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16. Abstract

Linear anomalies dominate the new geological information derived from ERTS-I imagery, total lengths now exceeding 6000 km. Experimentation with a variety of viewing techniques suggests that conventional photogeologic analyses of band 7 results in the location of more than 97 percent of all linears found. Bedrock lithologic types are distinguishable only where they are topographically expressed or govern land-use signatures. The maxima on rose diagrams for ERTS-I anomalies correspond well with those for mapped faults and topographic lineaments, despite a difference in relative magnitudes of maxima thought due to solar illumination direction. A multiscale analysis of linears showed that single topographic linears at 1:2,500,000 became dashed linears at 1:1,000,000 aligned zones of shorter parallel, en echelon, or conjugate linears at 1:500,000, and shorter linears lacking any conspicuous zonal alignment at 1:250,000. Most circular features found were explained away by U-2 airfoto analysis but several remain as anomalies. Visible glacial features include individual drumlins, best seen in winter imagery, drumlincids, eskers, ice-marginal drainage channels, glacial lake shorelines and sand plains, and end moraines.

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PREFACE

This progress report summarizes investigative methods and accomplishments to date on a project to evaluate the usefulness of ERTS-I imagery as a spectral geological mapping tool. The investigation concentrates on the geologically usable imagery over New York State, although major new structural elements will be studied where they extend into adjacent regions. Work to date indicates that ERTS-I imagery is particularly well suited to detect topographically-expressed features, including numerous large-scale structures which would probably never have been discovered without a regional synoptic cability such as that provided by ERTS-I.

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1. INTRODUCTION

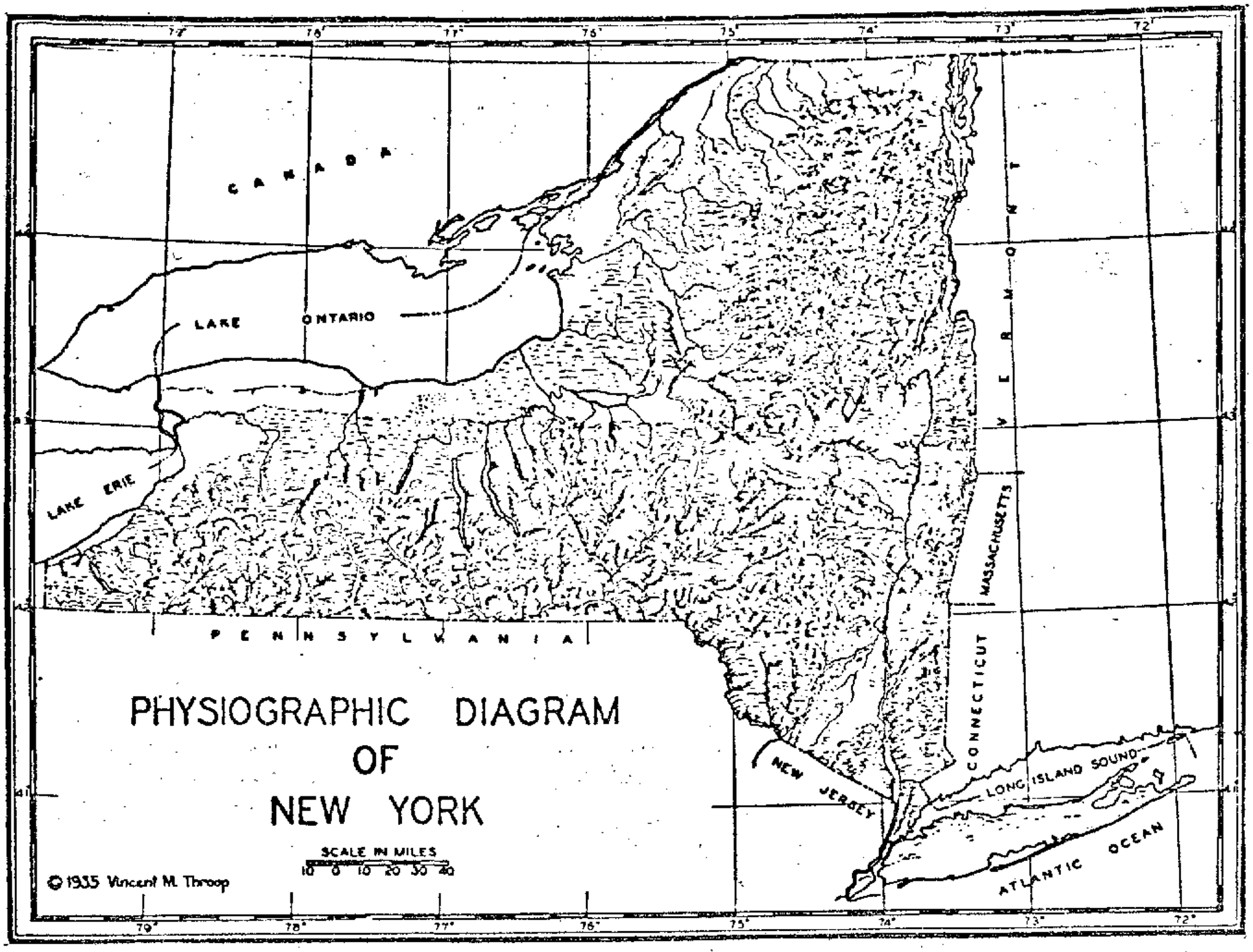
1.1 ~~The~~ major objective of this study is to extract a maximum amount of new geological information from ERTS-I imagery, and thus to evaluate ~~its~~ potential as a spectral-geological mapping tool. Analysis of the imagery is being supplemented with remote sensor data acquired by high, intermediate, and low-level aircraft, in addition to ground study. The investigation is being carried out at three scales, 1:1,000,000, 1:500,000 and 1:250,000, with the bulk of the work completed to date having been done at the smaller scale. The latter two scales correspond, respectively, to those of Tectonic Atlas maps for the State now in progress, and the recently published Geologic Map of New York State (Fisher and others, 1971).

1.2 New York State provides a highly varied test area for evaluating ERTS-I imagery as a source of new geological information not readily seen at conventional mapping scales. The State covers a number of well defined physiographic provinces (Figure 1), and contains lithologic units ranging in age from Proterozoic to Pleistocene (Figure 2). It stretches east-west across five tectonic provinces as follows (Figure 3): 1) a continental platform (Platform I) consisting of Lower and Middle Paleozoic strata resting on a Proterozoic basement, 2) the Adirondack Dome Mountains which are located on the eastern edge of this platform and expose Proterozoic basement of the Grenville Province, 3) the Appalachian Foldbelt with its several subdivisions including the Hudson Highlands (reactivated Proterozoic basement) and the Taconic allocthones, 4) the Triassic Fault Trough (Palisadian Taphrogen) and 5) Cretaceous coastal plain sediments on Paleozoic basement (Platform II).

1.3 For a general description of the geology and physiography of the State the reader is referred to Broughton and others(1966); the tectonic subdivisions are discussed in Fisher and others (1971).

2. DATA HANDLING AND INVESTIGATIVE PROCEDURE

2.1 The overall procedures for data handling and imagery analysis are shown by flow chart in Figure 4. Incoming imagery, consisting of 9.5 inch positive transparencies and 70 mm positive and negative transparencies of New York State and adjacent areas are logged according to scene designation (Figure 5) and other identifying factors, including delineation of cloud-free areas (Figure 6). For convenience, the scene designations shown in Figure 5 are used throughout this report. Image descriptors are tabulated at this stage. Diazo paper prints of bands 5 and 7 are then made for the browse file. Selected cloud-free imagery is set aside for photographic reprocessing of all bands to produce high contrast positives for later color-additive viewing.



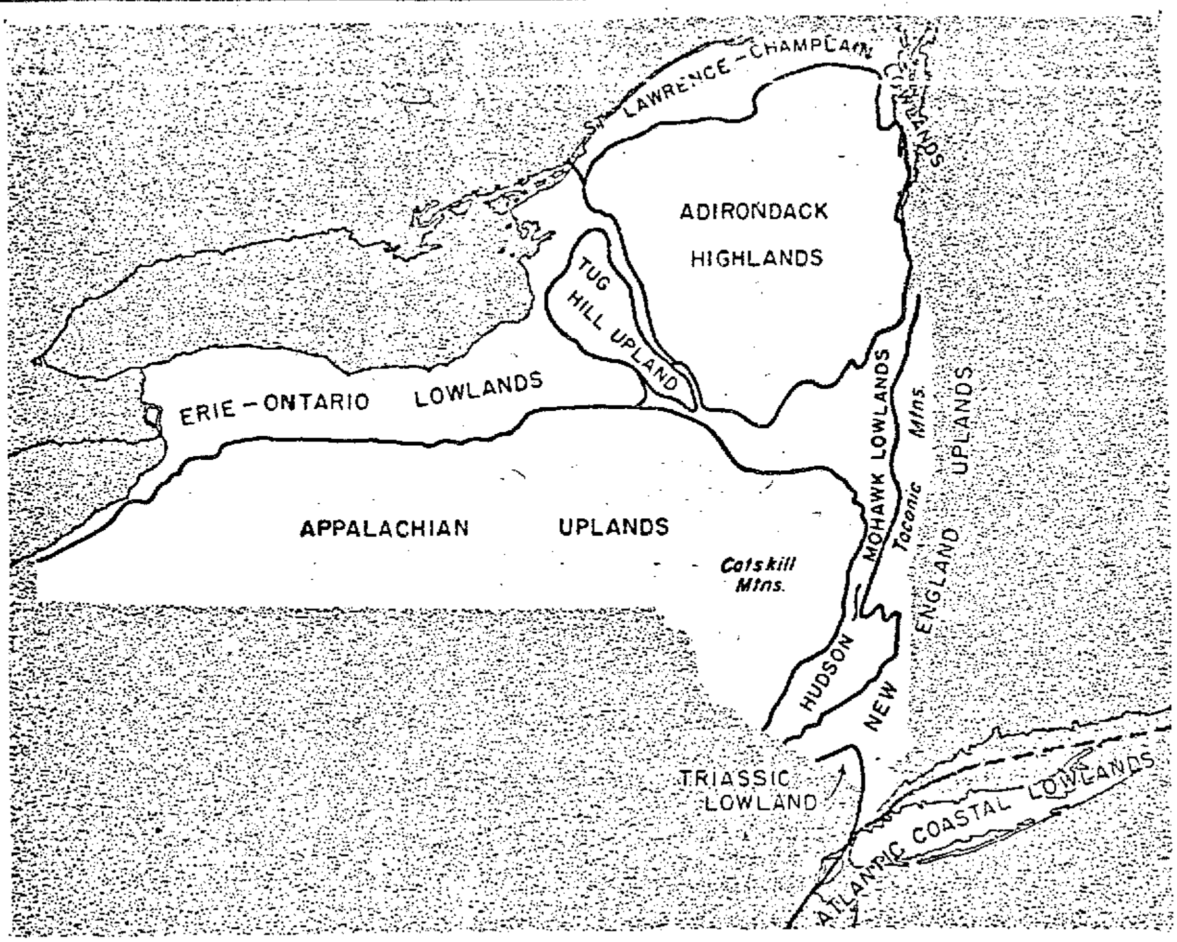


Figure 1. Physiographic subdivisions of New York State. Lower diagram from Broughton and others, 1966.

Figure 2. GENERALIZED BEDROCK GEOLOGY OF NEW YORK STATE

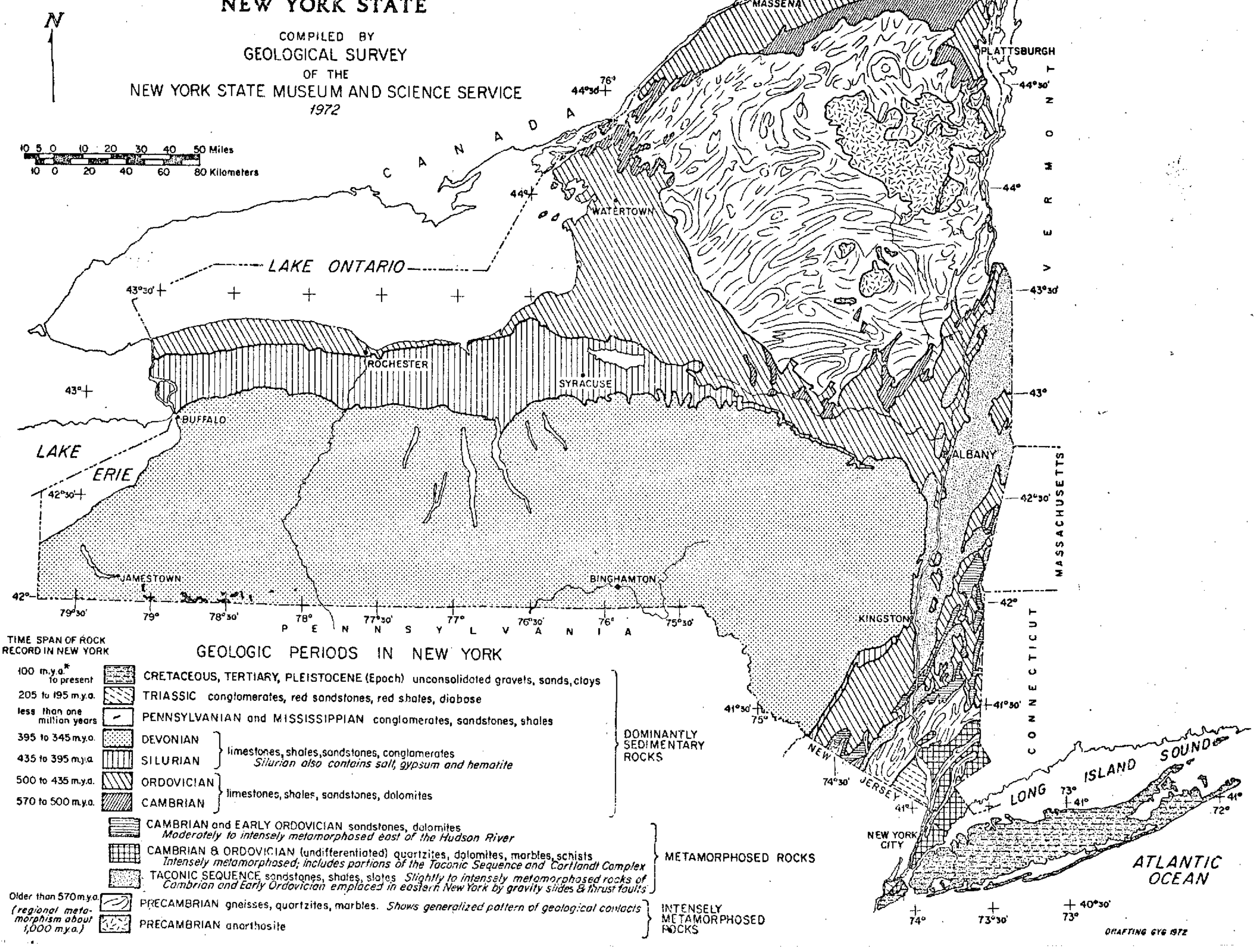
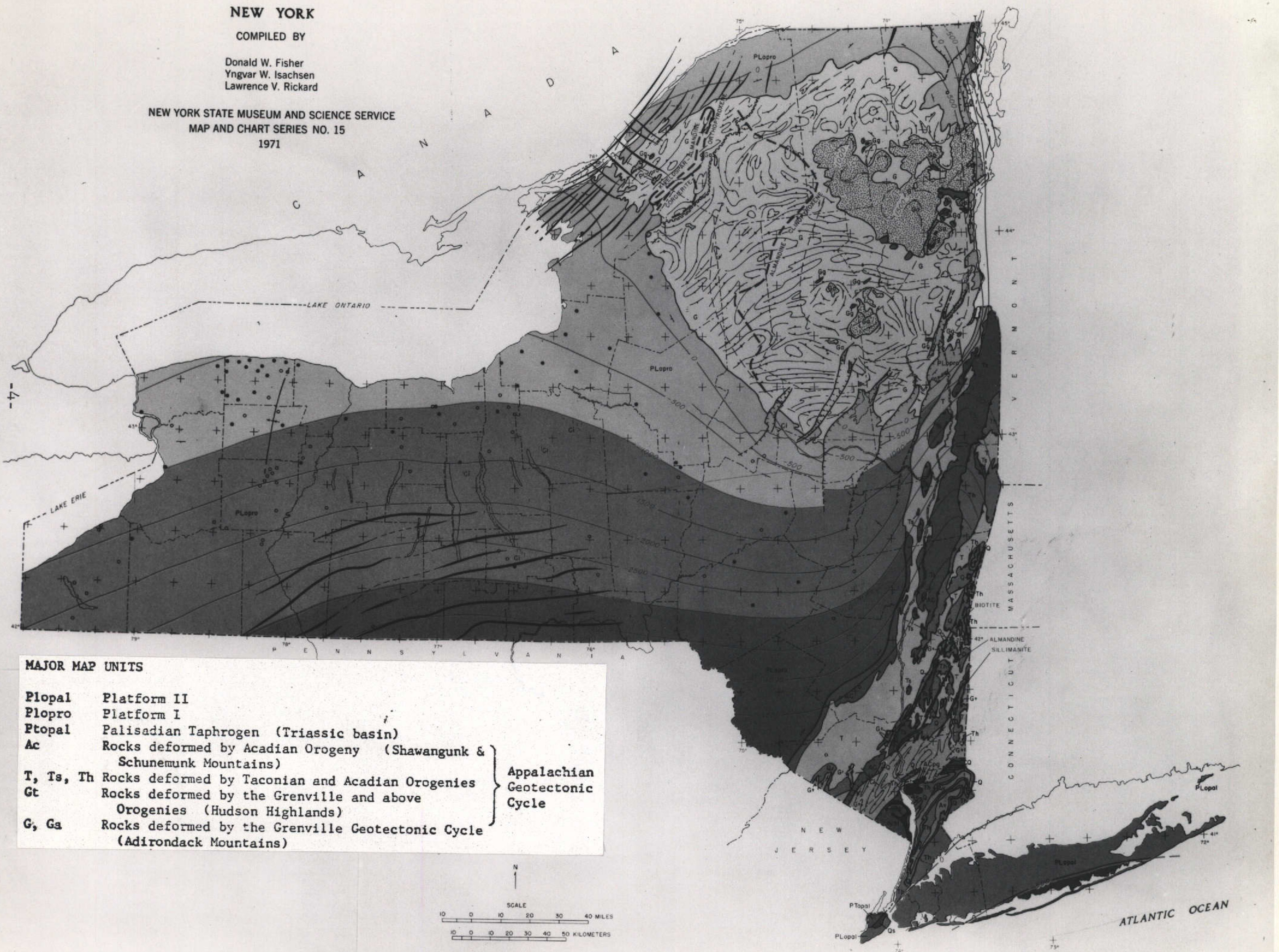


Figure 3. **GENERALIZED TECTONIC - METAMORPHIC MAP of NEW YORK**

COMPILED BY

Donald W. Fisher
Yngvar W. Isachsen
Lawrence V. Rickard

NEW YORK STATE MUSEUM AND SCIENCE SERVICE
MAP AND CHART SERIES NO. 15
1971



MAJOR MAP UNITS

Plopal	Platform II	
Plopro	Platform I	
Ptopal	Palisadian Taphrogen (Triassic basin)	
Ac	Rocks deformed by Acadian Orogeny (Shawangunk & Schunemunk Mountains)	Appalachian Geotectonic Cycle
T, Ts, Th	Rocks deformed by Taconian and Acadian Orogenies	Appalachian Geotectonic Cycle
Gt	Rocks deformed by the Grenville and above Orogenies (Hudson Highlands)	Appalachian Geotectonic Cycle
G, Ga	Rocks deformed by the Grenville Geotectonic Cycle (Adirondack Mountains)	

