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ABSTRACT

OS-17-SSEL Technical Report 16-75

PHOTOINTERPRETATION OF SKYLAB PHOTOGRAPHY

H. W. Weeden, C. Kleeman, S. Daelhausen, and G. Hesler

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Skylab scenes from three areas in Pennsylvania were studied. Photography from the S190A and S190B sensors were first compared. It was found that major drainage, ridges, and limestone quarries (with verification from aircraft photography) were visible on all of the photography. With the exception of S190A stations 1 and 2 (0.7 to 0.8 and 0.8 to 0.9  $\mu$ m, respectively), forests versus agricultural land; second order drainage; color/tone variations in water bodies due to silt; and major cultural features, such as railroad rights-of-way, large industrial buildings, and roads (some with verification from aircraft photography) were seen on all the photography. S190A stations 1 and 2 photographs were useful primarily for identification of water bodies and major gaps in the ridges.

The S190B photography, which was identified in the above analysis as clearly superior to any of the S190A photography, was then studied for terrain features. The following identifications were successfully made:

1. relief differences of 600 to 800 feet (rarely features of lower relief),
2. regional geologic features and regional strike and dip,
3. wind and water gaps and drainage above second order (changes in drainage density were important indicators of geology),
4. forest vegetation versus patterns of fields (individual crops could not be identified),
5. soil associations on the level of the soil association maps prepared by the Soil Conservation Service,
6. urban versus suburban and industrial versus agricultural land uses,
7. utility and railroad rights-of-way, quarries, and large industrial buildings (occasionally concrete highways could be differentiated from asphalt), and
8. silted versus clear water in rivers and lakes.

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Interim Report

ORSER-SSEL Technical Report 16-75

PHOTOINTERPRETATION OF SKYLAB PHOTOGRAPHY\*

H. A. Weeden, C. Kleeman, S. Daelhausen, and G. Hesler

Skylab EREP Investigation 475  
Contract Number NAS 9-13406

INTERDISCIPLINARY APPLICATIONS AND INTERPRETATIONS OF EREP DATA  
WITHIN THE SUSQUEHANNA RIVER BASIN

Resource Inventory, Land Use, and Pollution

Office for Remote Sensing of Earth Resources (ORSER)  
Space Science and Engineering Laboratory (SSEL)  
Room 219 Electrical Engineering West  
The Pennsylvania State University  
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Principal Investigators:

Dr. George J. McMurtry  
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Date: August 1975

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\* User Identified Significant Results

## PHOTOINTERPRETATION OF SKYLAB PHOTOGRAPHY

H. A. Weeden, C. Kleeman, S. Daelhousen, and G. Hesler

This study was undertaken to determine the limits of refinement within which landscape units could be identified from Skylab photography. The project was approached from an engineering (practical) point of view. The area of interest was the Susquehanna River Basin within the State of Pennsylvania, for which ORSER had received various photographic forms of data from the S190A and S190B sensors onboard Skylab, collected on the third (SL3) and fourth (SL4) missions.

Initially, all the photographic forms available in the ORSER laboratories for this area were reviewed. Selected scenes from these were then compared, in order to determine the sensor/film/filter combination best suited for photointerpretive analysis. Three scenes, representing several different physiographic sections and two seasons in Pennsylvania, were then studied, using the photographic format previously chosen to be the most promising for analysis.

### METHOD OF INVESTIGATION

Skylab photography, taken at an altitude of approximately 270 miles, was analyzed here using techniques for aerial photography interpretation developed for civil engineering purposes. These techniques are described in detail in ORSER-SSEL Technical Report 17-75 (Weeden, 1975). The data, methods, and results of this particular study are described below.

#### Sensor and Film/Filter Characteristics

##### Skylab

Two cameras, the S190A and the S190B, provided the photographic transparencies studied in this investigation. Table 1 lists the major characteristics of these two camera systems. The S190A, a multispectral photographic camera, consisted of a bank of lens stations which simultaneously recorded six frames within specified bandwidths of the photographic spectrum. Two infrared black and white, two panchromatic black and white, one infrared color, and one high resolution color positive photograph were simultaneously exposed at each photo position. The S190B photography consisted of one high resolution color positive transparency for each frame of study. A summary of the camera, accessory, and film package characteristics appears in Table 2. Technical data on the individual films can be found in Table 3.

