satellite Corporation
1747 Pennsylvania Avenue, N.W.
Washington, D. C. 20006

Attention: Mr. Frank J. Wobber and Mr. Kenneth R. Martin

Dear Sirs:

The State Geologist of the Commonwealth of Massachusetts, Mr. Joseph Sinnott, has showed us your letter to him of July 20, 1973, which enclosed a recent ERTS image of the Cape Cod area for his information. We have been working closely with Mr. Sinnott on a proposed ground water investigation of Cape Cod.

It would be very helpful to us in terms of water, land use and other resource management projects in which we are involved, to have copies of this ERTS image of the Cape Cod area available to the Cape Cod Planning and Economic Development Commission. Would you be able to send us a negative from which we could have copies made? Alternatively, could we purchase copies of the print from your Corporation? Has this image been released to the press by your Corporation?

We appreciated the opportunity to see this ERTS image, and were greatly impressed with the amount of detail visible on the Cape land mass and it is even possible to make out sand shoals in the surrounding waters.

We look forward to hearing from you.

Sincerely yours,

C. W. Burlin

C.William Burlin
Economic Development
Coordinator

CWB:bc

APPENDIX D

APPENDIX D

GLOSSARY OF TERMS

Ablation---------------------------- Processes which reduce the depth of snow or ice cover including melting, sublimation and wind erosion.

Anticline--------------------------- A fold, the core of which contains stratigraphically older rocks; it is convex upward.

Anticlinorium----------------------- A composite anticlinal structure of regional extent, composed of lesser folds.

Berkshire massif-------------------- A massive topographic feature in the Berkshire mountain range consisting of metamorphosed igneous rocks more resistant than those of the surrounding rock strata.

Fault------------------------------- A fracture surface or zone in rock along which appreciable displacement has taken place.

Fold-------------------------------- A curve or bend of a planar structure such as rock strata, bedding planes, foliation or cleavage.

Foliation--------------------------- A general term for a planar arrangement of textural or structural features in any type of rock.

Fracture---------------------------- A surface along which loss of cohesion has taken place, i.e. a general term for any break in a rock including joints and faults. In this report the term is used to describe fracture traces (surficial expressions of subsurface fractures) as well as surficial fractures.

Glacial Drift----------------------- A general term for any material that has been transported by glaciers.

Fracture-Lineament------------------ Structurally controlled features judged to be surface expressions of bedrock fractures. May represent a single fracture or series of fractures.

Glacial Striae---------------------- A series of long, usually straight and parallel furrows or lines inscribed on a bedrock surface by the gouge and scour of rock fragments embedded at the base of a moving glacier; usually oriented in the direction of ice movement.

Joint------------------------------- A surface of actual fracture or parting in a rock without displacement of either side relative to the other.

Metamorphic Rock-------------------- Rock that has formed under conditions of high temperature and pressure, having an interlocking arrangement of mineral grains known as crystalline texture. Chemical rearrangements and changes in shapes of mineral grains have occurred without actual melting of the rock from which they formed. Metamorphic rocks commonly have mineral grains arranged parallel to each other. Examples include slate, schist, gneiss, marble and amphibolite.

Snow Dusting------------------------ A very light, layer of snow cover.

Snow Enhancement-------------------- The accentuation of various phenomena on the Earth's surface resulting from the differential accumulation and/or melting of snow cover, or its obscuration by vegetative cover.

Snow Obscuration-------------------- The masking of underlying snow cover from aerial sensors by varying densities of vegetative overstory.

Taconic Orogeny--------------------- A major period of late Ordovician tectonic activity in the Northern Appalachian mountains during which the rocks making up the Taconic mountains were thrust westward to their present position.

Test Area------------------------- Regional areas (e.g. Southern New England) which are analyzed to develop and refine a given hypothesis or technique.

Test Sites------------------------- Localized areas of high geological interest within the test areas which receive intensive analysis.

Thrust Fault----------------------- A fault with a dip of 45° or less in which the hanging wall appears to have moved upward relative to the footwall, characteristically with a horizontal compression rather than a vertical displacement.

Validation------------------------- A deductive system for giving increasing weight to a fracture-lineament using manual and/or electro-optical techniques.

APPENDIX E

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

NDPF USE ONLY
D
N
ID

DATE 19 November, 1973

PRINCIPAL INVESTIGATOR Dr. Frank J. Wobber

GSFC SR 141

ORGANIZATION Earth Satellite Corporation

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	River	Lake	Lineament	
E-1401-15004-4,5,6,7	X	X	X	Mountains Valleys Basin Dendritic Drainage Fault Dike Coast Line Urban Area
E-1402-15060-4,5,6,7	X	X	X	Mountains Valley Dike Bedding Faults Urban Area
E-1420-15060-4,5,6,7	X	X	X	Coast Line Fault Urban Area
E-1421-15112-4,5,6,7	X	X	X	Mountains Valley Faults Urban Area Cuesta
E-1421-15114-4,5,6,7	X	X	X	Bedding Faults Thrust faults Mountains Valley Urban Area

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

MAIL TO ERTS USER SERVICES
CODE 563
BLDG 23 ROOM E413
NASA GSFC
GREENBELT, MD. 20771
301-982-5406

GSFC 37-2 (7/72)

APPENDIX F

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