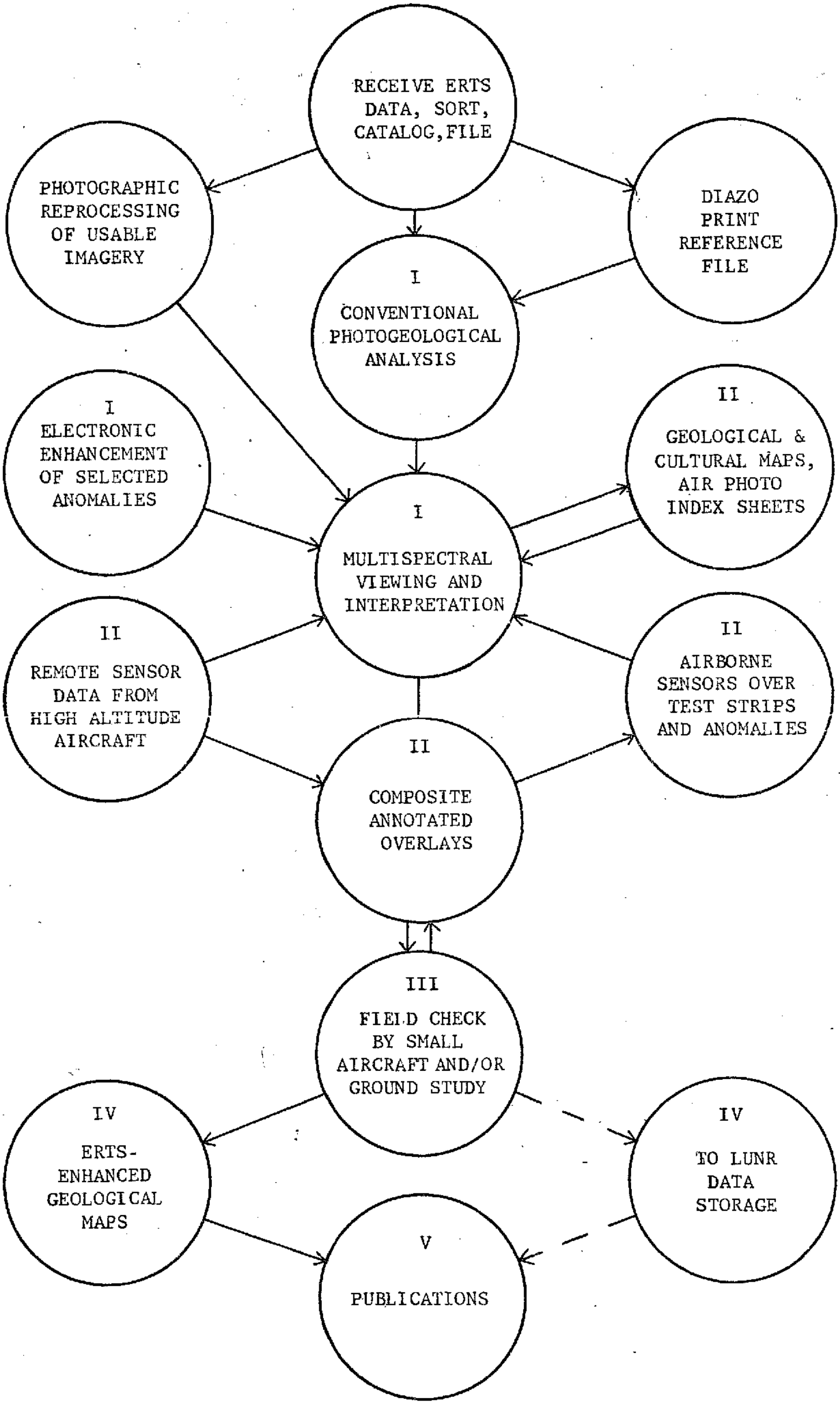
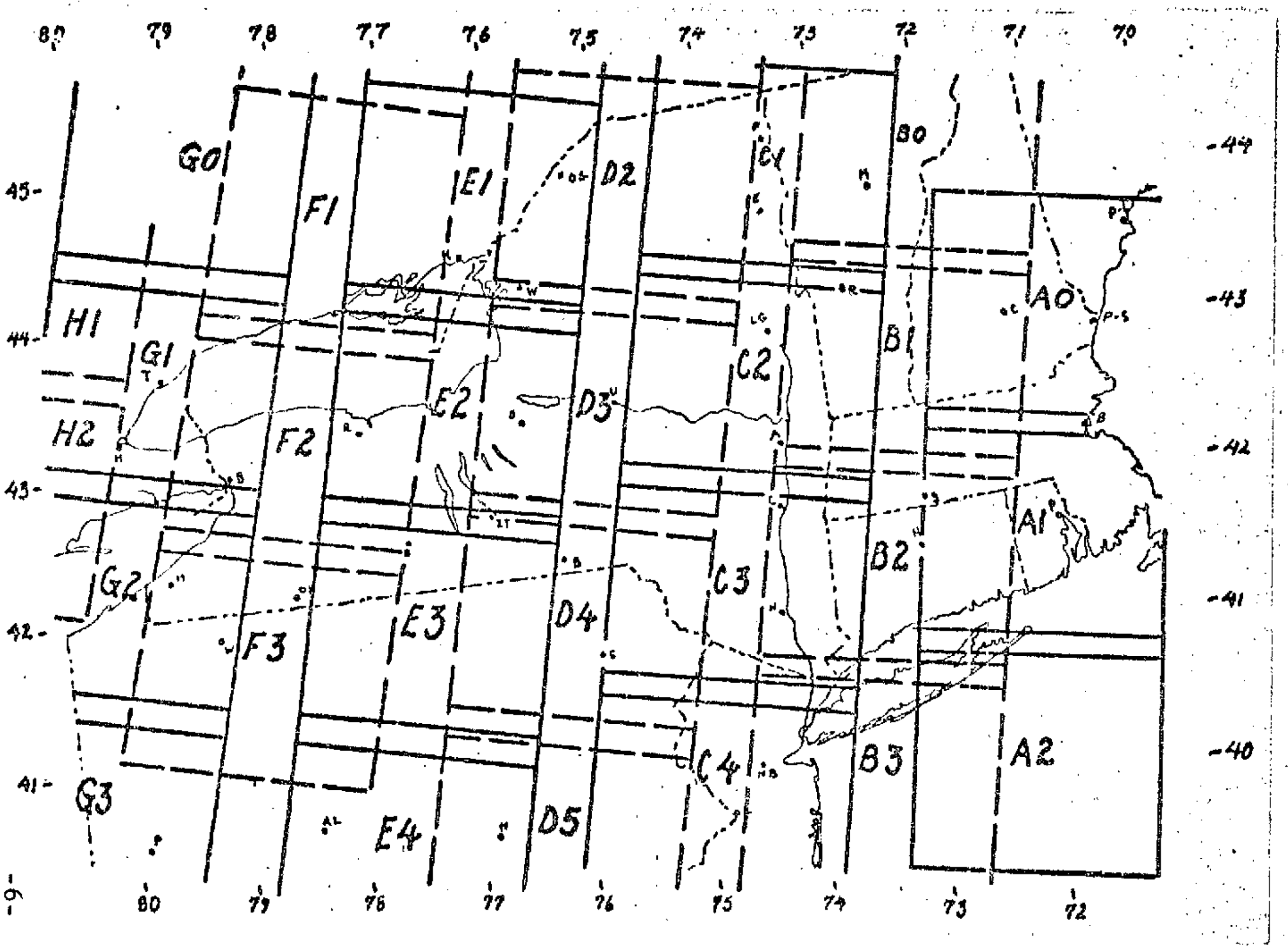


Figure 4. Flow chart of data handling and imagery analysis for ERTS-1 products. Roman numerals signify stage of study as discussed in text.



Symbol	Locality Designation
A0	New Hampshire - Maine
A1	Rhode Island
A2	Long Island
B0	No. Vermont - New Hampshire
B1	So. Vermont - New Hampshire
B2	Connecticut
B3	New York - Long Island
C0	Montreal East
C1	Lake Champlain
C2	Hudson - Mohawk
C3	Catskill - Hudson Highlands
C4	Philadelphia
D1	Montreal West
D2	Adirondacks
D3	Utica - Binghamton
D4	Scranton
D5	Harrisburg
E0	Ottawa
E1	Kingston
E2	Finger Lakes
E3	Elmira
E4	South Mountain - Alleghany Plateau
F0	Pembroke
F1	Rochester
F2	Genesee River
F3	Alleghany River
G1	Toronto
G2	Lake Erie East
G3	Pittsburgh - Youngstown
H1	Lake Ontario - Lake Huron
H2	Lake Huron - Lake Simcoe

Figure 5. Scene designation for repetitive ERTS-I imagery covering New York State and adjoining areas, on file at the New York State Geological Survey. The alpha-numeric symbols have been placed in the center of each 115 x 115 mile scene. Note the 40 percent sidelap.

1	2	3	4	5	6	7a	7b	8	9	10	11		12	13	14
Bands rec'd	Orbit	Date flown ----- rec'd	Product I.D.	% Imagery usable	1 2 3 / 4 5 6 / 7 8 9 Location of usable areas	Prints made	photo - reprocess ?	Worth annotating	Annotation on master	Useful bands, in decreasing order	Img. dscrptrs	Examined via: Stereo	Examined via: SDC settings or other	SDC photos	D2 Remarks
9PN 4-7	0612	5 Sep 72 19 Oct 72	1044-15173	50	1,2, 4-6 9	✓	No	Yes	✓	7,5,6,4	✓		a number of useful settings		
9PN 4-7	0863	23 Sep 72 31 Oct 72	1062-15172	100	all	✓	Yes	Yes	✓	same	✓		same		
9PN 4-7	1114	11 Oct 72 9 Nov 72	1080-15174	100	all	✓	Yes	Yes	✓	same	✓		same	✓	
9PN 4-7	1616	16 Nov 72 2 Jan 73	1116-15181	85	all	✓	Yes	Yes	✓	same	✓		same		
9PN 4-7	2118	22 Dec 72 15 Feb 73	1152-15181	0	–	0	No	No	–	–	✓		–		
9PN 4-7	2369	9 Jan 73 1 Mar 73	1170-15175	90	all	✓	Yes	Yes	✓	7,5,6,4	✓		a number of useful settings		
9PN 4-7	2871	14 Feb 73 16 Mar 73	1206-15182	85	all	✓	Yes	Yes	✓	7,5,6,4			same		
9PN 4-7	2620	27 Jan 73 9 Mar 73	1188-15180	20	5-9	0	No	No	–	–			–		
9PN 4-7	3624	9 Apr 73 29 May 73	1260-15183	90	all	✓	Yes	Yes		7,5,6,4					
9 1-3,7 / PN 1-7	0111	31 Jul 72 21 Mar 73	1008-15171	55	all	✓	No	Yes							

Figure 6. Sample page of log book for ERTS-I data products received from NASA. (Under Bands rec'd. formats are abbreviated thus: 9 = 9.5 inch transparency, P = 70 mm positive transparency, N = 70 mm negative transparency).

2.2 After completion of these "housekeeping duties", the imagery is subjected to analysis following an investigative procedure which may be expressed in terms of three stages: I. photogeologic identification of suspected geological signatures in ERTS-I imagery; II. laboratory screening of these signatures; III. field investigation of remaining "ERTS-I anomalies". The investigation is followed by: IV. Preparation of ERTS-enhanced geological maps; V. Publication.

2.2.1 Stage I: Identification in the 9.5 inch film positives of all spectral signatures (points, lines and areas) which may be geologically-linked. These are traced onto clear acetate or mylar overlays which may be color-coded according to the spectral band on which they are best displayed. The overlay data are then assembled to produce a preliminary, "spectral geologic work map" of New York State and adjoining areas at 1:1,000,000 (e.g. Isachsen and others, 1973, Figure 2). This map is continually updated, using both new imagery as it arrives, and the screening procedures described below. A companion ERTS-I image mosaic made from diazo paper prints is also assembled for each season, using the most cloud-free imagery available. Similar procedures are now being followed with 1:500,000 and 1:250,000 black and white and color prints of selected ERTS-I imagery. Multiband color viewing of photographically reprocessed 70 mm positives, utilizing either a Spectral Data Corporation (SDC) Model 64 Viewer-Projector, or sandwiched diazo color film positives on a light table, is being used on an experimental basis to corroborate or expand the above spectral signatures. Selected anomalies may be investigated further by electronic ehancement techniques, using equipment generously made available by the Rome Air Development Center and State University of New York at Albany.

2.2.2 Stage II: Evaluation of these suspected geological signatures in terms of existing information (geological, cultural and other maps, airfoto mosaics, and other remote sensor data, particularly that obtained by supportive NASA aircraft) in order to identify them as one of the following:

a. clearly non-geological (e.g. power transmission lines, railroads)

b. clearly geological and previously mapped (e.g. faults, topographic lineaments, formational boundaries)

c. other signatures not previously known, which may be geologically linked (e.g. tonal discontinuites or lines, aligned drainage features, straight segments of streams). These are classified as "ERTS anomalies".

3. EXPERIMENTATION WITH VIEWING METHODS

3.1 ERTS-I imagery received to date totals 267 frames covering 34 scene areas over New York State and portions of adjacent states and Canada. An inventory of the imagery on hand through May 1973, in terms of geological usefulness, is as follows: useful (0-50 percent cloud cover), 55 percent; marginally useful (50-70 percent cloud cover), 12 percent; useless (70-100 percent cloud cover), 33 percent.

3.2 The entire state is now covered by at least one image having greater than 70 percent cloud-free area for summer and fall, and 90 percent cloud-free in winter. Mosaics made from diazo paper prints of the summer-fall and the winter images at 1:1,000,000 are reproduced as Figures 7 and 8.

3.3 The 1:1,000,000 film positives of the usable imagery have been analyzed in transmitted white light (i.e. Stage I analysis) and the data have been combined into a statewide "spectral geological map" at 1:1,000,000 (Isachsen and others, 1973, Figure 2). For the late summer and fall imagery, it was found that bands 5 and 7 complement each other and contain all the spectral signatures which appear to be geologically-linked; no additional data were found on bands 4 and 6. The data referred to above have subsequently received Stage II analysis, with the resultant ERTS-I anomaly map shown in Figure 9 which will be discussed later.

3.4 After all the more obvious features of possible geological linkage were extracted from the standard black and white film positives, it was decided to experiment with other photogeologic methods as follows:

1. Experimentation to determine what effect photographic reprocessing to produce higher contrast prints might have on the identifiability of linears in ERTS-I, band 5. A cloud-free C2 image (1079-15122-5) was chosen for the experiment because it includes a variety of geological provinces, namely: the Adirondack Mountains, consisting of high-grade metamorphic rocks, the Alleghany Plateau (or Appalachian Uplands) comprising horizontal Silurian and Devonian strata, the Mohawk and Hudson Valleys underlain by variably faulted and folded Cambrian and Ordovician sedimentary rocks, and the Taconic Mountains which consist of allocthonous Cambrian and Ordovician sedimentary rocks. The two prints in question are reproduced as Figures 10 and 11. The photographic reprocessing method used was as follows: from a 70 mm ERTS-I negative, a Kodalith film positive was prepared by contact printing. From this positive, a 70 mm high-contrast negative was made with Kodak Professional Copy film. D-72 developer was used. Paper enlargements were then made at 1:1,000,000 of both the reprocessed and unreprocessed 70 mm negatives, and identifiable linears (some 270) were inked on clear mylar overlays. A comparison showed that all linears identifiable on one image were clearly recognizable on the other, although the expression of linears was greater on the high-contrast reprocessed image.

Figure 7. ERTS-I mosaic of New York State and surrounding regions made from the 1:1,000,000 late summer and fall imagery of 1972, band 7. (Image nos. 1077-15011, 1096-15072, 1096-15074, 1079-15115, 1079-15122, 1079-15124, 1079-15131, 1080-15174, 1080-15180, 1080-15183, 1080-15185, 1027-15231, 1027-15233, 1027-15240, 1045-15243, 1046-15292, 1046-15295.

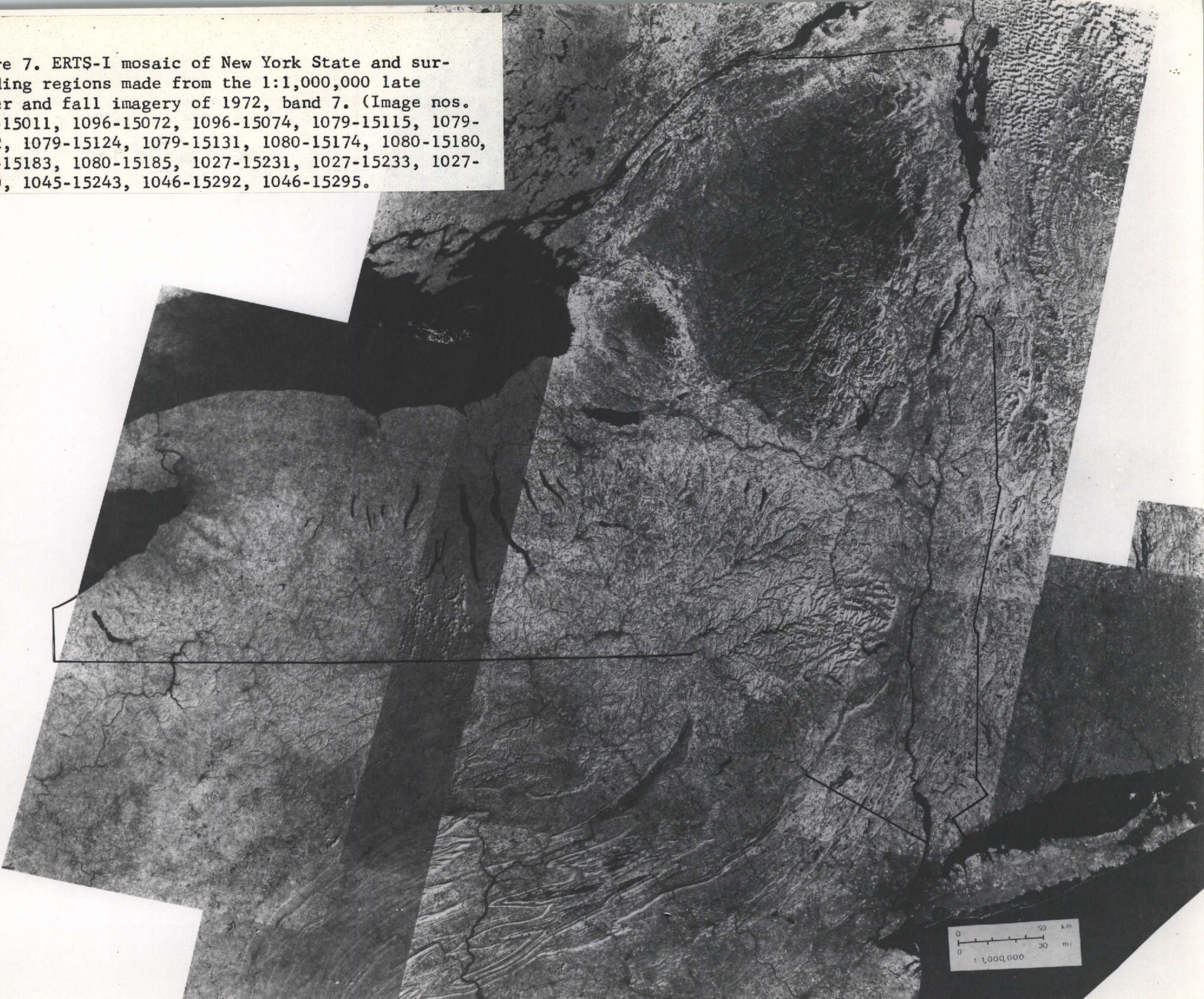


Figure 8. ERTS-I mosaic of New York State and surrounding region made from the 1:1,000,000 winter imagery of 1972-73, band 7. (Image nos. 1167-15013, 1168-15065, 1132-15074, 1132-15080, 1169-15121, 1169-15123, 1205-15132, 1133-15135, 1170-15175, 1170-15182, 1170-15184, 1170-15191, 1243-15242, 1243-15244, 1243-15251, 1243-15253, 1244-15300, 1244-15303.

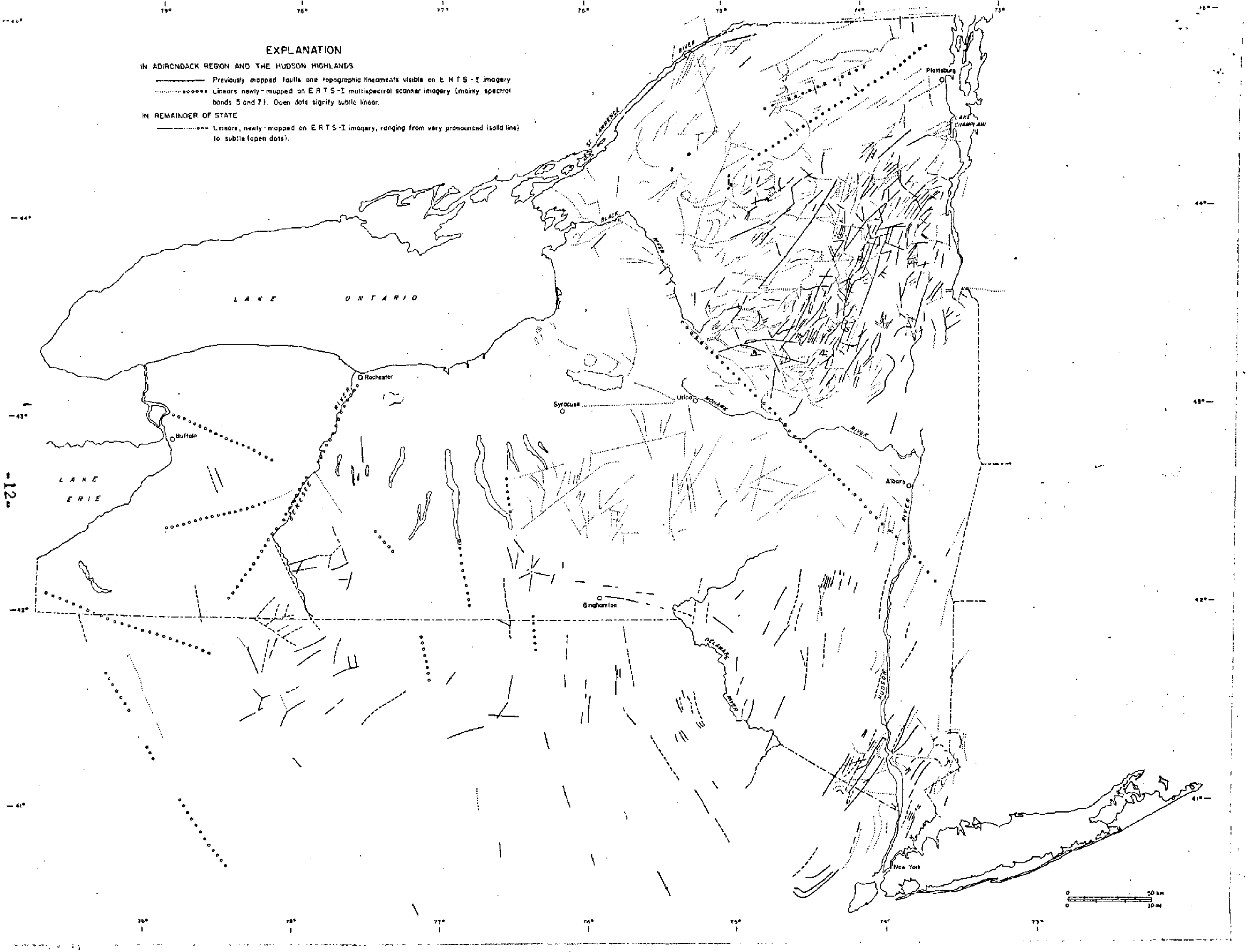


Figure 9. Stage II work map of ERTS-I anomalies mapped at 1:1,000,000.