##### Aircraft

Aircraft photography was used to re-evaluate Skylab photography, after an initial study of the Skylab photography had been made without such aid. Evaluations were made of specific aircraft underflight scenes covering selected portions of each Skylab test site. A summary of the aircraft data used, by scene location, is provided in Table 4.

Table 1: Skylab Camera Characteristics

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S190A

Multispectral photographic camera

Six f/2.8 lenses with 6 inch focal length

101 x 101 statute mile field of view

Original film size: 70 x 70 mm, with 2.5 x 2.5 inch  
format

Original scale: 1:3,000,000

Scale of 9 x 9 inch enlargements: 1:690,000

S190B

Earth terrain camera

A single f/4 lens with 18 inch focal length

69 x 69 statute mile field of view

Original film size: 5 x 5 inches with 4.5 x 4.5 inch  
format

Original scale: 1:920,000

Scale of 9 x 9 inch enlargements: 1:500,000

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Table 2: Skylab Film/Filter Characteristics

Sensor	Camera Station	Film Package	Bandwidth with filter ( $\mu\text{m}$ )	Approximate Color Range	Resolution (Feet)
S190A	1	IR Aerographic B&W EK-2424	0.7-0.8	Red to near IR	210
	2	Same as above	0.8-0.9	Near IR	230
	3	Aerochrome IR Color EK-2443	0.5-0.88	Green to near IR	200
	4	Aerial Color SO-356	0.4-0.7	Blue to red	120
	5	Pan-X Aerial B&W SO-022	0.6-0.7	Orange to red	100
	6	Same as above	0.5-0.6	Green	100
S190B		Aerial Color SO-242	0.5-0.9	Blue to red	60

#### Location of Study Areas

The Susquehanna River Basin is located in the central portion of Pennsylvania, bounded approximately by longitude  $75^{\circ} 45' \text{W}$  and  $78^{\circ} 30' \text{W}$ . As seen on Figure 1, nearly complete Skylab coverage of this area was available from the combined data sources of SL3 and SL4. Orbit 44 of SL3 and orbit 73 of SL4 provided the best coverage and are the only orbits referred to in the remainder of this report. Unfortunately, seasonal variability of the data sources limited the degree of comparison possible between SL3 and SL4 photography; however, it permitted assessment of seasonal advantages or disadvantages. NASA U2 and C130 seasonal aircraft underflight photography was available for limited regions covered by the Skylab photography.

Within the coverage limits of SL3 and SL4, specific test sites were selected to evaluate the interpretive potential of the Skylab photography (Figure 2). These sites, well documented in the available literature, are representative of several Pennsylvania physiographic regions. They are located in central and south-central Pennsylvania and are identified herein by the local prominent cultural feature of the area. The sites are centered around Sayers Dam in Clinton County; the Harrisburg area in Dauphin, Perry, York, and Cumberland Counties; and the Reading area in Berks County. Study guides, consisting of ground-truth information on each area, were prepared from the literature.

Table 3: Skylab Film Descriptions

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S190A FilmsKodak Infrared Aerographic Black and White, EK2424

- Sensitive from ultraviolet to infrared (0.9 $\mu$ m)
- Maximum sensitivity from 0.76 to 0.88 $\mu$ m
- Suited well for haze effects

Kodak Aerochrome Infrared Color, EK2443

- A "false color" film for infrared discrimination
- False color films differ from conventional films in that three layers are sensitized to green, red, and infrared radiation rather than to blue, green, and red.
- When used with yellow filter, as in the S190A:
  - Green appears Blue
  - Red appears Green
  - IR appears Red

Kodak Aerial Color, SO-356

- A Kodak special order color reversal film
- High resolution
- High contrast
- Good color separation

Kodak Panchromatic-X Aerial Black and White, SO-022

- Panchromatic negative camera film
- Intermediate speed
- High contrast
- Very high resolution
- Extended red sensitivity

S190B FilmKodak Aerial Color, SO-242 (High Definition)

- A daylight balanced color reversal film
  - High contrast
  - Good color saturation characteristics
  - Extremely fine grain
  - High resolving power and definition
-



Table 4: Aircraft Data Used\*

Test Sites:	Sayers Dam	Harrisburg	Reading
Aircraft:	U2	C130	C130
Mission:	74-060A	74-016	74-016
Flight Line:	--	--	--
Roll No:			
Color IR:	17	23	23
Color Pos:	--	--	--
Frame Nos:			
Color IR	8097-8098	6052-6057 6090-6093	5987-5990
Color Pos:	--	--	--
Date (1974):	Apr 25	Feb 5	Feb 5
Scale:	1:130,000	1:130,000	1:130,000
		1:31,200	1:20,760

\* All frames were in 9 x 9 inch format.