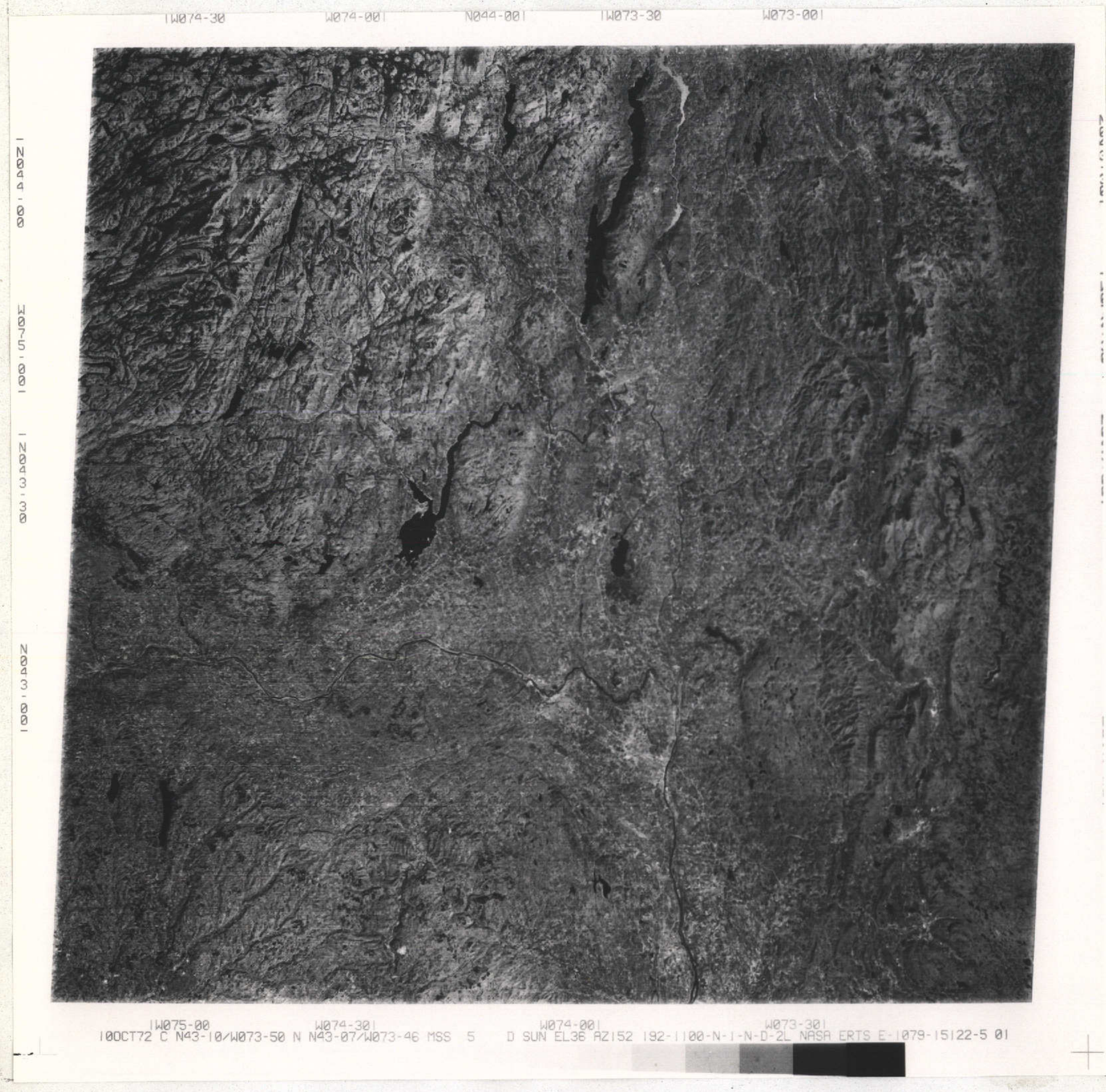


Figure 10. Image 1079-15122-5 of scene C2, not photographically reprocessed.

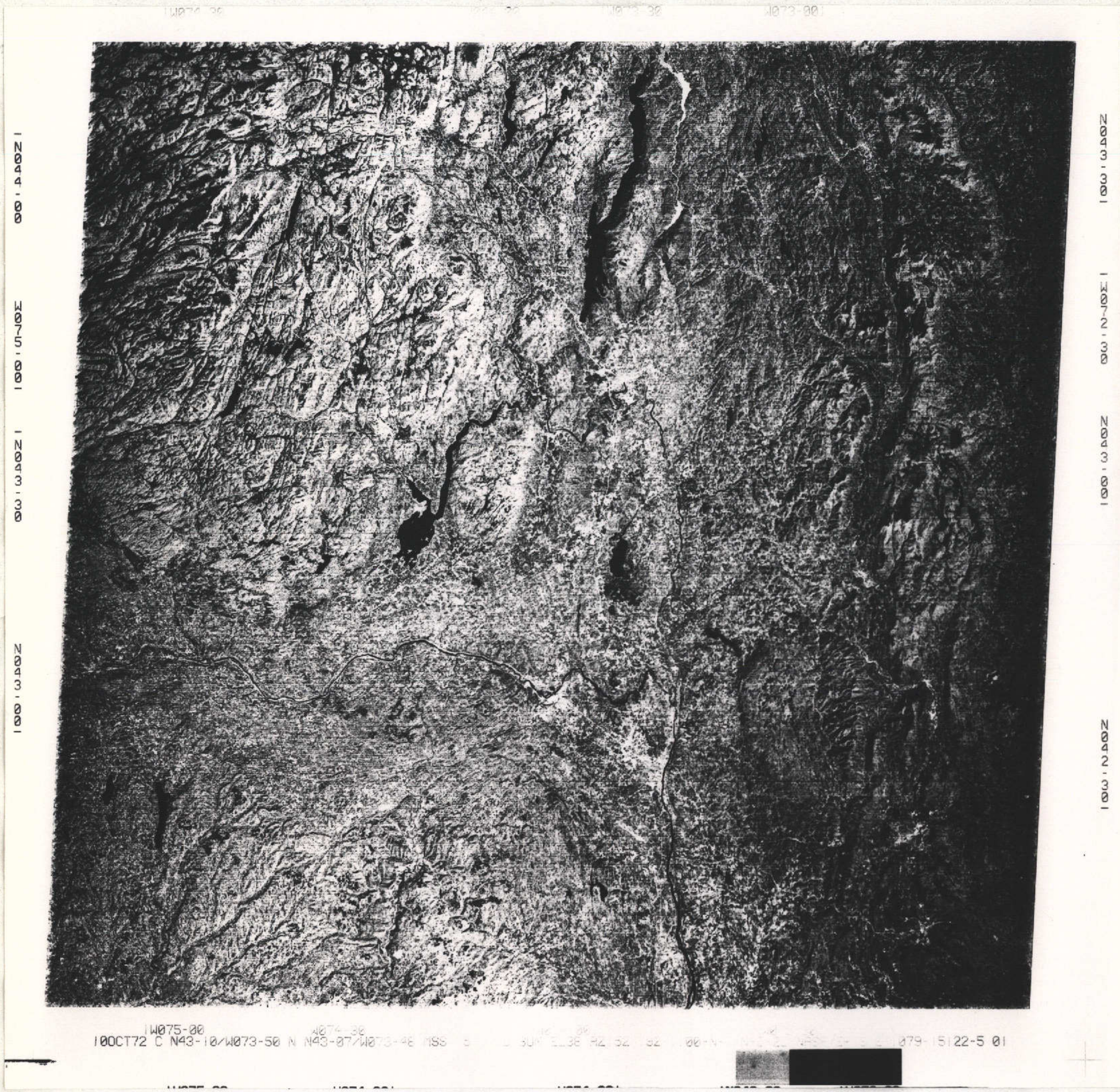


Figure 11. Image 1079-15122-5 of scene C2 after photographic reprocessing to increase contrast.

2. Multispectral color-additive viewing of 70 mm positives of bands 4, 5, 6, and 7, as received from NASA, using the SDC Viewer-Projector. Despite considerable experimentation with a variety of scenes, no information was added to that obtained by conventional viewing in transmitted light. Later attempts, using photographically reprocessed imagery, are described under 4, below.

3. Pre-formatting of ERTS-I 70 mm film positives for multispectral viewing, to avoid the time consuming task of separately registering each band in the Viewer every time a scene is to be viewed. After some experimentation, a successful method was devised as follows: on a 9.5 x 12 inch piece of 0.005 inch clear mylar, the positions of the four viewer windows in the 9.5 inch roll film holder are roughly located. Two perfectly parallel horizontal lines are then drawn to guide the placement of the upper edge of the 70 mm film positives. Using these lines, the images are carefully taped in perfect parallelism. This preformatted array permits rapid registration, requiring only limited x-y adjustment, the need for rotational adjustment having been eliminated.

4. Multispectral color-additive viewing of photographically reprocessed film positives, using a SDC Model 64 Viewer-Projector or diazo color film sandwiches. Experimentation with several ERTS scenes using numerous combinations of spectral bands, color filters, and illumination intensity produced a variety of striking effects (e.g. Figure 12). Most of the color patterns produced merely accentuate tonal differences which are readily observable in the black and white imagery. Some, however, are subtle and are not visible in the black and white images. An attempt was made to determine the cause of these subtly-colored areas by comparison with numerous different kinds of maps. A cloud-free image (D2 taken 11 Oct 72, scene no. 1080-15174) was chosen for the comparisons. This image covers the Adirondack Highlands which are dominantly forested, and the St. Lawrence Lowlands which are mainly given over to dairy farming. Kodacolor prints of the SDC image were superimposed on the various maps, using a Bausch and Lomb Zoom Transfer Scope, model ZT-4. The maps used were as follows:

   a. Geologic Map of New York, Adirondack Sheet, reduced from Fisher and others (1971)

   b. Physiographic diagram of New York State (Figure 1)

   c. Pleistocene Geology of the St. Lawrence Lowland (MacClintock and Stewart, 1965)

   d. Map of areas burned by Adirondack forest fires of 1903 (Suter, 1904)

Figure 12. Kodacolor print of color-additive projection of scene D2 (1080-15174) with filter-light intensity settings on the SDC Model 64 Viewer-Projector as follows: band 5, blue 10, band 6, green 10, band 7, white light 3. Color-distinct areas which could not be detected tonally in black and white images such as figure 14, are irregularly shaped, and range in area from 12 to 2500 km^2. A dark yellow patch occurs near the southeast border of the image. The other patches are scattered in a 60 km-wide belt which extends from the lower edge of the image at left center, northeasterly for about 100 km. The color anomalous patches are pale blue immediately surrounding Cranberry Lake (except for several yellow patches) and extending about 40 km to the east, dark yellow brown south, plus several other smaller areas of pale blue and yellow.

e. Forest-type areas map (Stout, 1958)

f. Economic viability of Farm Areas (Conklin and Linton, 1969)

g. Soil Association map of New York State (Cline, 1961)

h. Ground Water in New York (Heath, 1964)

In only one instance was any correlation noted with the subtle color patterns; comparison with the forest-type map indicates a rough, local delineation (less than 5 percent) of the boundary between areas of aspen-grey birch-paper birch and spruce-fir-northern hardwoods northeast of Cranberry Lake. The virtual lack of correlation with this map was somewhat surprising because Hoppin (1973) in the Bighorn region found a good correspondence between false-color patterns and dominant forest types.

5. Multidate color-additive analysis of ERTS-I imagery. An experimental multidate comparison was made of a scene for which there exists imagery for four essentially cloud-free passes, namely D 2 for 23Sept72, 11Oct72, 18Nov72, and 9Jan72. Photographically unreprocessed 70 mm film positives of bands 5 and 7 for these dates were projected in registry using the SDC Model 64 Viewer-Projector. The most tonally varied and informative image (11Oct72) was projected in red, and the other images were superimposed, in turn, using first a blue and then a green filter to determine what "color features" were added. The results were as follows:

   a. the September image, which is a rather flat, light grey image, added no new information, but merely produced an overall green wash which was accentuated where the October image is dense and hence transmitted very little red light.

   b. the November image, in which the Adirondacks have an overall dark grey tone, highlights mines, dry tailings ponds and unforested summits of some of the high peaks. The cause appears to be snow cover which makes the image more transparent in these areas.

   c. the January image, which is very dark grey overall, adds only frozen, snow-covered lakes, which have an expectable high albedo.

   This experiment will be repeated with photographically reprocessed film transparencies.

6. Experiment with log e dodged prints of ERTS-I imagery. In the southern Adirondacks, any tendency for the dominant east-west arcuate trend of lithological units to reflect characteristic <u>tonal</u> signatures, would be masked by the strong NNE topographic grain (Figure 7) which is accentuated by the low-angle solar illumination. We were able to subdue this high density contrast

through the cooperation of Charles Woodward of Lockwood. Kessler and Bartlett who provided log e dodged film negatives for all bands of image no. 1080-15174 for study. The technique was successful in subduing density contrast to a limited extent, but no new tonal variations were seen.

7. Experimentation with color-encoded presentation of imagery. One of the objectives of this project was to experiment with the electronic image-processing equipment generously made available at Rome Air Development Center. An afternoon was therefore spent with Captain James Turinetti, using that part of the Center's "System 800" made by Spatial Data Systems, Inc. which converts the grey scale of black and white film products into a 32-color video display.

   ERTS 9.5" film positives of the four spectral bands of the northern Adirondacks (scene D2, no. 1080-15174) were examined, using a great variety of color combinations in a search for linear or areal spectral information which had not been detected by conventional photogeologic analysis. Regardless of instrument manipulation, of the 15 shades on the ERTS grey scale, only the 11 darker shades were detectable as separate colors. A mosaic of positive transparencies of the entire Adirondacks was also examined on the color display (1080-15174, 1080-15180, 1079-15115, 1079-15122). By calibrating only to the grey scale it was possible to distinguish 11 of the 15 shades.

   The principal limitation was not that of density spread, however, but the low resolution of the SDS display. Although the resolution would appear to be adequate for color enhancement of small-area, high-resolution conventional aerial photography, it degrades ERTS imagery to a degree that is not compensated for by the asset of color visualization. In short, geological information was diminished in the color display, and no new potentially-geologic information was seen.

3.5 The experiments described above were intended not as rigorous investigations, but rather as relatively rapid tests to help determine which methods, beyond the more conventional approaches, would yield a sufficient amount of new geological information to justify the time involved. From the largely negative results obtained, we conclude that, for the region under study, the most advantageous method of photogeologically analyzing ERTS-I imagery is to study bands 5 and 7 separately. A small additional increment of information may be derived by examination of <u>photographically reprocessed</u> imagery, using color additive methods. Additional experimentation with electronic enhancement will be attempted using high-resolution video equipment at SUNY-Albany.

4. ERTS-I AND BEDROCK GEOLOGY

4.1 Regional geological features

4.1.1 The synoptic value of ERTS-I imagery is readily appreciated from a single satellite image, but perhaps even more from a mosaic of an entire State (Figures 7 and 8) where, despite the loss in resolution due to photo-reduction of the original mosaic, major physiographic, geologic, and tectonic provinces can be seen (compare with Figures 1, 2, 3). Major tectonic provinces visible in the mosaics include the Adirondack Dome Mountains, Platform I, the narrow belt of upturned Silurian-Devonian rocks deformed during the Acadian Orogeny, the Appalachian Foldbelt, the Palisadian Taphrogen, and Platform II. Two physiographic regions which are independent of the tectonic provinces appear prominently in the imagery, namely the Tug Hill Upland, which is defined both topographically and by its forested plateau surface, and the Catskill Mountains. (Both are composed of erosionally-resistant deltaic rocks, one Ordovician, the other Devonian).

4.1.2 Outlining the Adirondacks can be seen the major unconformity between the Grenville basement and the onlapping Paleozoic section which has at its base the Potsdam Sandstone of Upper Cambrian age. The contact is accentuated by a topographically-induced land use boundary, namely forest versus farmland, but it is also well delineated geologically, particularly along the southwestern, southern and eastern Adirondacks, by the abrupt termination of the east-west arcuate pattern in the basement at the Potsdam contact. This pattern results from differential erosion of the basement lithologies.

4.1.3 Along its northern, western, and southwestern borders, the crystalline Adirondack basement is expressed on ERTS-I imagery as a slightly dissected planar surface which dips gently away from the central part of the Adirondack Dome, (Figures 7 and 14). This surface is exposed in a belt ranging in width from 10 km in the north to about 20 km along the western perimeter, and corresponds closely to the physiographic section designated as the "Fall Zone Belt" by Buddington and Leonard (1968, p. 8). It is doubtless a tilted erosion surface, from which the Paleozoic units have been stripped by erosion. A striking feature of this paleoplane in the northern Adirondacks is its abrupt termination to the southeast, along a topographic lineament which had not previously been mapped, to produce a pseudo-cuesta. Along the northern border of the Adirondacks, the contact between this erosion surface and the Potsdam Sandstone is well displayed as a boundary between forest and cultivated farmlands. About 10 km to the north, is the contact between the Potsdam Sandstone and the Theresa sandy dolostone, again marked by a change in land use influenced by bedrock.

4.1.4 Along the southwestern border of the Adirondacks, the basement-Potsdam contact is accentuated by the Black River. In the intervening section, basement exposures are continuous from the Central Highlands, across the Frontenac Arch of the Northwest Lowlands, into the main Grenville Province of Canada. Potsdam occurrences are here limited to scattered relict patches.

4.1.5 Within the Appalachian Foldbelt, major subdivisions can be seen in the ERTS-I imagery at the original 1:1,000,000 scale, albeit notably better at 1:500,000. In Figure 22, the Alleghany Plateau with the

Catskill Mountains as its eastern projection, is readily identified by its dendritic drainage pattern. The straight eastern edge of the Catskill Mountains, which has long been referred to as the "Wall of Manitou", is prominently displayed. A major insight into its cause has been provided by ERTS-I imagery, as will be discussed later.

4.1.6 About 20 km south of the Catskills, the Shawangunk Mountains begin, and extend southwestward into New Jersey where they are known as the Kittatinny Mountains. They represent a belt of upturned Silurian and Devonian rocks, dominated by the Shawangunk conglomerate, which marks the western boundary of the Appalachian Foldbelt.

4.1.7 An angular unconformity between the titled Shawangunk conglomerate and isoclinally-folded Ordovician shale and graywacke beds is seen on the imagery as the eastern edge of the Shawangunk Mountains. These beveled Ordovician rocks extend eastward to the resistant Proterozoic basement rocks of the Hudson Highlands, north of the Hudson River. Southwest of the river, a synclinal belt of down-faulted Silurian and Ordovician strata occurs between the beveled Ordovician rocks and the Highlands. This belt is marked by the elongate Greenwood Lake at its southern end, and by the isolated Schunemunk Mountain mass at its northern end located about 10 km southeast of the point at which the Hudson River enters the gorge (fiord) through the Hudson Highlands. The Highlands extend northeastward, where they appear to merge, in the 1:1,000,000 imagery, with the more highly-metamorphosed Paleozoic rocks of New England. (In the 1:500,000 imagery, the northern boundary of the Hudson Highlands is well delineated). The elongate Housatonic Highlands, a separate Proterozoic mass, can be seen northeast of the Hudson Highlands. The belt of Taconic allocthones north of the Hudson Highlands are not well delineated in the 1:1,000,000 print, but can be seen at the 1:500,000 scale.

4.1.8 The Triassic basin borders the Hudson-New Jersey Highlands along the Ramapo normal fault, and is bounded on the east by the Hudson River. The Palisades diabase sill forms a vertical escarpment along the west shore of the river. It can be seen in the imagery as a faint line parallel to, and within 500 meters of, the shoreline. The Hudson flows along the onlapping contact between the Triassic red beds and the high-grade Appalachian basement rocks to the east. This basement, in turn, forms the substrate for the Cretaceous and Pleistocene formations of Long Island.

4.1.9 Within the Adirondacks, many previously-mapped geological structures in addition to lineaments can be identified. These include the major east-west arcuate folds extending across the southern Adirondacks (Figure 7 and 14) and a number of domical structures, plunging folds, refolds, and other structures which have topographic expression (Figure 14). However, because the emphasis here is on newly-discovered geological features, and because an evaluation of non-linear structure is better attempted at the 1:500,000 and 1:250,000 scales now under study, the remaining discussion will center on linear features.

4.1.10 The word "linear" is used in this report in the sense of Dennis (1967, p. 103), to designate lines of uncertain origin on aerial photographs or imagery. The term "lineament", on the other hand, is reserved for a naturally occurring linear feature (e.g. Hobbs, 1904, Lattman, 1958), i.e. one that has been confirmed to exist on the ground.

4.1.11 The remainder of this section on ERTS-I and bedrock geology will begin with a comparison between linears seen on imagery from the ERTS-I and NIMBUS I satellites over New York State. This will be followed by the results of Stage I, Stage II, and Stage III studies on ERTS-I imagery in the Adirondack region, a Stage I analysis for southeastern New York, a preliminary Stage III study in the Catskill Mountains, and preliminary analysis of circular features in the State.

4.2 ERTS-I linears in New York State

4.2.1 Without question, the most significant contribution of ERTS-I imagery to date in New York State has been the location of more than 500 Stage II linears which had not previously been recognized. This linear-detecting capability of ERTS-I imagery was the most frequently, cited geological application at a recent Symposium on Significant Results from the Earth Resources Satellite, ERTS-I (Short, 1973).

4.2.2 A work map of Stage II linears observed on ERTS-I imagery at 1:1,000,000 is shown on Figure 9. They represent those remaining from a Stage I work map (Isachsen and others, 1973) after the removal of "cultural linears" such as transmission lines, railroads, abandoned railroad beds, and highway segments. The Stage II linears range from strongly-developed topographic lineaments to very subtle linears which are defined by faint tonal, rather than topographic signatures.