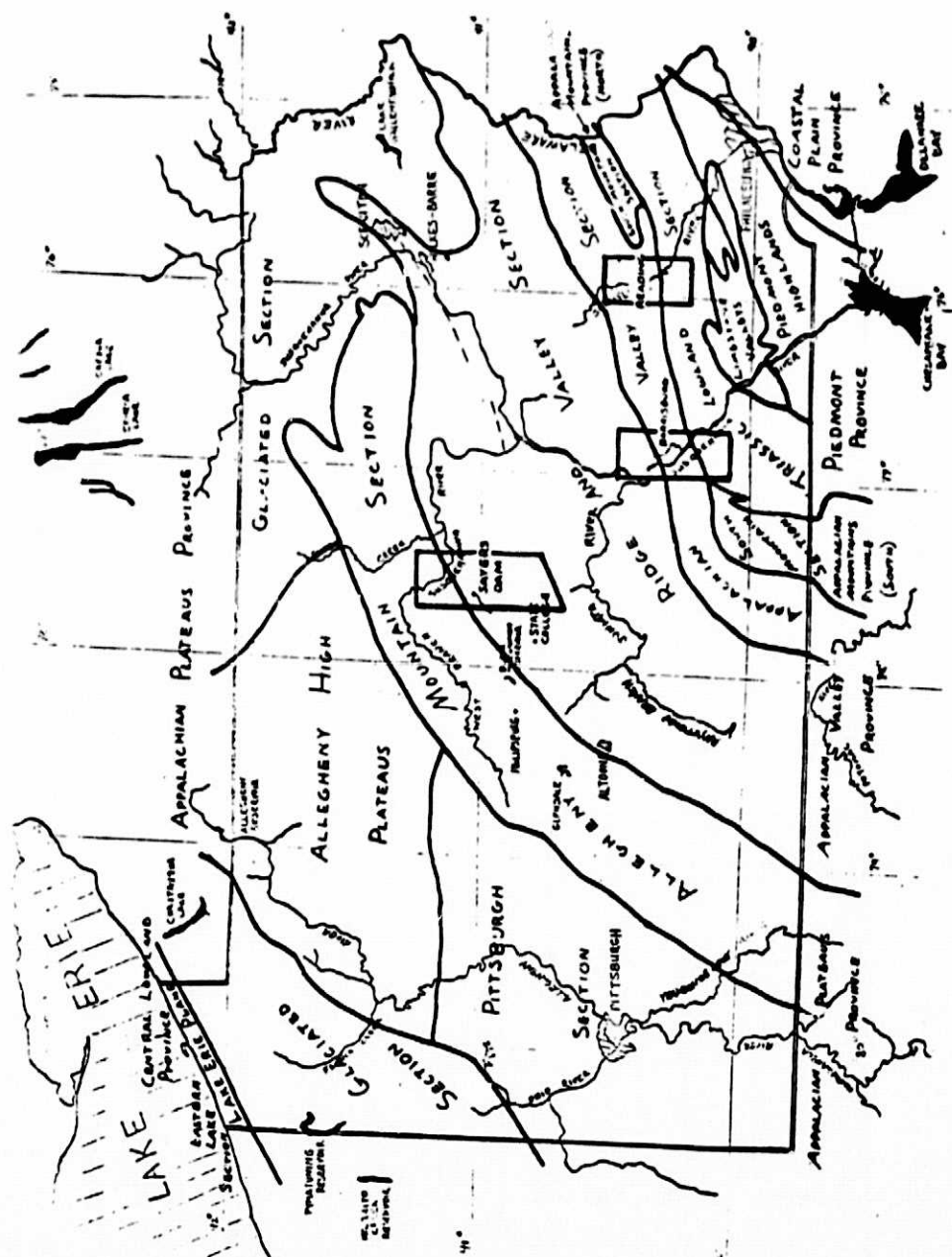


Figure 2: Physiographic map of Pennsylvania showing the three test areas.

### Study Techniques

The evaluation of Skylab scenes was performed by two graduate students and one undergraduate senior in Civil Engineering, under the supervision of a professor in that department. The work was accomplished in the ORSER laboratory. The analysts performed their first look using black and white film on a light table with the Old Delft Scanning Stereoscope at magnifications of 1.5X and 4.5X. This was the observing tool to which they could best adapt for obtaining a stereoscopic model.

It became apparent quite early that the interpretation of Skylab photography would be heavily dependent upon detailed drainage delineation. This was attempted using: 1) a high quality overhead projector, 2) a Bausch and Lomb Zoom Transferscope (ZTS), and 3) the Old Delft scanning stereoscope. After some initial trials, the method adopted was a combination of methods 2 and 3, that is, mapping using the ZTS with verification from the stereo model of the Old Delft. Although a Bausch and Lomb Zoom 95 stereoscope was available, the students found it difficult to adjust because it was not mounted on an X-Y stage<sup>1</sup>.

An effective method of analysis requires that the analyst should map slope breaks as well as drainage. Each interpreter established his own degree of accuracy in mapping these two features. A systematic approach was developed which centered around the use of a data form designed by the group. This form was filled out for each Skylab and aircraft scene studied. A sample of such a form appears as Figure 3.

### Skylab Photography Evaluation

The six S190A photographs and the one S190B photograph (plus adjacent frames for stereo viewing) were studied for each test site. A series of photo-elements were chosen for analysis (e.g., slope breaks, street patterns, railroad rights-of-way, etc.) and it was determined whether each of these was visible on a particular photograph. A data sheet, such as that shown in Figure 3, was compiled for each photograph, and the results of these individual photo-studies were later compiled. The area study guides and aircraft photography were used as source material, where necessary, to verify the identity of smaller features.

### Terrain Analysis for the Three Test Sites

After the initial analysis of the films available, each of the three students chose a scene from the S190B sensor, determined to be the most promising film format, for evaluation of his test area. Standard techniques for aerial photointerpretation developed for civil engineering purposes (Weeden, 1975) were used to analyze the photographs.

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<sup>1</sup>ORSER has recently acquired an X-Y mounting for the Zoom 95, and it is anticipated that it will be the preferred instrument for further studies of this nature.

<u>Mission</u>	<u>SL-3</u>	<u>Sensor:</u>	<u>SL90A</u>
<u>Roll No.:</u>	<u>48</u>	<u>Film Type:</u>	<u>SO-022 Pan-X B&amp;W</u>
<u>Frame No.:</u>	<u>29,30,31</u>	<u>Bandwidth, <math>\mu</math>m:</u>	<u>0.5-0.6</u>
<u>Orbit No.:</u>	<u>44</u>	<u>Filter Type:</u>	<u>AA</u>
<u>Location:</u>	<u>Harrisburg</u>	<u>Camera Station:</u>	<u>6</u>
<u>Date:</u>	<u>9-16-73</u>	<u>Transparency Size:</u>	<u>9 x 9</u>
		<u>Original Size:</u>	<u>70 mm.</u>

General Quality: Fair to Good; less contrast and detail than on Roll 47.

Smallest Identifiable Units: Highways, bridges, interchanges, islands in Susquehanna River, some individual farm fields.

<u>ANTICIPATED FEATURES</u>	<u>OBSERVED FEATURES &amp; COMMENTS</u>
1. Major folding of Appalachian Ridges.	1. Sandstone ridges and slope breaks visible. Sandstone-to-shale slope breaks visible from vegetative change. Less contrast between woodlands and lowlands.
2. Major Drainage.	2. Tonal variations in Susquehanna River present. All other major creeks visible.
3. Minor Drainage.	3. Dendritic tributaries to Swatara, Paxton, and Conodoguinet Creeks present. All minor drainage less visible than on Roll 47.
4. Great Valley rolling hills topography.	4. Visible but much less so than Roll 47.
5. Mountains of Triassic Lowland.	5. Visible from their vegetative cover.
6. Great Valley carbonates.	6. Visible only from the absence of drainage.
7. Little Mountain water gaps.	7. Little Mountain water gaps not visible.