4.2.3 The "subtle" linears shown by open circles in Figure 9 most closely resemble those visible on the Apollo 9 photographs of east-central Alabama (Powell and others, 1970). Both regions in question include portions of the Plateau, Valley and Ridge, and Piedmont Provinces, and both have a climate sufficiently humid to produce extensive vegetation. A major difference, however, is that the soils of New York State are, with the exception of a small area near the Pennsylvania border in western New York, not residual but transported, i.e. glacial.

4.2.4 The linears in New York State range in length from 5 to 200 km, and the majority are straight. The combined lengths of these ERTS-I linear anomalies exceeds 6000 km, not including linear portions of the Hudson River and the Finger Lakes.

4.3 ERTS-I and NIMBUS-I linears in New York State

4.3.1 Prior to the successful launching of ERTS-I the only orbital imagery available over New York State was that obtained by APT, ITOS, and NIMBUS-I satellites. With the exception of one frame of NIMBUS-I imagery, only the broadest geomorphological features could be seen at the low-resolution involved, i.e. the Adirondacks and the Tug Hill Plateau (e.g. Anderson, 1968).

4.3.2 In our original proposal to NASA we called attention to a long faint linear visible on a NIMBUS-I image of orbit 254, taken September 14, 1964. This image was taken at an altitude of 308 miles above Lake Ontario when the satellite malfunctioned, and instead of going into a circular orbit with a perigee of some 700 miles, went into an elliptical orbit with a perigee of 266 miles.

4.3.3 C.I. Taggart (1965) noted the close correspondence between tonal variations on this imagery and the rock units delineated on the 1:250,000 Geologic Map of Pennsylvania, particularly in the Valley and Ridge Province. Through his generous cooperation, and that of J.R. Kenney of the National Research Council of Canada, both of whom had noted linears in the imagery (written communication), we were able to obtain copies of this image for study (Figure 13).

4.3.4 The linears and circular feature shown in the lower part of Figure 13 were seen independently by two of us (Isachsen and Forster). The photograph is a second generation print of a video display of the signal received in Ottawa. The linear marked with dots at either end was taken from an image of the same transmission received and recorded at Frobisher Bay. It must be emphasized that any or all linears may be "electronic anomalies" rather than ground features; the absence of another oribital pass covering the same area precludes a check on this question. Nevertheless, it was decided to compare the NIMBUS-I anomalies with known geology and with anomalies seen in ERTS-I imagery.

4.3.5 The results are as follows:

1. The circular feature located just northwest of the St. Lawrence River near the U.S. - Canadian border has no manifestation whatever on the ERTS-I imagery, and remains unexplained.

2. The longest NIMBUS-I linear in the Adirondacks passes through Tupper Lake and corresponds with a series of roughly aligned ERTS-I linears and topographic lineaments. It is parallel to the dominent NNE set of Adirondack lineaments, and is considered a geologic rather than electronic feature. Tupper Lake is the large L-shaped lake in the western central part of the southeastern quadrant of Figure 14.

3. The other NIMBUS-I linears in the Adirondacks have as good or better ground identification, except for the two that form an open, west-facing V.

4. Elsewhere in the State, only the long, westernmost NNE linear corresponds with ERTS-I linears, and that only in the upper part, where it coincides with the Genesee River south of Rochester.

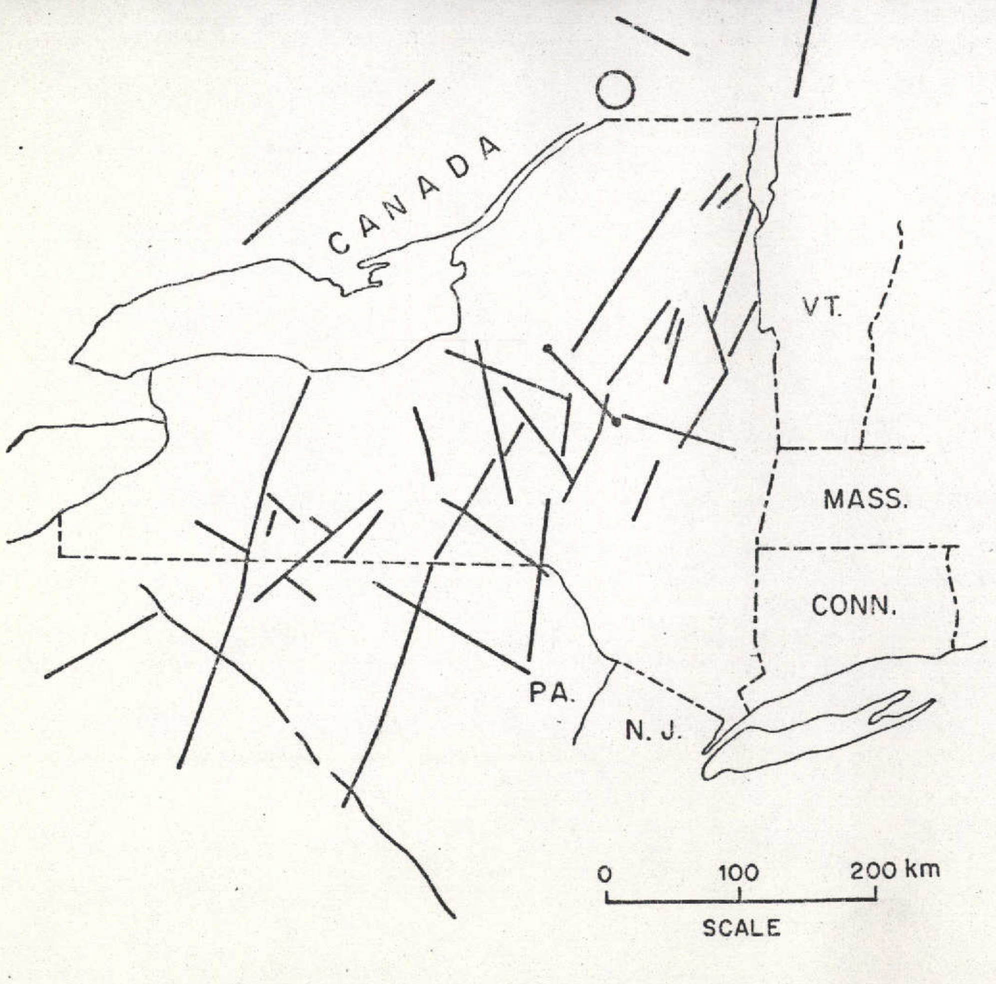


Figure 13. Linear and circular features seen on Nimbus I image, orbit 254.

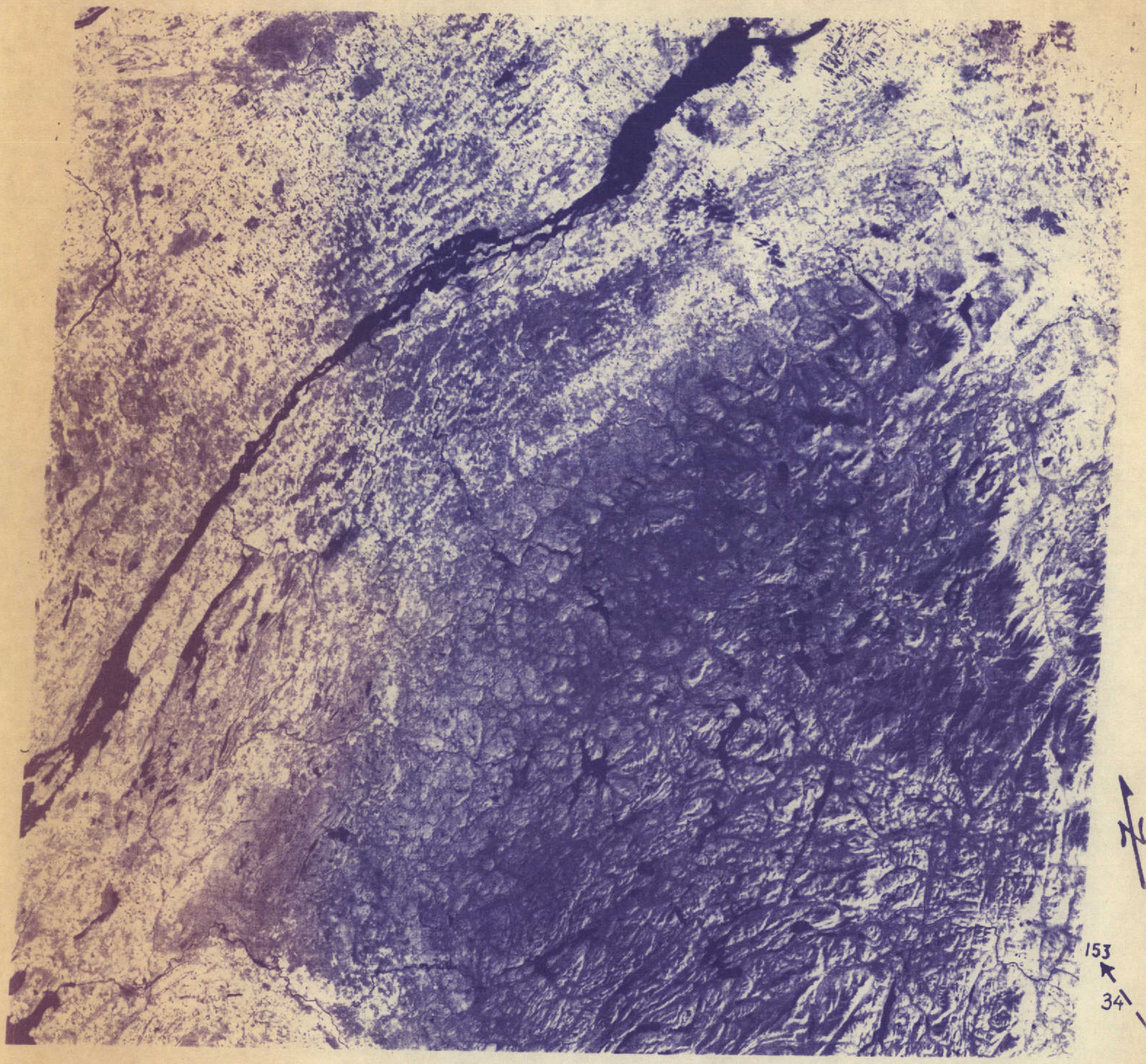


Figure 14. ERTS-I image of scene D2, band 7, (1080-15174) taken 11 Oct 72 over the northern Adirondack region. Dashed arrow indicates sun azimuth and angle. Scale: 1 mm = 1 km.

4.3.6 Future ERTS-I imagery will continue to be scrutinized for the NIMBUS-I linears.

4.4 ERTS-I linears in the Adirondack region, Stage II investigation

4.4.1 The most spectacular area of linear display in the State, if not in the whole northeast, is the Adirondack Mountain region (Figures 7 and 9). The linear features seen in the imagery include the majority of known faults and topographic lineaments shown on the Geologic Map of New York at 1:250,000 (Fisher and others, 1971; Isachsen, 1973). Of those not visible in the imagery at 1:1,000,000 (shown by black lines in Figure 15), most are short, and may turn out to be discernible at larger scales. The easternmost group occur in the Champlain Valley, an area of low relief, and are less likely to be expressed in the imagery.

4.4.2 A numerical summary of the Adirondack linear information shown in Figures 7 and 14 is tabulated below:

Category	Number	Combined length, km
Previously mapped faults and topographic lineaments seen on ERTS-I imagery	232	1890
ERTS-I linear anomalies which have survived Stage II investigation	364	3131
Total linears seen on ERTS-I imagery	596	5021
Previously mapped faults and topographic lineaments not discernible on ERTS-I imagery	297	1750

4.4.3 The linear data shown in Figure 15 represents unscreened Stage I information, whereas that in Figure 9 has had lithologically-controlled and "cultural linears" removed. Subsequently, each of the ERTS-I linear anomalies (i.e. Stage II linears) in the Adirondacks was located by inspection, on 1:62,500 airfoto index mosaics (uncontrolled). They were then classified as to photogeologic character (see appendix for work sheets and location map). A summary of the photogeological classification given in the appendix is as follows:

Cultural "linears"	20
Linears parallel to lithological trends	51
Straight segments of stream courses	96
Straight stream valleys	27
Winding streams	7
Elongate lakes or straight shorelines	7
Ridge crests	3

Figure 15. Stage I linears and circular features seen on ERTS-I imagery (image no's. 1079-15115, 1079-15122, 1080-15174, 1080-15180). Dotted lines represent unscreened new features, pale solid lines indicate previously-mapped faults and topographic lineaments seen on the imagery, and heavy solid lines show previously-mapped faults and topographic lineaments not shown on the imagery. Large dots and short thick line represent open pit mines dry tailings ponds. Scale: 1 mm = 1 km.

Edge of topographic high or aligned segments of same	5
Alignments of vegetation:	
dark vegetation strips (may be valleys)	30
vegetation border	7
Combinations of one or more of the above	57
Unexplained	125
TOTAL	435

4.4.4 The ERTS-I linear anomaly data for the Adirondack region are summarized in the two rose diagrams of Figure 16. The upper diagram is an unweighted plot of the total number of linears, whereas the lower diagram takes the lengths of linears into account.

4.4.5 The generally similar appearance of the two diagrams holds up well under closer scrutiny. The maxima appearing in the weighted diagram can also be seen in the unweighted one, namely: N75W, N45W, N20W, N-S, N25E, N40E, N50E, N60-70E, N85-90E. This close correspondence indicates that in general the lengths of the anomalous linears are proportional to their frequency for any given azimuth.

4.4.6 When the above diagrams are compared with analagous plots of previously mapped faults and topographic lineaments (Figure 17), both differences and similarities appear. The most noteable difference is that the major concentration of ERTS-I linear anomalies occurs in the 30° sector (N40E to N70E), whereas previously-mapped linear structures fall in the 35° span between N15E and N50E. This may reflect differences in the geological control and expression of these newly discovered linears. More likely, however, to the extent that they are topographic linears, they are so well expressed in this sector because it is essentially orthonal to the azimuth of solar illumination in October (153°, 34° elevation). Consistent with this interpretation is the low incidence of linears parallel to the direction of illumination (N20-40W), despite the fact that linears in this direction are fairly abundant on the ground (Figure 17). Wise (1969) has demonstrated experimentally the critical effect of direction of illumination on the display of linears, although he used considerably lower elevations (5 to 20 degrees). The interpretation presented above is consistent with the conclusions reached by MacDonald and others (1969) from a look-direction study of side-looking radar images.

4.4.7 Despite the difference in relative <u>magnitudes</u> of the maxima, a very close correspondence exists for their <u>directions</u>, except for two. The maxima of Figure 17, which also appear as prominent directions (within 5 degrees) on the imagery, are as follows: N70W, N45W, N20W, N-S, N40E, N50E, N70E, and N80E. On the ERTS-I linear diagram, however, a N25E set is prominent rather than the N15E set mapped on the ground. The most prominent ERTS-I set (N60E) is very subordinate among the known ground linear features. However, its trend is within 3° of being perpendicular to the direction

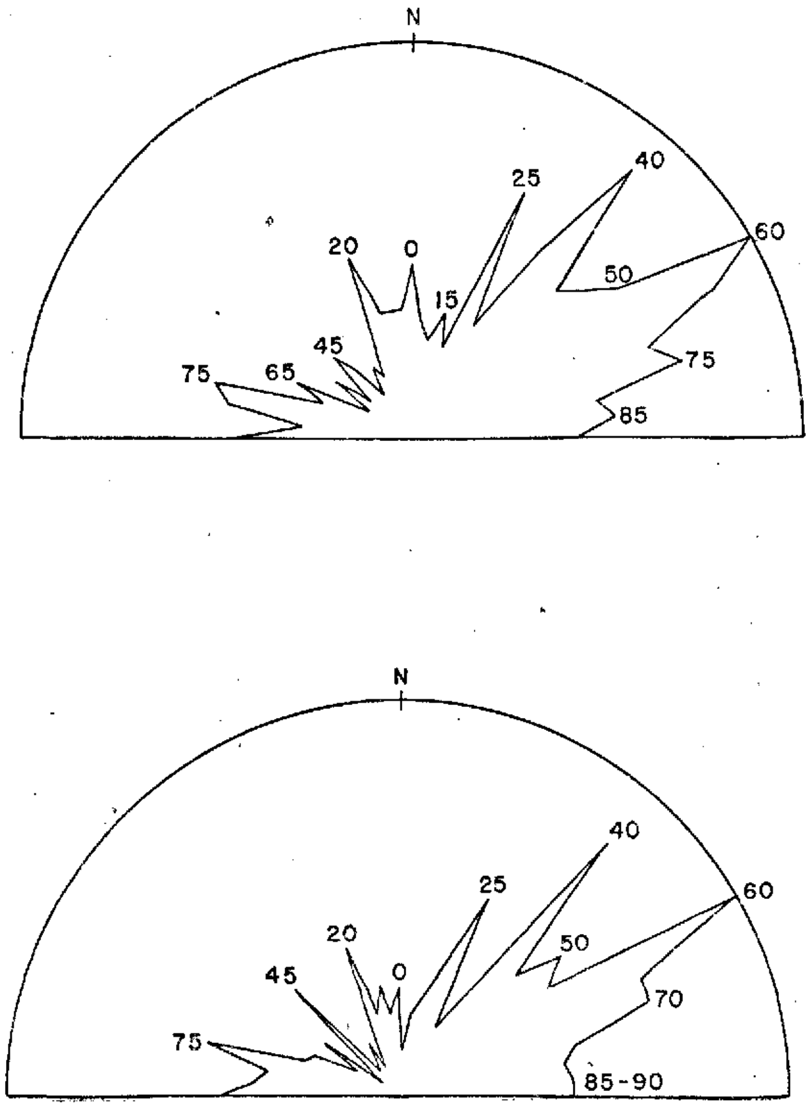


Figure 16. Rose diagram of ERT-I anomalies, i.e. features which have survived Stage II analysis, in the Adirondack region, with data lumped into 5 degree intervals. Upper diagram is a plot of total <u>number</u> of linears (364), whereas lower diagram sums total <u>lengths.</u>

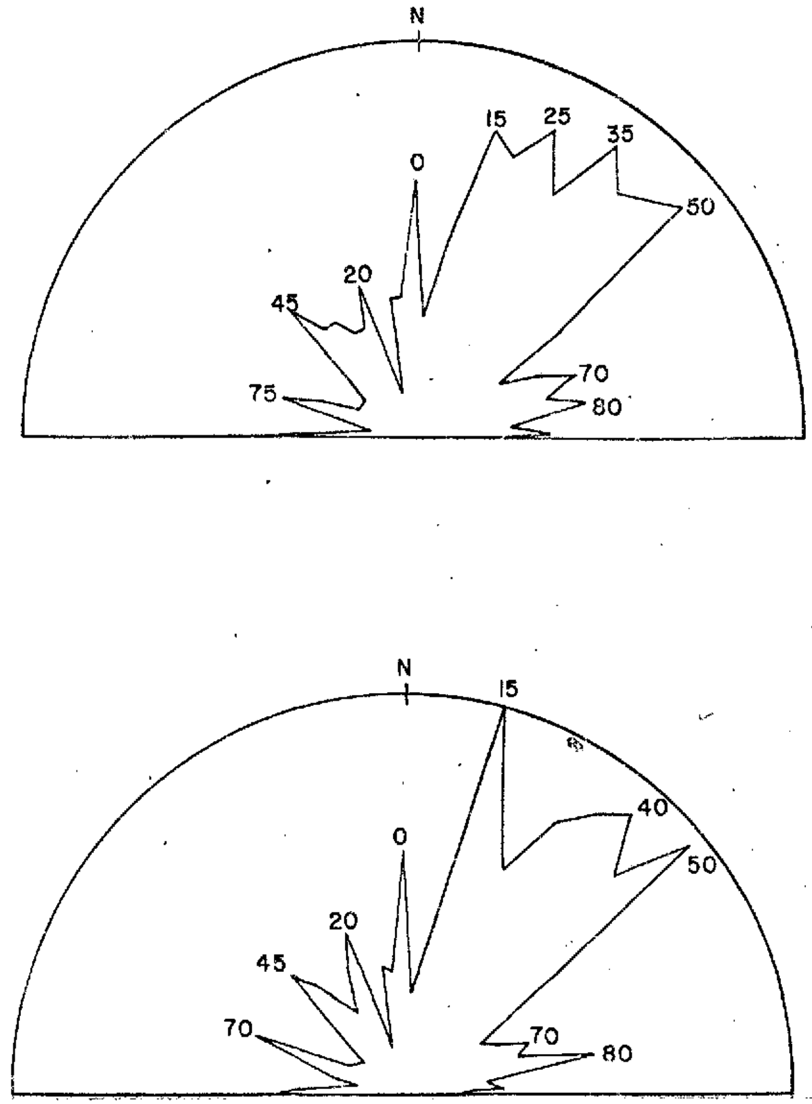


Figure 17. Rose diagram of previously mapped faults and topographic lineaments in the Adirondack region with data lumped into 5 degree intervals. Upper diagram is a plot of total <u>number</u> of linear features (335), whereas lower diagram sums total <u>lengths</u>. Curved lines were arbitrarily excluded.

of solar illumination and this probably explains its prominence.

4.5 Stage III investigation of ERTS-I linear anomalies in the Adirondack Mountains

4.5.1 A major problem associated with field checking of ERTS-I anomalies is locating them on the ground. As indicated earlier, this is greatly facilitated by visually transferring data from the ERTS-I photographic product to another photographic product at a more useful field scale, namely airfoto index sheets at 1:62,500. It is then relatively easy to plot the feature in the approximately correct location on 1:62,500 topographic maps, particularly if it is a topographic feature. The most economical and effective way to locate the feature on the ground is by viewing and photographing it from low level aircraft.

4.5.2 Photographs taken on such a flight can be seen in Figures 18 and 19. They show ERTS-I anomaly number 291 (Appendix I) which is located entirely within the Marcy Massif metanorthosite. The linear, now confirmed as a topographic lineament, turns out to be a 16 km-long southward extension of a previously mapped lineament. It extends both north and south of the portion shown in the photograph.

4.5.3 The contrast in relief between this new lineament and a previously mapped one (which has of course, a stronger expression in the imagery) can be seen by comparing Figures 18 and 20. The Ausable Lakes lineament is marked photogeologically not only by topography, but, also by a vegetation boundary, i.e. conifers on the east slope, deciduous tress on the west.

4.5.4 A far more subtle topographic lineament found in the ERTS-I imagery is shown in Figure 21. This broad, relatively short (6 km) linear valley extends WNW, transecting at nearly right angles the North River-Mt. Marcy range. The northern edge of the North River Mountains appears in the left middleground. The linear is terminated to the west by a major NNE linear which passes just east of Popple Hill, the dark mountain in the middle of the valley. White Lily Pond is in the foreground.

4.6 Geological identification and origin of ERTS-I linears

4.6.1 A considerable literature exists on the nature and origin of lineaments. Much of it has been assembled in our ERTSLAB and is now being read and digested in terms of our own experience with ERTS-I linears, faults, and topographic lineaments in New York.

4.6.2 Although data gathering and collation must dominate our activity for some time before valid synthesis and interpretation can begin, there is good reason to suspect that the NNE topographic lineaments will prove to be traces of high-angle faults and fracture zones. This is based on the experience of Matt Walton, who made detailed bedrock geological maps of four contiguous 15 minute quadrangles in the eastern Adirondacks where these linear fractures are so abundant. Walton (oral communication) found that fault breccias and/or stratigraphic displacement could generally be demonstrated for these structures.

Figure 18. ERTS-I linear 291, shown here to be a topographic lineament. It strikes N43E and extends in both directions across Clear Pond in the foreground. View is northerly. The mountain peaks west of the linear are McComb (with slide), Hough (sharp peak), Dix, the valley of Hunters Pass, and Dial. Hunters Pass is part of a topographic lineament 25 km in length which extends across Elk Lake in the middleground. All bedrock in clear view is metamorphosed anorthosite.

Figure 19. Central and upper portion of linear shown in figure 18. Topographic expression is slightly enhanced by the contrast between deciduous trees in the valley and conifers plus rock outcrop along the ridge.

Figure 20. View looking NNE along Ausable Lake topographic lineament, a previously mapped feature parallel to and west of the as yet unexplained ERTS-I linear no. 289; located entirely within Marcy Massif metanorthsite; slides on Gothics discernible at 1:500,000; Mt. Marcy 15' quadrangle.

Figure 21. ERTS-I linear no. 287, extending N52W from White Lily Pond; entirely within Marcy Massif metanorthosite; Mt. Marcy and Santanoni 15' quadrangles.

4.6.3 If this relationship can be established for one or two of the new ERTS-I lineaments having this trend, it will be possible to concentrate our field investigations on the less familiar linear directions and on the subtle tonal linears.

4.7 <u>Multi-scale analysis of scene C3, Catskill-Hudson Highlands</u>

4.7.1 Introduction

4.7.1.1 A stage-I multi-scale photogeologic analysis has been made of linears visible on scene C3 (taken 10 Oct 72; 1079-15124) using the following data sources: at 1:1,000,000, positive transparencies of bands 5 and 7 and a false-color composite print of bands 4, 5, and 7; at 1:500,000 and 1:250,000 black and white prints of band 7; at approximately 1:2,500,000, the mosaics shown in Figures 7 and 8. In addition, linears were searched for and "mapped" on topographic maps at 1:62,500 of the Margaretville and Phoenicia Quadrangles in the Catskill Mountains, and on an aerial mosaic index sheet of the same area at the same scale.

4.7.1.2 Scene C3 (Figure 22) spans a number of physiographic, geologic and tectonic provinces, as may be seen by comparing it with Figures 1, 2, and 3. Reference will be made later to the variation in spectral characteristics of linears as a function of tectonic province.

4.7.1.3 The linear information was recorded on clear acetate overlays for each of the above data sources. All linear features which were recognizably lithological or cultural were excluded, but a rigorous Stage II evaluation remains to be done.

4.7.1.4 After all the images had been analyzed, they were compared by using scale-changing viewers (Bausch and Lomb Zoom Transfer Scope and an overhead viewing projector) on which acetate overlays from one scale were superimposed on those of other scales, and differences recorded by color notation. Only the 1:1,000,000 composite is reproduced herein, but comparisons of linear data at the several scales are discussed in some detail.

4.7.2 General results

4.7.2.1 In the initial compilation, it was found that, of the total number of linears visible on bands 5, 7, and the false-color composite, more than 97 percent were visible on the band 7 image.

4.7.2.2 All spectral lines are borders between different image tones. However, because of the low sun angle many tonal boundaries are clearly recognizable as topographic. These are referred to herein as topographic linears, and are drawn at the valley bottoms. Another group of tonal boundaries and lines are not discernibly topographic features; they are more subtle, and generally occur in low, flat-lying areas. Some may be related to cultural or botanical featuressuch as farm borders or forest boundaries. These are designated tonal linears. The two types have been distinguished in Figures 23 and 24.

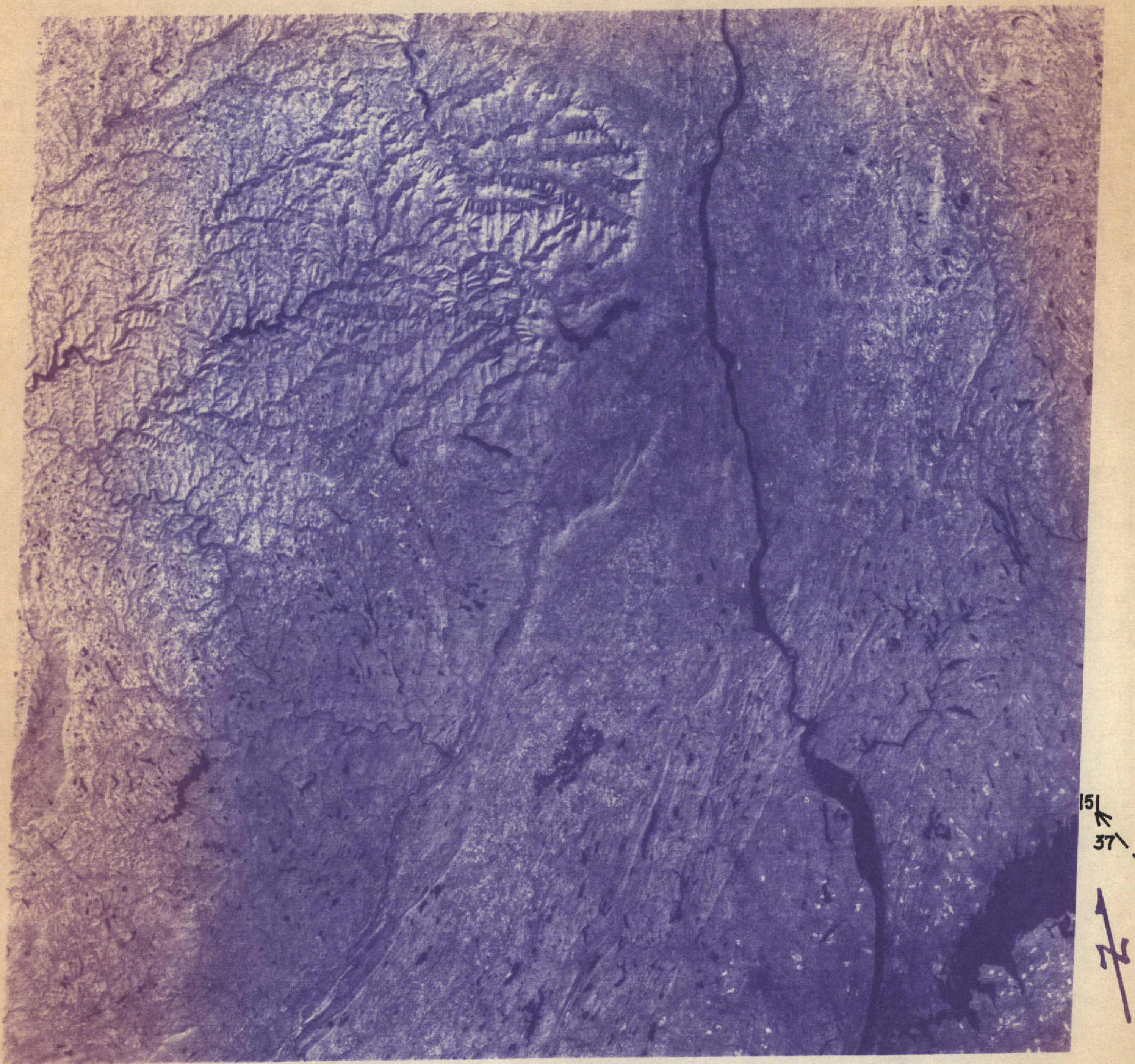


Figure 22. ERTS-I image of scene C3, band 7 (image no. 1079-15124) of 10 Oct 72 over southeastern New York State. Dashed arrow indicates sun azimuth and angle. Scale: 1 mm = 1 km.

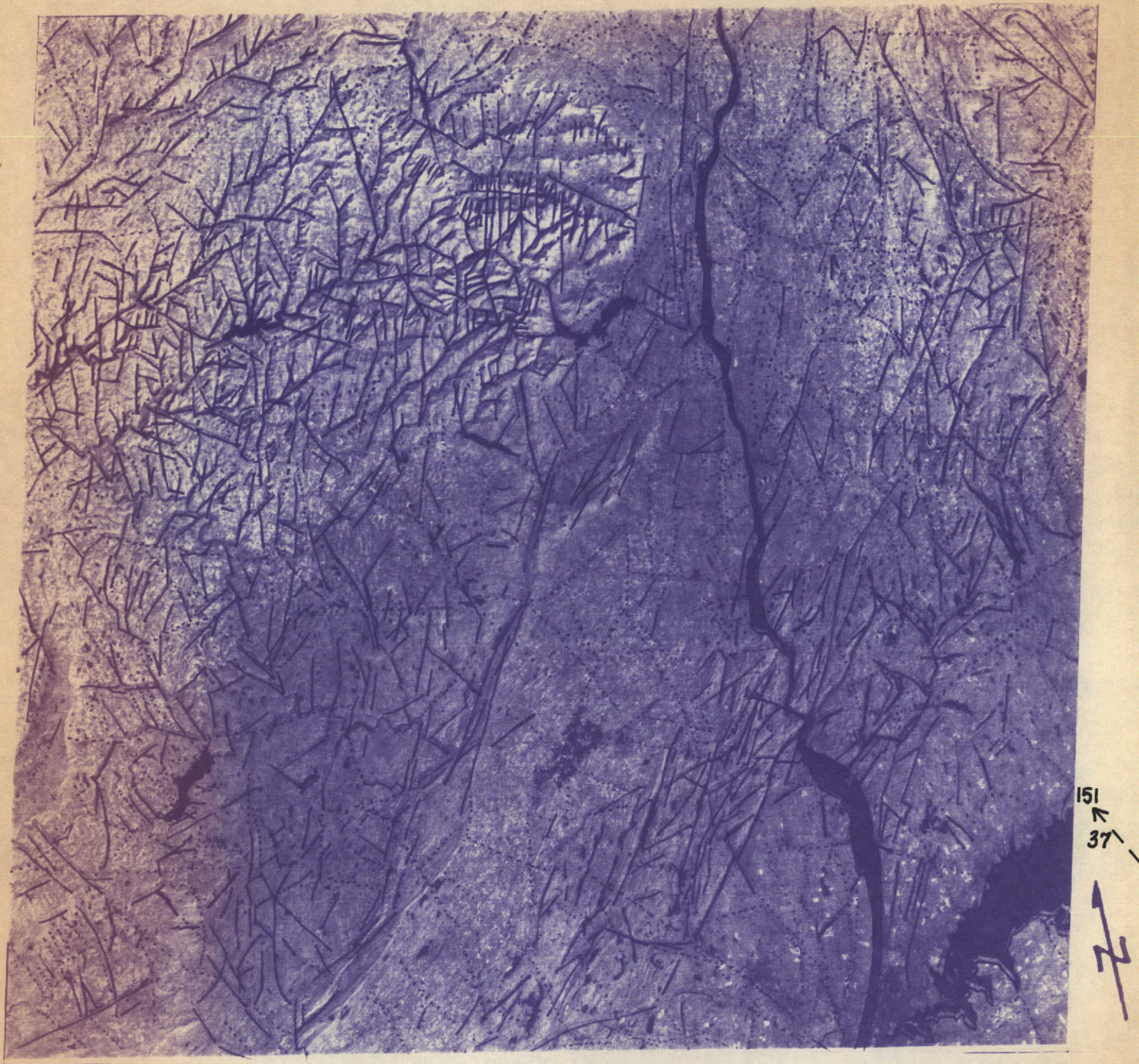


Figure 23. ERTS-I image shown in figure 22, with Stage I linears added. Scale: 1 mm = 1 km. Solid lines represent topographic linears, dotted lines signify tonal linears. Dashed arrow indicates sun azimuth and angle.

Figure 24. Stage I linears seen in scene C3 (1079-15124). Solid lines represent topographic linears, dotted lines signify tonal linears. Dashed arrow indicates sun azimuth and angle. Scale: 1 mm = 1 km.

4.7.2.3 Eleven major linear directions were found on image C3 (Figure 25).

The following discussion compares these sets in terms of the following variables, which are summarized in Figure 26: 1) relative prominence in the various geologic provinces; 2) whether topographic or tonal in expression, 3) length, 4) straightness or direction of concavity, 5) density of occurrence: dense, if generally less than 5 kilometers apart; moderate, if generally 5 to 10 kilometers apart, and sparse, if generally more than 10 kilometers apart, 6) regularity of spacing: regularly spaced, or irregularly spaced and 7) clarity of expression on the image: weak, if hard to see; moderate, if generally easy to see, and strong, if they are the most prominent tonal or topographic feature on the image.

4.7.3 Nature of linears at various scales

4.7.3.1 The features recorded as linears are simply lines having "sufficient length" to determine that they are straight. The shortest lines classified as linears at the various scales were: 1,2,500,000, 5 km; 1:1,000,000, 2 km; 1:500,000, 1 km; 1:250,000, ½ km.

4.7.3.2 This expectable inverse linear relationship between scale of imagery and length of linears results from the thought that a line must be at least 2 mm long before it could confidently be called a "straight line", and that numerous short, aligned segments at the larger scales appear to coalesce into single long linears at the smaller scales. This occurs as long as the smaller segments lie in a straight line or zone, whether they strike parallel to that line, en echelon to it, or are conjugate sets no matter what the strike. As one example, the N65E trending set of linear segments near the northeast corner of Figure 29, produce at 1:2,500,000 what appears to be a single linear several hundred kilometers long, at 1:1,000,000 a dashed line (Figure 24), and at 1:500,000 a series of two sets of en echelon segments lying in a N65E zone. At 1:250,000 the individual linears are no longer recognizable as having a zonal alignment.

4.7.3.3 Other examples were seen where single linears at small scales appear as zones of zig-zag and even crossing segments at larger scales.

4.7.3.4 As indicated in Figure 25A, the major length-weighted linears seen at the 1:1,000,000 scale trend N20W, N15-20E, N20E, and N65E.

4.7.4 Straightness of linears

4.7.4.1 Most topographic and tonal linears are straight, but a number of the longer tonal linears are gently curved (Figure 24). The directions of concavity vary, but a consistency exists within some sets (Figure 26). Stage II and III analyses will be required before anything more can be said about the cause or significance of the curvatures.

4.7.5 Cross-cutting relationships of linears

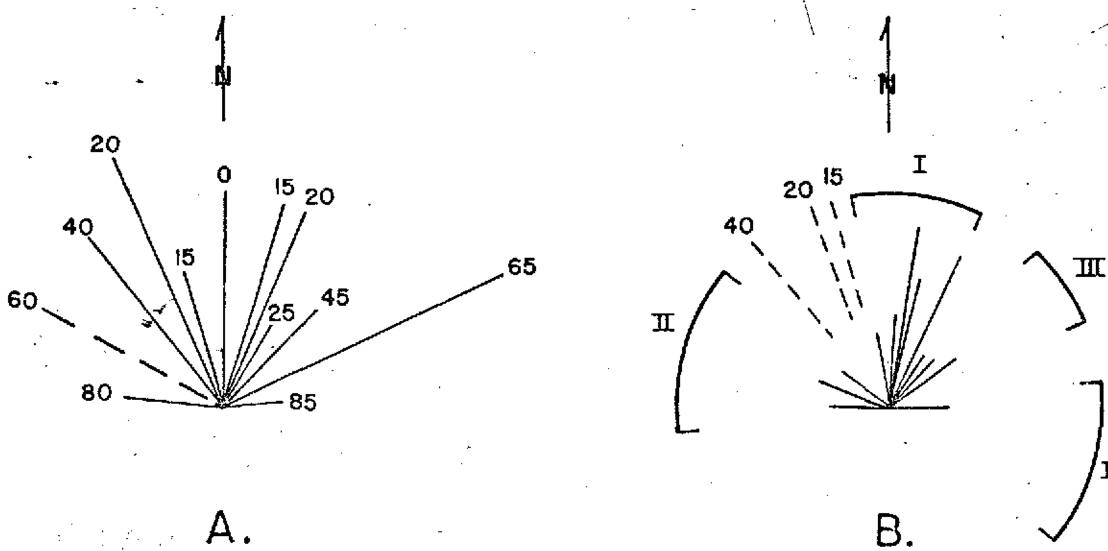


Figure 25. A. Azimuth plot of the linears shown in figure 29. Lengths are proportional to qualitative estimate of summed lengths of linears. The N60W direction may represent curved extensions of the N40W direction.

B. Compilation of joint sets observed by Parker (1942) within the area of scene C3 (figure 29). The three ERTS-I linear directions not noted as prominent by Parker are shown by dashed lines.

DIRECTION	BAND 7 1 : 1,000,000 PROVINCE	LINEAR TYPE (minor expression in parentheses)	LENGTH in km	STRAIGHTNESS AND CONCAVITY DIRECTION	DISTRIBUTION	SPACING	MOSAIC PRINT FALL	MOSAIC PRINT WINTER	1:500,000	1:250,000	TOPO MAPS	AERIAL PHOTO
N80W	all except Atlantic Coastal plain	tonal	10-50	slightly curved to N and S	sparse	even	topo in Catskills	tonal in Appalachian Plateau	poorly expressed	All directions expressed. All long linears are tonal, all short are topo. All directions have less dense distribution and all are unevenly spaced.	prominent, 1-20 km	prominent 1-2 km
N40W	west of Hudson River	topo-tonal	10-50	straight	dense in NW sparse in south & east	even or uneven in zones	topo in Catskills; tonal in east	poorly expressed	poorly expressed N60E tonal linear 30-50 km prominent in Hudson Highlands		moderately expressed 2-5 km	1-2 km
N20W	all	tonal (topo)	5-40	straight in Catskills slightly curved in S, to NE, NW	dense	even	topo in west tonal in east	topo in west tonal in east	poorly expressed tonal (topo)		prominent 5-15 km	moderately expressed 2-5 km
N15W	west of Hudson Highlands and Taconics	tonal	10-40	short-straight long-curved to east	sparse	uneven	topo in west	poorly expressed	poorly expressed		poorly expressed 2-5 km	prominent 1-2 km
N-S	Catskills Hudson Highlands Manhattan Prong Atlantic C. P.	topo (tonal) tonal (topo) tonal tonal	10-50 10-50 25 10	slightly curved to east & west	dense	even	topo in Catskills; tonal in south	topo in west tonal in east	short topo in Catskills; all other areas tonal		moderately expressed 2-5 km	poorly shown
N15E	all	topo (tonal) (topo only in Catskills)	5-30	straight	dense in all but Shawangunks	even to uneven	topo in Catskills; topo-tonal in east	topo in west tonal in east	topo in Catskills; all other areas tonal		prominent 2-15 km	prominent 5-15 km
N20E	all	topo-tonal	5-40	straight to slightly curved to west	dense in all but Shawangunks	uneven and in zones	topo in west; topo-tonal in east	topo in NW tonal-topo in east	topo in Hudson Highlands; all other areas tonal		poorly expressed	moderately expressed 2-5 km
N25E	Catskills Shawangunks Hudson Highlands Taconics	topo (tonal)	5-10 10 10 10	straight	sparse	uneven	short topo in south + Catskills	poorly expressed	prominent short topo in Catskills		moderately expressed 5 km	moderately expressed 1-2 km
N45E	Hudson Highlands Manhattan Prong	tonal (topo)	5-15 5-15	straight	sparse	uneven	topo in Hudson Highlands	topo in southeast	short topo in Catskills; long tonal in Hudson Highl.		prominent 15-20 km	moderately expressed 2-5 km
N65E	all	topo-tonal	5-100	straight	dense	even and in zones	long topo in Catskills; short topo in Hudson Highl.	long topo in Catskills	short topo everywhere long tonal in south		moderately expressed 5-10 km	prominent 2-5 km
N85E	Catskills Hudson Highlands Taconics	topo (tonal)	5-20 5-25 5-25	straight	sparse	uneven in zones	short topo in Catskills	poorly expressed	poorly expressed		moderately expressed 5 km	prominent 5 km

Figure 26. Chart summarizing the directions and characteristics of Stage I linear features for scene C3 multi-scale study. Abbreviations: C.P. = Coastal Plain; Highl. = Highlands; topo. = topographic. Mosaic Print refers to figures 7 and 8, and Aerial Photo refers to airfoto index sheet.

4.7.5.1 Tonal linears commonly cross both topographic linears and other tonal linears (Figure 24). Topographic linears, on the other hand, generally do not cross each other except in parts of the Taconics and Catskills; short topographic linears almost nowhere cross each other. Stage II and Stage III studies will be needed to explain these relationships, but two tentative working hypotheses are here advanced.

1. In the Taconics, the two cross-cutting linear sets may represent the intersection of a prominent joint set with lithological contacts.

2. In the Catskills, the prominent N65E linear set may because of its great length, represent a basement feature (fault?) which is expressed at the surface as a set of closely-spaced joints; the N15-20E cross-cutting joints may be more local, stress-related sets. Small-scale displacement has occurred along at least some linears of the N15-20E set, as will be discussed in a later section.

4.7.6 Comparison joint studies by Parker and by Nickelsen and Hough

4.7.6.1 The only regionally synthesized joint study which applies to the C3 image area is that of Parker (1942), whose analysis is restricted to the flat-lying sedimentary rocks of the Alleghany Plateau, including the Catskill Mountains. Parker generally found only two or three joint sets at any one locality, and noted that the directions of these sets, do not vary significantly across the area of a single 1:62,500 quadrangle. Across the entire western part of the State, however, he found a systematic clockwise rotation of the joint directions.

4.7.6.2 A comparison of ERTS-I imagery, Stage I linears and Parker's joint data for the Catskills shows that almost all of the joint directions are represented by ERTS-I image linears (compare Figures 25A and B). Two linear sets seen on the imagery, however, those trending N40W and N20W, are not represented in his joint diagrams. Parker divided the joint distribution into Sets I, II and III. Set I, which is generally represented by two sets (interpreted and conjugate) averaging 19° apart at any locality, corresponds to the ERTS-I linear sets between N-S and N20E, Set II corresponds to linear sets between N50W and N88E, and Set III corresponds to the linear sets between N45E and N67E.

4.7.6.3 The joints of Parker's Set I are generally vertical and remarkably planar. They cut all sedimentary features in the outcrop and are expressed in all types of sedimentary rock. They extend from a few centimeters to 60 m in length, and are the most numerous set in any one outcrop, generally accounting for 50 to 70 percent of all joints present. He interprets this set to have resulted from shearing.

4.7.6.4 The joints of Parker's Set II are generally irregular, both horizontally and vertically through arcs of up to 25 degrees, and have rough surfaces. They constitute about 25 percent of all joints recorded in a given 1:62,500 quadrangle. They are interpreted by Parker as tensional fractures. Their relative lengths were not specified.

4.7.6.5 The joints of Parker's Set III are generally long, vertical, and planar, although many are curved. They generally change character in passing from one stratigraphic horizon to another. They constitute about 15 percent of the total number of joints recorded in a given 1:62,500 quadrangle. Parker interprets them as tensional.

4.7.6.6 Interpretations of the nature of jointing in New York and Pennsylvania which differ from Parker's, have been presented by Nickelsen and Hough (1967). They interpret the joint set pairs of Parker's Set I as an early set overprinted by a later one, rather than as a conjugate shear set. Nickelsen and Hough think there may be as many as five, distinctly different joint sets present throughout New York - Pennsylvania Plateau region rather than a system of three-sets which rotate clockwise across the region from west to east.

4.7.6.7 Many of the linear patterns expressed in the ERTS-I imagery of the Catskills look surprisingly similar to joint maps of outcrops illustrated by Parker. However, the five-or-more joint set model of Nickelsen and Hough would also produce a pattern very similar to the regional linear features observed in the imagery. It seems possible then that this conflict of opinions about the nature of jointing may be resolved by field checking of the linears shown on ERTS-I imagery. If so, some basic ideas about the structural geology and the tectonic framework of New York and Pennsylvania would have been focused upon by ERTS-I imagery analysis. For example, if the joints do gradually rotate across the Plateau, and, if the joint directions are expressed by linears as is the case in the Catskill Mountain part of the Plateau, a gradual rotation should be demonstratable on an ERTS-I linear made at a suitable scale.

4.7.7 Summary and regional implications of Stage I linears

4.7.7.1 Recognizing once again the preliminary nature of this Stage I analysis, the following are offered as tentative generalizations:

1. Linears are abundantly expressed on the ERTS-I imagery of southeastern New York, and in general extend across physiographic, geologic, and tectonic province boundaries.

2. Each linear set has a characteristic expression in the imagery which is usually consistent within a give geologic province. These characteristics include whether topographically or tonally expressed, length, straightness or concavity, density, spacing, and cross-cutting relationships.

3. What defines a topographic linear can be very much a matter of the scale at which viewed.

4. Linears are clustered into eleven major directions at 1:1,000,000, called linear sets.

5. Linears sets generally correspond to mapped joint sets (Figure 25). The two exceptions are the N40W and N20W linear sets which are not represented by mapped joint sets.

6. Because of their great length, some linear sets, especially the N65E set seen at the smaller scales may be surface expressions of deep-seated basement fracture systems with possible plate-tectonic implications.

7. ERTS-I imagery appears to have the potential for resolving two diverse current interpretations of regional jointing in the Alleghany Plateau of New York and Pennsylvania.

4.7.8 Field study of the N20E linear set

4.7.8.1 The eastern edge of the Catskill Mountains is a notably straight steep escarpment (Figure 22) along which the Mountains rise abruptly for 800 m from the broad Hudson River Valley to adjacent summits which exceed 1,000 m in height. This escarpment, long known as the "Wall of Manitou" extends south from the latitude of Catskill for a distance of 20 km.

4.7.8.2 West of the "Wall", the Catskill Mountains are eroded to produce prominent, northwest trending, ranges and valleys. Crossing these ranges at a high angle are numerous topographic lineaments which trend about N15E, and parallel the Wall of Manitou. The pervasive nature of this set, extending westward for at least 25 km, was never recognized before, and its geologic origin has only received brief mention. Chadwick (1944, p. 17) interpreted the two prominent valleys which occur 10 km west of the Wall of Manitou as being controlled by closely spaced joints along which "the internal settling known as 'keystone' faulting (Crosby, 1925)" might have occurred, although "as yet actual faulting has been demonstrated in only the easternmost of these lines, namely that which is tangent to the east end of North Lake." The fault referred to is located at the northern end of the "Wall" at the upper break in slope on Chadwick's geological map.

4.7.8.3 The Wall of Manitou and several of the parallel linears were examined and photographed from small aircraft before the leafing of deciduous trees. Figure 27 illustrates the straightness of the "Wall," and also shows traces of an orthogonal N75W set which is not well shown on the ERTS-I imagery. Figure 28 shows a sag pond developed in the lower part of the "Wall", a feature which may indicate the trace of a "keystone" or other type fault, and will be examined in the field.

4.7.8.4 A vertical aerial photograph recently taken by NASA at 24,000 feet altitude of an area 12 km west of the Wall of Manitou (Figure 29) provides a useful calibration device to determine how short a linear my be mapped on the ERTS-I imagery with confidence. As expected, the relatively long N20E linears are readily confirmed, a particularly good example being the Stony Clove linear. More impressive, however, is the fact that the two short N75E linears, spaced only 1 km apart, with the shorter one being less than 2 km long, can be discerned on the imagery; we would have been unwilling to identify such short lines on the imagery as linears without the assurance provided by the aerial photography. This suggests that, despite the "busy" pattern of linears on Figure 24, many additional very short linears can be added.

4.7.8.5 Low level aerial reconnaissance of the Stony Clove linear confirms it as a well defined topographic lineament (Figure 30). A closer view of the Stony

Figure 27. Aerial oblique view of small segment of "Wall of Manitou" showing its straightness. Note also, perpendicular to the wall, at least four parallel linears: two tonal and two tonal-topographic. The bedrock consists of interbedded red and green shales and cross-bedded sandstones of the Catskill facies. From color-infrared photo.

Figure 28. Aerial oblique view of suspected sag pond located on the Wall of Manitou. The apparent inclination of the horizontal strata is a photographic illusion. From color-infrared photo.

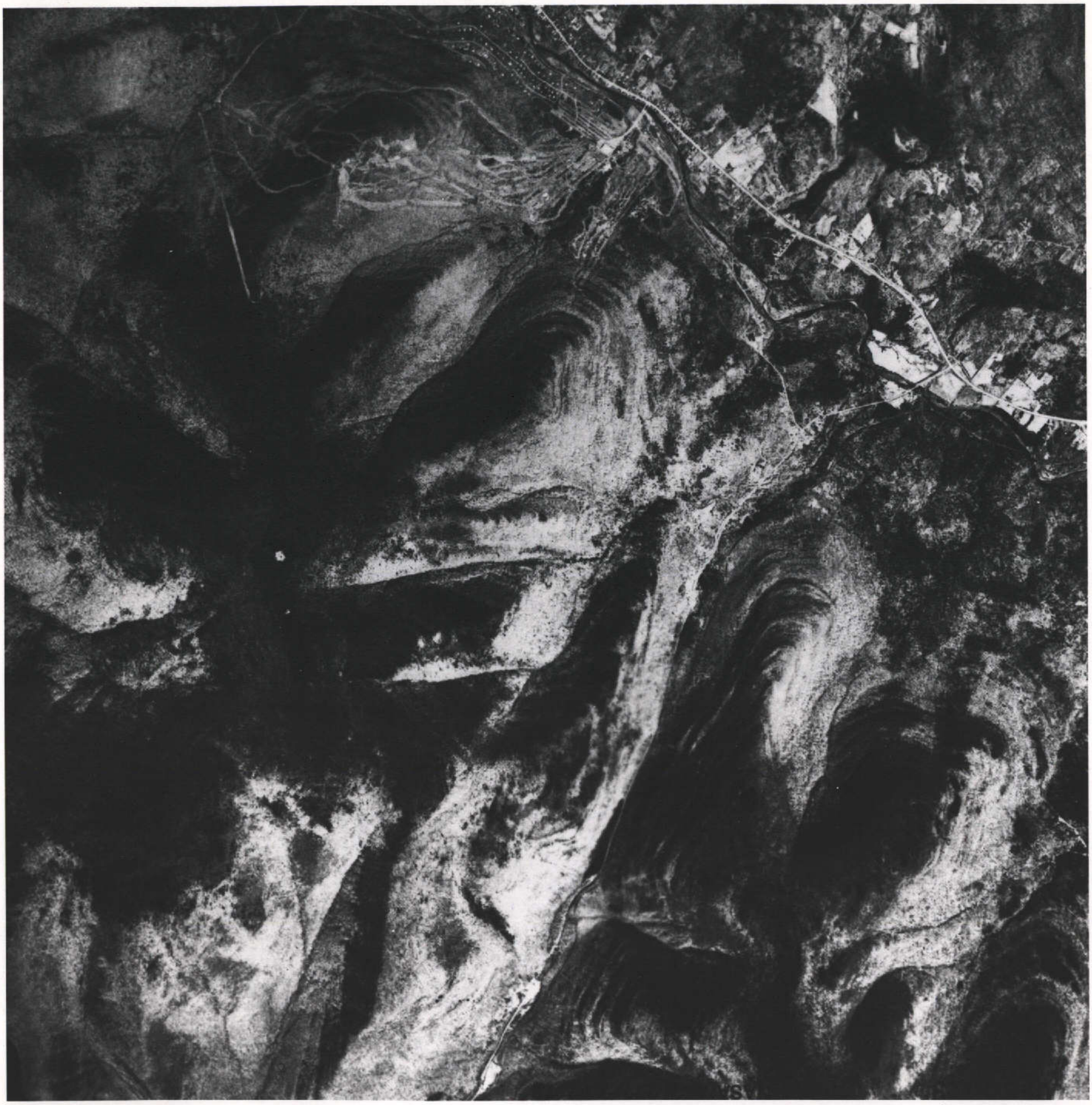


Figure 29. Print from color transparency aerial photograph over the eastern Catskill Mountains. Clove Valley linear extends about N15E from the south center of the photo; Hunter Mountain ski area is near the north edge of the photo. Note the pair of N75E topographic linears. Photo by NASA, 30 Apr 73. Scale: 1 cm = 4 km.

Figure 30. Stony Clove topographic lineament, looking N15E over Edgewood (hidden behind hill in foreground), with drainage divide at Clove in middleground; Hunter $7\frac{1}{2}$' quadrangle. From color-infrared photo.

Figure 31. Stony Clove drainage divide of figure 30, showing possible vertical offset of the resistant Stony Clove sandstones of the Upper Devonian Lower Walton Formation.

Clove drainage divide (Figure 31) suggests that vertical displacement may have taken place, a question of considerable importance in field evaluation of the prominent N15-20 E set of linears, and one scheduled for field study.

4.8 Circular features on ERTS-I imagery

4.8.1 As shown on Figure 9, several circular anomalies have been found in the ERTS-I imagery: a cluster of three southeast of Rochester, one north of Oneida Lake, and three in the Adirondacks. Those in the Rochester area can be seen in Figure 32 where their upper contacts are indicated by arrows. The three additional circular features visible south and southwest of Oneida Lake in Figure 32 are not anomalous, because the one in the center was identified in U-2 aerial photography as a fortuitous arrangement of urban signatures and those on either side correspond in large part to lithological contacts along the northern edge of the Alleghany Plateau.

4.8.2 The two circular features southeast of Rochester are well resolved in the U-2 aerial photograph of Figure 33. Only the central one is well defined in the U-2 photograph, and results from the combination of a scalloped drainage pattern forming the upper and lower parts of the circle, and elongate fields forming the side. The east-west valley that extends across the photograph beneath the scalloped drainage is an ice-marginal drainage of glacial Lake Dawson. The valleys which form the circular anomaly may have a related glacial origin. They remain to be investigated further. The small circular anomaly north of Oneida Lake is not visible on airfoto index sheets, so remains unexplained. That located to the NNE across the Black River is formed in the main by a possible fortuitous arrangement of two stream courses.

4.8.3 The most striking of the "circular" features is the much larger one that occurs in the west-central Adirondacks, centering on Cranberry Lake, and here termed the Cranberry Lake anomaly. It is elliptical in outline, and resembles a deformed, spoked wheel. Seven of the radial valleys are arms of Cranberry Lake, at least in part. The long axis of the feature measures about 30 km, the short axis about 22 km. In a very general way it has a central domal high surrounded by a ring depression, with a lake basin at the center of the feature. The maximum topographic relief measured from lake bottom of the higher mountains within the feature is about 830 m. In the eastern and southern parts of the feature, a suggestion of concentric rings can be seen in the imagery (Figures 14 and 34). A recently published gravity map of the Adirondacks (Simmons and others, 1973) shows a two milligal simple Bouguer gravity anomaly over the Lake basin. Taken together, the above observations suggest the possibility that the Cranberry Lake anomaly may be a cryptoexplosion structure.

4.8.4 The relationship between the topography of the anomaly and bedrock geology may be seen by comparing Figures 34 and 35. Southwest of Cranberry Lake, the rim depression coincides with the alluvial-filled (Q) Oswegatchie River Valley which is cut into hornblende-biotite granitic gneiss (hbg). The strike of foliation in the gneiss differs by 90 degrees on opposite sides of the valley. The rim valley fails to extend northward across the northeast-trending antiform of quartzofeldspathic gneisses represented by units phqs, ffg, and lgr. To the south and east, however, the river

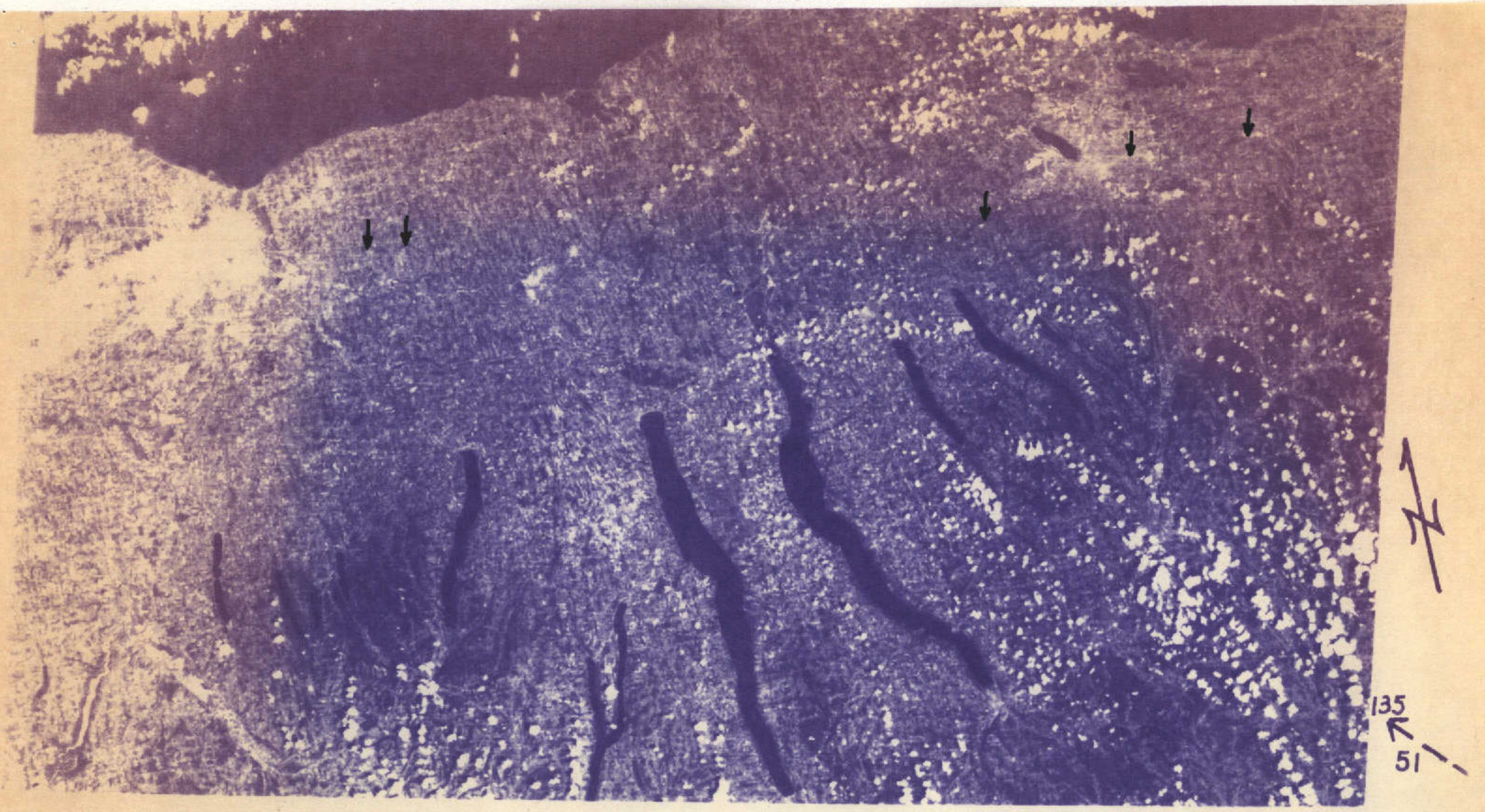


Figure 32. Southern portion of scene E2 (image no. 1027-15233), band 5, showing circular features by arrows; dashed arrow indicates sun azimuth and angle. Scale: 1 mm = 1 km.

Figure 33. Print of high altitude (U2) color infrared aerial photograph showing circular feature southeast of Rochester. The east-west topographic low which forms the southern boundary of the feature is an ice-marginal drainage channel. Photo by NASA, 27 Apr 72. Scale: 1 cm = 2.3 km.

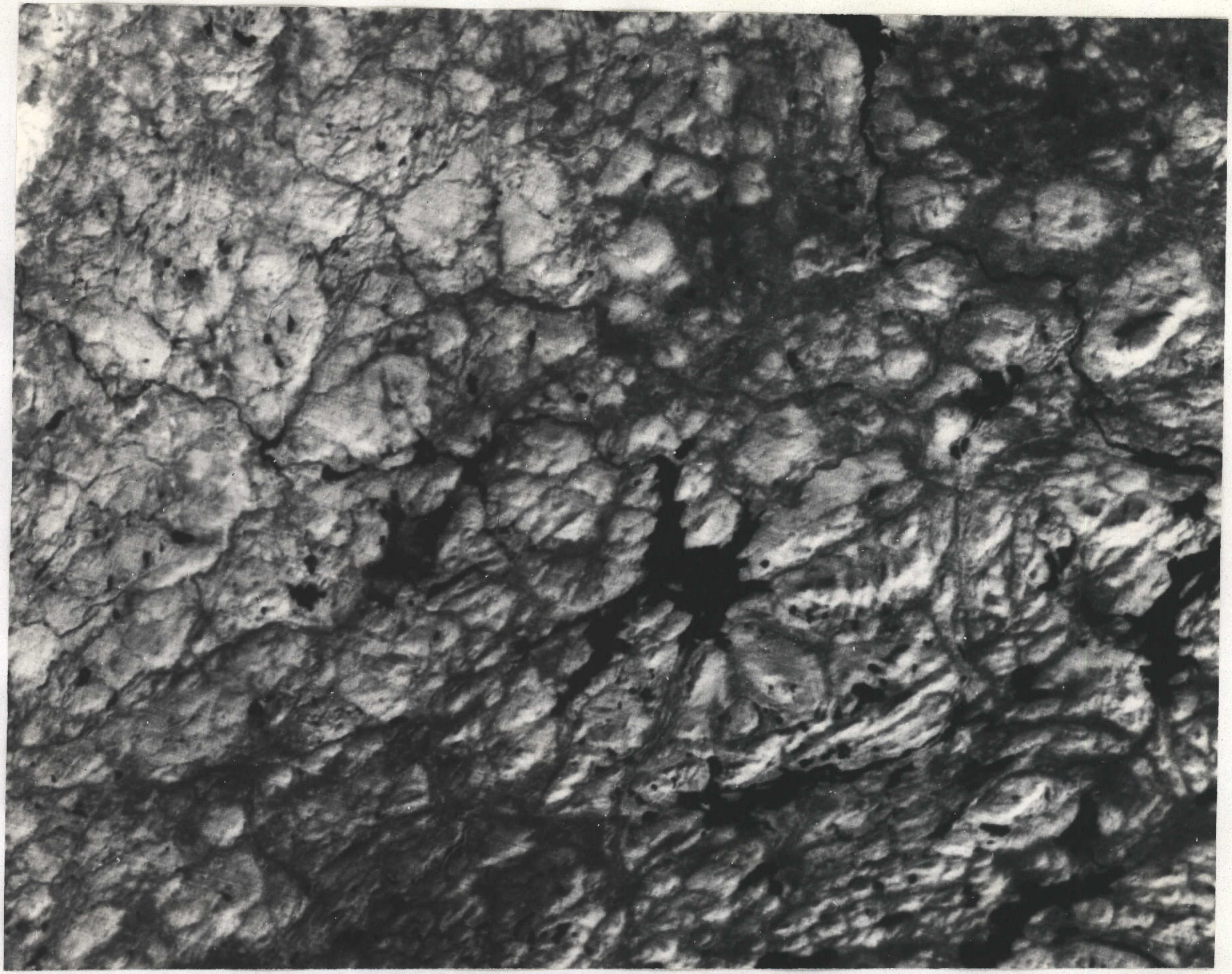


Figure 34. ERTS-I image at 1:250,000 of Cranberry Lake area, west-central Adirondacks, from scene D2, band 7 (1080-15174). North is parallel to sides of photo. Scale: 1 mm = .25 km.

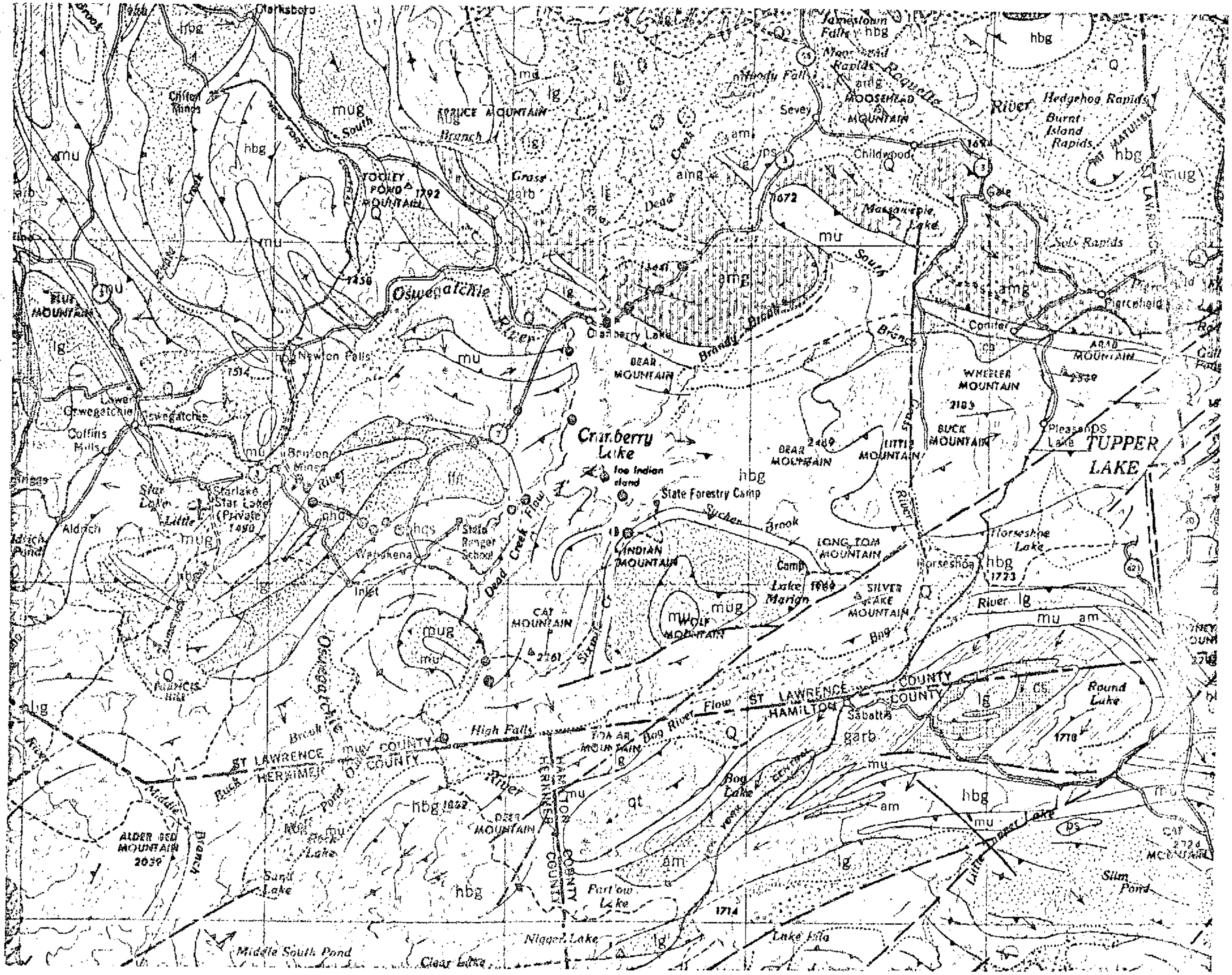


Figure 35. Geologic map of same area shown in figure 33, at slightly larger scale. Black dots signify exposures studied. From Geologic Map of New York, 1971; bedrock geology by Buddington and Leonard, 1962.

valley corresponds with that seen in the imagery, until it crosses Bog River Flow to follow the NNE-trending topographic lineament past Lake Marian, along Long Tom Mountain, and then directly north through the Grass River Valley which cuts orthogonally across a mass of resistant pyroxene syentic gneiss (ps). North of this, the valley merges with the broad lowland area of alluvium north of Cranberry Lake, and looses definition. West of Cranberry Lake and north of the resistant quartzofeldspathic units referred to above, the rim valley corresponds with the narrow belt of alluvium extending northeastward from Benson Mines, transecting bedrock lithology (hbg and metasedimentary rocks, mu) at right angles. The rim valley then disappears again in the same alluvial-filled lowland north of Cranberry Lake.

4.8.5 In summary, the rim valley parallels bedrock trends along part of its course, transects it along, others, and fails to develop at all across an antiform of quartzofeldspathic units in the southwest.

4.8.6 Aeromagnetic trends in the Cranberry Lake anomaly area (unpublished map of Zietz) show no anomalous deviation from the mapped lithologic trends.

4.8.7 The major radial valleys, except for Sucker Brook and Sixmile Creek which are eroded along a thin metasedimentary unit, are probably fracture-controlled inasmuch as they cross the foliation trends of resistant gneisses. Buddington and Leonard (1962, p. 130) suggest that Dead Creek Flow is a probable fault, while noting that "the inquiring geologist cannot reach out his hand and place it on the fault surface of any one of the major faults in the district".

4.8.8 To date, only three days have been spent investigating the Cranberry Lake anomaly on the ground, in a search for criteria indicative of cryptoexplosion structures (e.g. Short, 1968), particularly shatter cones, megabreccias or injection breccia veins. An initial road traverse was made to examine all roadcuts encountered across the feature; outcrop sites visited are shown on Figure 35. No shatter cones were seen, and no fracturing was observed beyond normal jointing, except in the second road cut west of Cranberry Lake village where the rock is much fractured, but lacks evidence of brecciation or displacement. Rocks encountered on the traverse were all crystalline gneisses, mainly granitic.

4.8.9 Judging from observations at Sudbury (Bray and others, 1966), such lithologies would not be expected to yield good shatter cones, although Dietz (1968, p. 273) indicates that crude but convincing examples have been found in crystalline gneisses at several localities. Quartzite is apparently an ideal lithology for development of shatter cones (Bray and others, 1966), and one remote quartzite unit (qt) located between Tomar Mountain and Bog Lake will be visited.

4.8.10 Outcrops of hbg exposed along shorelines and on Islands of Cranberry Lake have been examined for abnormal fracturing, with negative results; in most outcrops the granitic gneiss is only moderately jointed. The Benson Mines open pit located along the western periphyry of the anomaly, has received limited examination, but an additional search for fine-grained lithologies will be made.

4.8.11 An outcrop of diopside-rich calcsilicate rock collected from the metasedimentary rock unit (mu) at the west end of Inidan Mountain contains large, kink-banded pyroxene crystals. Kink-banded pyroxene has been reported from the Holleford Crater (Short, 1968), but its presence does not prove shock metamorphism.

4.8.12 In conclusion, it remains possible that the Cranberry Lake anomaly is a cryptoexplosion feature, but compelling evidence, either field or petrographic remains to be found. The search goes on.

4.8.13 Beginning 15 km north of Childwold is a roughly circular feature 30 km diameter which is bounded by a narrow valley (Figures 5, 9 and 14). This feature forms the major part of an irregularly-shaped area which has a northeasterly elongation. The topography and tone are clearly different in appearance from any other part of the Adirondacks. The area appears in the imagery as a broad depression with sparse, irregularly-scattered hills, suggestive of "broken ground" on a very large scale. The area is, in regional terms, a terrace (The Childwold Terrace of Buddington and Leonard, 1962, p. 8) with valley bottoms having elevations of 1200-1300 feet on the northwest and 1600 feet on the southeast. The scattered hills rise up to a mazimum of 400 feet above the valley floor. This physiographic belt has an anomalously high percentage of sand plains and swamps, and the lowest density of bedrock outcrops of any large area in the Adirondacks (see Fisher and others, 1971). The reason for this is not known. The area does not show any gravity anomaly (Simmons and others, 1972).

5. ERTS-I AND GLACIAL GEOLOGY

Before discussing glacial features visible on ERTS-I imagery some observations will be made with reference to winter imagery which has proved to be particularly informative in terms of glacial geology.

5.1 Although there are impressive instances where partial or even total snow cover produces topographic enhancement and advantageously reduces terrain noise (e.g. Wobber, 1972, Gregory, 1972), conventional aerial photography is rarely taken during the winter months, because the combination of snow and winter sunlight generally tends to diminish contrasts between different terrain features. Because of the general unavailability of aerial photography taken in the winter months, the first such products seen by the present investigators were the ERTS-I images taken January 8 and 9, 1973 covering the C and D strips. As expected, snow-covered open fields and lakes appear white, but it was surprising to find that the extensive forests of the Adirondacks, the Tug Hill Plateau, the interfluves of the Alleghany Plateau, and scattered woodlands elsewhere, are dark gray to black in all spectral bands despite a deep ground cover of <u>dry</u> snow (these were the coldest days of the month, the maximum temperature reached in Albany being 7°F). This unusually low albedo characterizes not only the conifer forests of the high peaks area, where it is to be expected, but also the mixed hardwood forests at lower elevations. The effect is not due to faulty photographic processing, because all 15 shades in the gray scale are identifiable. It thus appears that, although in winter at conventional flight elevations such hardwood forests would have a high or intermediate albedo, at the lower resolution of satellite imagery the low reflectance of leafless trees (together with their ground shadows) dominates the spectral response. The resultant imagery gives the heavily-wooded Adirondack Mountains the appearance of a carved ebony plaque having both lower reflectance <u>levels</u> and reflectance <u>contrasts</u> that the imagery of other seasons (compare Figures 7 and 8).

5.2 If the above explanation is correct, it is unclear why the darkest imagery is not that of late fall, when neither broad-leaved vegetation nor snow cover are present.

5.3 In terms of geological usefulness, the most noteable advantage of the winter imagery observed at 1:1,000,000 is the supression of terrain noise, and hence the increased detectability of small-scale topographic features. The most notable examples are individual drumlins, which can be identified directly as topographic features rather than indirectly by their control of agricultural land use patterns. These are discussed below.

5.4 Numerous previously-mapped glacial features can be seen on ERTS-I imagery at 1:1,000,000. These include more than ten drumlin fields, drumlinoid glacial streamline forms, glacial lake sand plains and deltaic deposits, segments of glacial lake shorelines, ice-marginal drainage channels, and end moraines (Figure 36). No new glacial features have been identified to date. The search for mapped glacial features on ERTS imagery is greatly facilitated by using a scale-changing device such as the Bausch and Lomb Zoom Transferscope model ZT-4.

5.5 Several drumlin fields can be located on the summer and fall imagery due to the topographic effect of drumlin topography on land use pattern, but most are obscured. However, when snow cover obliterates land use patterns and the low sun angle of winter months highlights their relief, drumlin fields, and even individual drumlins, can readily be identified. Indeed, the stoss and lee sides of drumlins can be distinguished in some cases. Good examples can be seen south of the Mohawk River (1169-15123, 1170-15182) and in the Finger Lakes region (1243-15244). In the latter area, however, snow cover is less complete, and field patterns tend to camouflage the topography. For this reason only portions of the extensive drumlin fields of the Finger Lakes region can be identified, and of an estimated 10,000 drumlins in central New York State (Flint, 1957) only 228 could be identified. South of the Mohawk River, 316 drumlins were counted. On the ground, the drumlins measure 2 km in length, 400 m in width and 25 m in height. It appears likely that optimum winter imagery could easily be "calibrated" using topographic map information and then used to make a rapid, relatively accurate, inexpensive inventory of the drumlins in any region of the State.

5.6 Numerous glacial features are visible east of Lake Ontario. On the Tug Hill Plateau, glacial streamline forms or drumlinoids with northwest axes are extensively developed. In contrast to the drumlin fields mentioned above, these are best shown on the fall imagery (1080-15180). This is understandable because the Plateau is evenly forested, rather than being camouflaged by agricultural patterns. On a topographic map, the drumlinoids average 2-4 km in length, about 80 m in width, and 15 m in height. No published data are available to indicate to what extent they are depositional landforms or erosional bedrock features.

5.7 A small drumlin field can be seen in the winter imagery on the northwest slope of the Tug Hill Plateau (1170-15182, 1170-15175). It is not apparent in earlier imagery. Also visible in the winter image are several glacial lake drainage channels which roughly parallel the contours around the north slope of the Plateau. Although these could be seen to some extent in the fall imagery (1080-15180) they are enhanced in the winter imagery due to

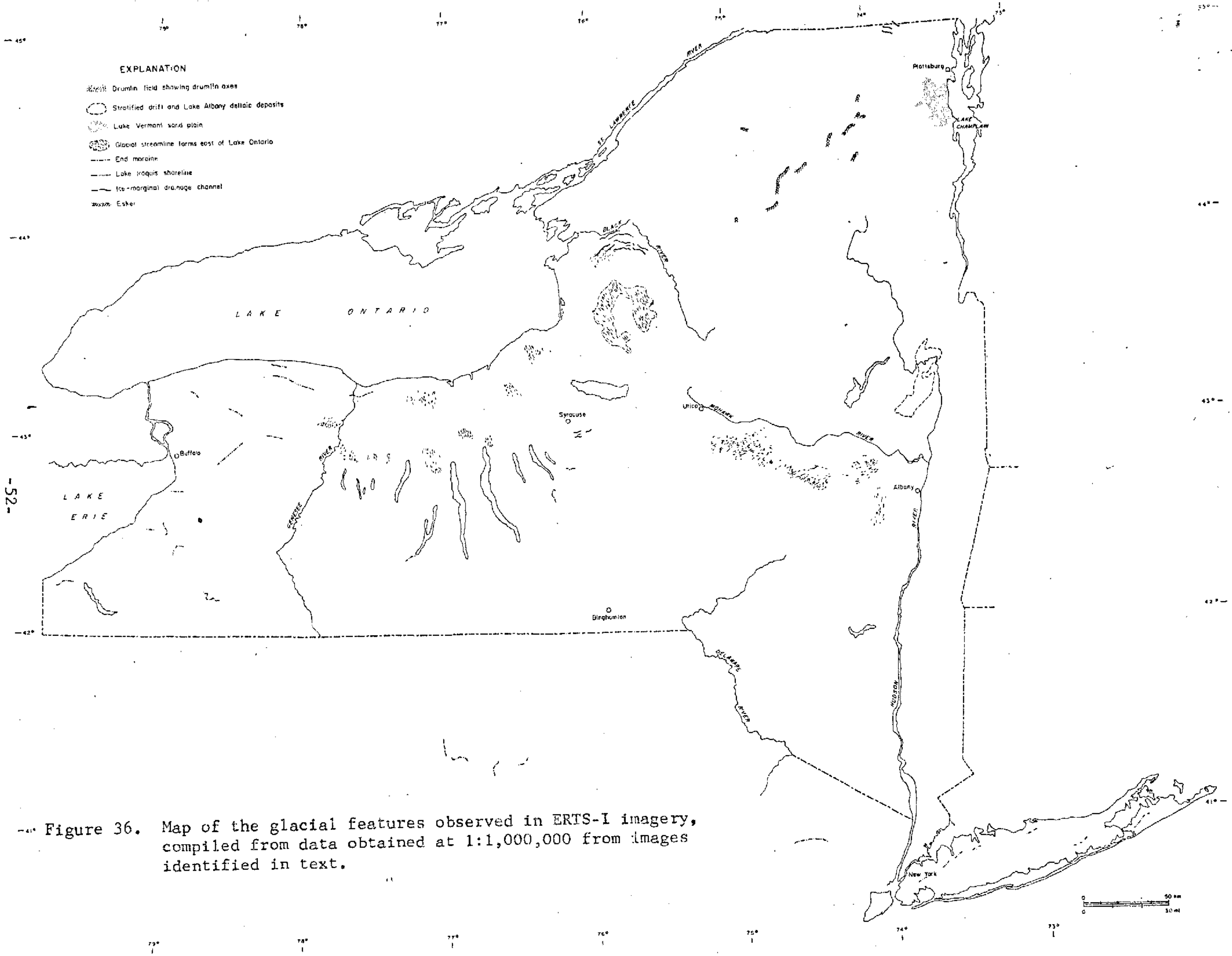


Figure 36. Map of the glacial features observed in ERTS-I imagery, compiled from data obtained at 1:1,000,000 from images identified in text.

the contrast between shadowed channels (accentuated by low sun angle) and surrounding snow. On the ground they are 2-17 km long, 200-700 m wide, and 20-30 m deep.

5.8 Comparison of the imagery with existing glacial maps of the Tug Hill region (Stewart, 1958; Forster, 1971) revealed no correlation. Farther north, in the St. Lawrence Lowland, image D 2 (1080-15174) was compared with the maps of MacClintoch and Stewart 1965 and a rough correlation was noted between the extensive areas of intermediate gray density located west of Malone, and areas mapped as peat and muck (swamp). An even better correlation was found when the imagery was compared with the woodland overprint on the 1:250,000 topographic map of the USGS (N118-11, 1961)--another example of a geological signature linked to land use.

5.9 In the Central Highlands of the Adirondacks, numerous segments of eskers show up in the imagery as narrow ridges bounded by bodies of water. On the ground these are 200-400 m wide and 15-25 m high.

5.10 At the northernmost part of the State, the Covey Hill drainage channels for glacial Lake Iroquois can be recognized on image 1079-15115. On the ground, these channels are 2-4 m long, approximately 300 m wide, and 20 m deep. On the same image can be seen an area south of Plattsburg which has a distinct, uniform, tonal density. This area was found to correspond quite closely with that of a sand plain mapped by Denny (1967) as a deposit formed in glacial Lake Vermont.

5.11 Farther south, two thirds of the distance to Albany, is a tonally distinct gray area whose borders were found to have a fair to excellent correspondence with the boundary of stratified drift and deltaic deposits associated with glacial Lake Albany, as shown on an unpublished 1:250,000 glacial map of the area prepared by R. Dineen.

5.12 In the southeastern part of the State, a series of moraines mapped by Connally and Sirkin (1967) in the Wallkill and Hudson Valleys were searched for on both fall (1079-15124) and winter (1205-15132) imagery. On neither image was any indication seen for these moraines.

5.13 Imagery of Long Island (1096-15074) was compared with a map of the Harbor Hill and Rankankam moraines using a direct overlay. A few short segments of these moraines were detected because of different land use on the moraine compared with surrounding areas.

5.14 Using a 1:1,000,000 enlargement of the Glacial Map of the United States east of the Rocky Mountains (Flint et al, 1959) imagery for New Jersey and Pennsylvania (1205-15135, 1170-15184, 1243-15251) was searched for end moraines and other glacial features. As shown on Figure 36, only a few short segments of moraine are visible.

5.15 For the western part of New York State the imagery (1243-15244, 1243-15251, 1244-15303, 1046-15292, 1244-15305) was compared with a compilation of moraines and beach ridges (Muller, 1972). Perhaps because of land use camouflage and low relief of these ridges (10 m), only small sections of a limited number of each was seen. Moraines searched for include the Valley Heads, Olean, Almond, Arkport, Clymer, Findley Lake, Gowanda, Hamburg, Marilla, Alden, Buffalo, Niagara Falls, Batavia, Barre, Albion, Colton, Geneva, and Waterloo. Those sections seen are shown on Figure 36. Glacial lake shorelines of the following lakes were also searched for: Whittlesey, Warren, and Iroquois; only two sections of the Iroquois beach ridge were found (Figure 36).

5.16 Because one of us (Fakundiny) has a particular familiarity with the surficial geology of the western part of the State it was decided, despite the inferior quality of the best available imagery at the time of the study (images 1027-15233, 1046-15292, 1080-15180) to attempt an evaluation of tonal variations. Comparisons made with generalized soils maps at 1:1,000,000 of Arnold and others (1967) and of the Genesee/Finger Lakes Region Planning Board (1970) show only a 10 percent correspondence of soils contacts and tonal boundaries, and that correspondence applies mainly to valley bottoms; it thus appears to be principally a correlation with topography.

6. ERTS-I AND MAN-MADE FEATURES

6.1 No attempt is being made to catalog the major works of man which can be seen on ERTS imagery. The more obvious ones, in some places confused with linears, include railroads and abandoned railroad beds, the St. Lawrence Seaway, highways, canals and transmission lines. Point data include major airports and golf courses (which have a very diagnostic high albedo in the near infrared imagery of October 10th, image number (1079-15124) as well as a number of mines and dry tailings ponds in the Adirondacks (Figure 15): the ilmenite-magnetite open pit of National Lead Industries at Tahawus is very dark gray on band 6, black on band 7 and indistinguishable on band 5; the Benson Mines open-pit magnetite mine at Star Lake appears dark gray on band 7, white on bands 4 and 5 and an indistinguishable medium-gray on band 6; in the Edwards-Balmat-Talcville area, tailings ponds appear white on bands 4 and 5 but are an indistinguishable light gray on bands 6 and 7.

7. CONCLUSIONS

7.1 The overwhelming majority of bedrock features which can be seen in ERTS-I imagery are identifiable either by their direct topographic expression or by differences in land use patterns governed by topography. Variations in bedrock lithology which lack topographic expression are only seen where they strongly influence land use. A limited amount of lithological discrimination has been possible with respect to glacial deposits, in the delineation of previously-mapped glacial sand deposits.

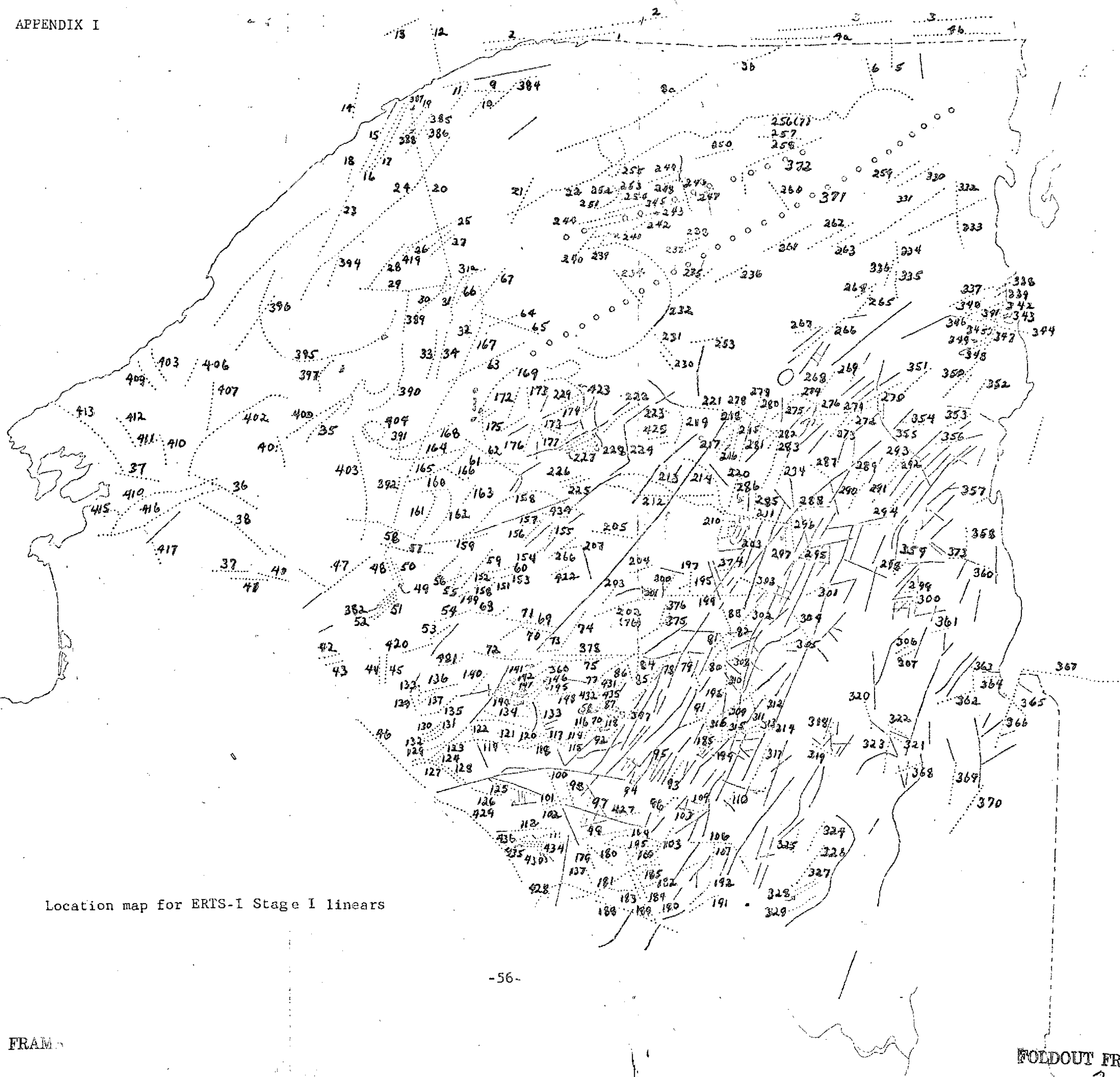
7.2 By far, the greatest geological contribution of ERTS-I imagery is in the delineation of hundreds of hitherto unknown linear features, both topographic and tonal, long (up to 200 km) and short (less than 1.5 km). (It was the 1:55,000, approximate scale, supportive airfoto coverage by NASA that demonstrated the capability of ERTS-I imagery to detect linears as short as 1.5 km, and as closely-spaced as 1 km). The new linear information will, in the short run, be incorporated into a regional tectonic synthesis now in progress. In the long run, because of its sheer magnitude it will doubtless occupy the attention of field geologists for decades.

7.3 A comparison of ERTS-1 linears with ground structures, indicates that some linears parallel known major fault trends while others parallel regional joint sets. There are doubtless a number of other genetic catagories represented.

7.4 It is anticipated that the ERTS-enhanced fracture map of the State now in preparation will prove to invaluable in seismic studies now underway by Lamont-Doherty Geological Observatory and the New York State Geological Survey. At present, virtually nothing is known about the relationhip between seismically and tectonics in New York. Both theoretical questions relating to seismicity within the North American Plate, and practical questions concerning seismic hazard are involved.

7.5 A number of potentially anomalous circular features seen in the imagery were explained through the use of U-2 aerial photography. An elliptical anomaly with a radial system of valleys, the Cranberry Lake anomaly, however, will require additional investigation.

APPENDIX I



Location map for ERTS-I Stage I linears

FOLDOUT FRAME 1

FOLDOUT FRAME 2

APPENDIX II

STAGE II IDENTIFICATION OF ERTS-1 ANOMALIES

Ident. #	Index Sheet #	Remarks
1	65	St. Lawrence Seaway, cultural feature
2	Can.	river has sinuous course, no continuation west of St. Lawrence River
3	Can.	probable highway
4a	Can.	probable highway
4b	Can.	probable highway
5	96	Allen Brook from St. Chrysostome into New York State
6	96	dark vegetation strip
7	96,80,81 66	lithologic contact; tonal contrast between Proterzoic and Potsdam ss.
8a	65,80	litholigc contact; 40 km. long; between Potsdam ss. and Theresa
8b	96	see Canada 1:250,000 map
9	65	irregular boundary between fields and roads
10	65	transmission line
11	65	border between swamp and farmland
12	65	combination of field borders and roads
13	Can.	off air photo indexes
14	Can.	off air photo indexes
15	53	southern half is several forest areas aligned and a stream section
16	53	linear wooded area and stream
17	53	road at southern end; rest is unexplained
18	53	unexplained
19	65	border of dark vegetation and stream
20	66	doesn't parallel field orientation; may include road in Southern part
21	66	parallels lithology and a road segment and narrow stretch of fields
22	66,80, 81	coincides with several roads

Ident. #	Index Sheet #	Remarks
23	53	coincides with highway
24	53	southern 1/3 is Beaver Creek; road and fields are mid 1/3, northern 1/3 is the Grass River
25	66	parallels lithology in southern part; rest is road and unexplained
26	66	transmission line
27	66,67	southern 1/2 is a road; northern 1/2 is field borders
28	54 66,67	southern 1/2 parallels lithology; northern 1/2 is probably a stream
29	54,67	road segment in center, possible woodland boundary
30	67	possible combination of several roads
31	67	stream valley
31 a	67	stream and transmission line
32	67	visible on index; explanation uncertain
33	67	unexplained
34	67	combination of road and transmission line
35	55	parallels lithology
36	43,56	northwest 1/2 is a road, southeast 1/2 is unexplained
37	43	transmission line
38	56,44	highway
39	56	unexplained; possible vegetation border
40	56	tree-lined stream valley
41	56	unclear on index; possible vegetation border
42	57	stream valley
43	57	unexplained
44	57	parallels lithology; also short section of river.
45	70	appears to parallel lithology, and stream segment

Ident. #	Index Sheet #	Remarks
46	71,58	southern /2 is road and stream; northern 1/2 is an elongate woodland.
47	56	highway
48	69	southern 2/3 parallels lithology; northern 1/3 is unexplained
49	69	southern 2/3 parallels lithology; northern 1/3 is unexplained
50	69	southern 2/3 parallels lithology; northern 1/3 is unexplained
51	70,57	parallels lithology
52	70,57	parallels lithology
53	70	lake; and parallels lithology
54	70	parallels lithology
55	69	unexplained
56	69	parallels lithology
57	69	straight stream
58	69	stream
59	69	northern 3/4 is a road; parallels lithology for entire length
60	69	lithologic controlled stream
61	68	southwest 1/2 is stream, northeast 1/2 is unexplained
62	68	southeast 2/3 is a straight stream; rest is probable stream
63	67	northeast 4/5 is straight stream; southwest 1/5 is unexplained
64	67	straight stream
65	67	mid 1/3 is unexplained; remainder is winding stream
66	67	transmission line
67	67	series of streams with possible lithologic control
68	70	unexplained
69	70,85	mid section is lake shore; rest is unexplained
70	70,85	valley and lake shore

Ident. #	Index Sheet #	Remarks
71	70	southern 2/3 is stream; northern 1/3 is apparent dry valley
72	70	straight stream
73	85	straight stream
74	85	stream valley
75	85	parallels lithology
76	85	edge of topographically high area
77	85	stream valley
78	85	southern3/4 is stream valley; northern 1/4 is unexplained
79	85	Indian Lake and unexplained
80	85	stream with possible lithologic control
81	85	sub-parallel to stream
82	85	unexplained
83	85	edge of topographically high area
84	85	winding stream valley
85	85	stream valley
86	85	apparent dry valley
87	85	parallels lithology
88	85	parallels lithology
89	85	parallels lithology
90	85	parallels lithology
91	85	unexplained
92	86	unexplained; parallels several mapped lineaments
93	86	possible vegetation border
94	86	ridge between two valleys
95	86	possibly parallels lithology
96	86	unexplained

Ident. #	Index Sheet #	Remarks
97	86	straight valley
98	86	lake and stream
99	86,71	stream + unexplained
100	86	unexplained
101	86	parallels lithology
102	86	parallels lithology
103	86	unexplained valley
104	86	winding stream valley
105	86	unexplained
106	86	highway and stream
107	86,87	northern part is stream; rest is unexplained
108	86	valleys with dark vegetation
109	86	unexplained
110	86	straight valley
111	86	straight valley
112	71,86	straight valley
113	86	straight stream
114	86	stream + unexplained
115	86	parallels lithology
116	86	stream parallels lithology
117	71,86	stream valley
118	71	parallels lithology
119	71	1/2 length is stream valley; rest is unexplained
120	71	river
121	71	mid 1/3 is stream; rest is unexplained

Ident. #	Index Sheet #	Remarks
122	71	stream
123	71	stream
124	71	stream
125	71	stream
126	71	unexplained
127	71	mostly unexplained, with some short stream segments
128	71	mostly unexplained, with some short stream segments
129	71	stream valley
130	71	three closely spaced linears: two are streams, the third is unexplained
131	71	
132	71	
133	70,71	stream
134	70	road + lake + unexplained + lake + unexplained
135	70	winding stream
136	70	semi-linear patches of dark vegetation + short stream segment
137	70	stream
138	70	small stream
139	70	lake and dark vegetation
140	70	lake - apparently lithologically controlled
141	70	northern 1/4 is stream; southern 3/4 is a road
142	70	stream - lithologically controlled
143	70	stream - lithologically controlled
144	70	stream - lithologically controlled
145	70	stream - lithologically controlled
146	70	stream - lithologically controlled
147	70	stream - lithologically controlled

Ident. #	Index Sheet #	Remarks
148	70,85	stream
149	69	stream
150	69	stream
151	69	border of dark vegetation area (also edge of topographic high)
152	69	stream
153	69	lake shoreline
154	69	unexplained
155	69,84	stream
156	69	stream
157	69	road
158	68,69,84	curvalinear: southern 1/2 parallels lithology; rest is streams and lakes
159	69	lake shoreline and boundary between topographic high and low areas
160	69	stream
161	69	stream segment + unexplained
162	69	stream
163	69	stream and lake
164	68	winding stream
165	68	stream and road
166	68	1/2 is stream; rest is unexplained
167	67,68,69	long linear composed of several streams, lakes and roads
168	68	stream
169	68	stream + lake shoreline
170	68	lake
171	68	unexplained

Indent. #	Index Sheet #	Remarks
172	68	stream and unexplained low area
173	68	Cranberry Lake shoreline
174	68,83	stream
175	68	narrow arm of Cranberry Lake
176	68	Cranberry Lake shoreline + lithologically controlled stream
177	68	portions of two lakes + topographically low area
178	68	stream-lithologically controlled
179	87	lake + dark vegetation patches
180	87	stream + lake + unexplained
181	87	straight stream + lakes + possible lithologic control
182	87	stream + lake shore + dark vegetation area
183	87	road + dark vegetation area + small valley
184	87	road + lake + low areas
185	87	stream + unexplained
186	87	lake + unexplained + stream
187	87	unexplained
188	87	stream + road + unexplained
189	87	unexplained
190	87	dark vegetation strip
191	87	stream + dark vegetation
192	87	parallels lithology
193	87	unexplained + short stream segment
194	86	dark vegetation strip in straight valley
195	86	dark vegetation strip in straight valley

Ident. #	Index Sheet #	Remarks
196	85	curvalinear: stream + dark vegetation area; possibly parallels lithology
197	84	dark vegetation strip in straight valley
198	84	dark vegetation strip in straight valley
199	84	stream + boundary of topographically high area
200	84	wide dark vegetation strip
201	84	unexplained
202	84	dark vegetation strip
203	84	stream valley with dark vegetation
204	84	stream valley
205	84	stream + low areas with darker vegetation
206	84	stream valley
207	84	stream valley
208	84	stream + lake + stream
209	84	stream valley + unexplained
210	84	dark vegetation strip
211	84,100	valley + lake + road
212	83	stream + small lake
213	83	unexplained
214	83	straight valley
215	83	road + straight valley
217	83	unexplained
218	83	unexplained
219	83	stream valley + lake shoreline
220	83	lake shoreline + edge of topographic high
221	83	streams
222	83	parallels lithology

Ident. #	Index Sheet #	Remarks
223	83	lake shore + unexplained
224	83	stream valley
225	83	stream; appears to parallel lithology
226	83	stream, appears to parallel lithology
227	83	parallels lithology
228	83	parallels lithology
229	83	stream
230	82	unexplained
231	82	stream + unexplained + stream
232	81,82	curvalinear - portions of a number of streams
233	82	road + railroad
234	82	stream valley + unexplained. Location only approximate
235	82	unexplained
236	82,97	valley-unexplained
237	81	unexplained
238	81	unexplained
239	81	stream
240	81	stream + unexplained + stream
241	81	stream
242	81	stream
243	81	stream + unexplained + stream
244	81	unexplained
245	81	unexplained
246	81	streams
247	81	low areas with dark vegetation

Ident. #	Index Sheet #	Remarks
248	81	stream
249	81	stream valley + unexplained
250	81	dark vegetation patches + unexplained
251	81	dark vegetation patches + stream valley
252	81	stream
253	81	stream
254	81	stream
255	81	dark vegetation strip
256	80,81,96	stream valley + margin of cultural areas + stream
257	96	several streams
258	96	"cuesta" ridge of northern Adirondacks; not visable on index
259	97	several ridges; probably lithologically controlled
260	97	stream
261	97	stream + unexplained + stream
262	97	stream
263	97	stream
264	98	stream
265	98	low area with dark vegetation
266	98	unexplained
267	98	dark vegetation strip
268	98	southern 3/4 is stream; northern 1/4 is unexplained
269	98	unexplained
270	99	vegetation border
271	99	unexplained
272	99	vegetation border

Ident. #	Index Sheet #	Remarks
273	99	unexplained
274	99	unexplained
275	99	unexplained
276	99	stream
277	99	unexplained
278	99	stream + unexplained
279	99	stream + unexplained
280	99	small stream
281	99	stream
282	99	stream
283	99	unexplained + stream
284	99	stream + lakes
285	99	stream
286	99	stream
287	99	stream + unexplained
288	99	stream + lake
289	99	unexplained
290	99	stream + unexplained ridge
291	99	low area with dark vegetation between two ridges
292	99	unexplained ridge
293	99	unexplained
294	99, 116	dark vegetation strip in sharp valley
295	100	stream
296	100	unexplained
297	100	stream valley

Ident. #	Index Sheet #	Remarks
298	100	stream + unexplained
299	100,117	stream
300	100,117	ridge top
301	100	stream
302	100,101	stream
303	100	stream + unexplained
304	101	stream + unexplained
305	101	stream + unexplained
306	101	dark vegetation strips in two aligned valleys
307	101	dark vegetation areas around stream
308	101	stream + lake + margin of dark vegetation areas
309	101	stream + unexplained
310	101	stream valley with dark vegetation
311	101	stream
312	101	stream + valley with dark vegetation
313	102	straight stream valley with dark vegetation
314	102	stream
316	102	stream
317	102	stream
318	102	straight stream
319	102	stream + unexplained
320	101,102	stream
321	102	dark vegetation strip
322	102	dark vegetation strip
323	102	dark vegetation strip

Ident. #	Index Sheet #	Remarks
324	102	stream
325	102	dark vegetation strip
326	103	stream + unexplained
327	103	dark vegetation strip
328	103	stream
329	103	stream
330	114	irregular dark vegetation strip
331	97,114	dark vegetation + unexplained + dark vegetation
332	114	dark vegetation strip
333	114	stream + unexplained + stream
334	114	stream
335	114,116	stream
336	114,115	unexplained
337	115	unexplained + lake
338	115	unexplained
339	115	unexplained
340	115	unexplained
341	115	stream + unexplained
342	115	unexplained
343	115	unexplained
344	115	stream + dark vegetation patch
345	115	dark vegetation area around topographic high
346	115	unexplained
347	115	stream + unexplained
348	115	ridge with lithologic control

Ident. #	Index Sheet #	Remarks
350	115	unexplained + stream + unexplained
351	115,116	unexplained + stream
352	115,116	stream + stream
353	116	unexplained
354	116	stream
355	116	two stream valleys
356	116	stream valley
357	116	short straight stream
358	117	lake + stream
359	117	lake + stream + dark vegetation area
360	117	stream + unexplained
361	118	unexplained
362	118	unexplained + lake + unexplained
363	118	stream + unexplained
364	118	unexplained
365	118	stream + dark vegetation area
366	118	winding stream + canal
367	118	stream + unexplained
368	119	stream + unexplained
369	119	unexplained
370	119	canal + unexplained
371	67,81,82 97,113	stream + unexplained + dark vegetation areas
372	81,97	edge of topographic high + lake
373	117	road + lake
374	100	stream
375	85	stream

Ident. #	Index Sheet #	Remarks
376	85	stream
377	85	dark vegetation strip
378	85	stream
379	82	stream + dark vegetation area
380	70	road + topographic high
381	70	parallel lithology
382	56	parallel lithology
383	56	parallel lithology
384	65	combination of stream and vegetation borders
385	65,66	dark vegetation border
386	65	dark vegetation border
387	65	dark vegetation border
388	65	dark vegetation border
389	67	stream valley
390	55,67 68	parallel lithology + transmission line + stream valley
391	68	dark vegetation area + stream valley
392	69	parallels lithology + dark vegetation area
393	69,56	Beaver River
394	54	stream
395	54	parallels lithology + stream + lake
396	54	parallels lithology
397	54,55	parallels lithology
398	55	dark vegetation strip in stream valley
399	53	stream + parallels lithology
400	55	stream + parallels lithology

Ident. #	Index Sheet #	Remarks
401	55	transmission lines
402	55	railroad + stream
403	55.56	river + dark vegetation area
404	55	stream + dark vegetation area
405	56	unexplained
406	42,43	parallels lithology
407	43	stream + unexplained
408	42,43	road
409	43,43	unexplained
410	43	stream + road
411	43	road
412	43	unexplained
413	43	unexplained
414	43,44	railroad + dark vegetation strip
415	44	stream + dark vegetation strip
416	44	stream + unexplained
417	44	stream + unexplained
418		unassigned number
419	66	unexplained
420	70	stream
421	70	stream + unexplained (half & half)
422	84	stream with dark vegetation strip
423	83,82	stream
424	69	stream with dark vegetation strip
425	83	unexplained + stream + dark vegetation strip

Ident. #	Index Sheet #	Remarks
426	83	lake + stream
427	86	small stream valley
428	87	stream
429	71	stream + lake
430	72	dark vegetation strip which parallels lithology
431	85	stream
432	85	dark vegetation strip
433	85	unexplained
434	72	dark vegetation strip which parallels lithology
435	72	dark vegetation strip which parallels lithology
436	71	parallels lithology

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