Figure 3: Sample Skylab photoanalysis data sheet.

The photographs were initially examined to determine the level of refinement possible for identifying detail without assistance from aircraft photography or other ground truth information. This was accomplished by delineating the details of drainage, slope breaks, vegetation, culture, and soils.

The Skylab S190B photography was then re-evaluated on the basis of details observed on the aircraft underflight photography and from information obtained from the study guides. In this way the level of maximum refinement possible in the interpretation from Skylab photography was determined.

## RESULTS

### Sensor/Film/Filter Analysis

The results of the comparison of the various Skylab film formats from the three test areas were closely similar. In Table 5, each of the seven sensor/film/filter combinations is related to a series of terrain-related features. In the discussion below, each of the formats are described.<sup>2</sup>

#### S190A, Sta. 1, B&W IR (0.7-0.8 $\mu$ m)

This photography appears at first to be of little value in terrain studies, as elements of fine detail, such as cultural and farm features, are not at all visible. However, this photography is excellent for the location of major streams, rivers, and reservoirs, which are usually difficult to spot amid the abundant vegetative, farm, and cultural features found on other Skylab photography. However, as this film appears to be sensitive to water surfaces, rather than vegetation, it is extremely difficult to locate first or second order drainage, such as small streams, creeks, and gullies, which are usually spotted by their accompanying vegetation. Braiding features in the Susquehanna River are prominent in this photography. Water and wind gaps are visible, whereas they are not easily seen in other Skylab photography. Limestone quarries appear as very dark spots and can be confirmed from underflight photography.

#### S190A, Sta. 2, B&W IR (0.8-0.9 $\mu$ m)

This film package differs from that of Station 1 only in the filter sensitivity. Its value for analyzing terrain features is basically the same as that described under Station 1, although many of the terrain features used for comparison are slightly more visible. Water and wind gaps can be seen most readily in this photography.

<sup>2</sup>Prepared by Kleeman from the Harrisburg area scenes. Results from the other two scenes were closely similar.

Table 5: Evaluation of Skylab Sensor Systems

	SL90A Sta 1 B&W IR	SL90A Sta 2 B&W IR	SL90A Sta 3 Color IR	SL90A Sta 4 Color Pos	SL90A Sta 5 B&W Pan-X	SL90A Sta 6 B&W Pan-X	SL90B Color Pos
Grain Texture:	coarse	medium	medium	fine	fine	medium	fine
Drainage:							
1st & 2nd order	no	no	no	no	yes	no	yes
3rd order & up	yes	yes	yes	yes	yes	yes	yes
Geology:							
500-800 ft relief	no	no	yes	yes	yes	no	yes
Strike & dip	no	no	yes	yes	yes	yes	yes
Water gaps	yes(N.C.) <sup>1</sup>	yes(N.C.)	yes(N.C.)	yes	yes	yes	yes
Slope breaks	no	no	no	no	no	no	no
Cultural Features:							
City street patterns	no	no	no	yes	yes(3) no(4) <sup>2</sup>	no(3) yes(4)	yes
Utility right-of-way	yes(N.C.)	yes(N.C.)	yes(N.C.)	yes	yes	yes	yes
RR right-of-way	no	no	no	yes	no	no	yes
Highways & bridges	no	no	yes(N.C.)	yes	yes	yes	yes
Airports	no	no	yes	yes	yes	yes	yes
Agricultural Practices	yes(N.C.)	yes(N.C.)	yes	yes	yes	yes	yes
Quarrying	yes(3)	yes	no	yes	no	no	yes
	no(4)	no	yes	no	yes	yes	yes
Large Industrial Bldgs.	no	no	yes(N.C.)	yes	yes	yes	yes
Tonal Variations:							
Water turbidity <sup>3</sup>	no	no	yes	yes	yes	yes	yes
Forest vs. cleared land	no	no	yes	yes	yes	yes	yes
Soils	no	no	no	no	no	no	no

<sup>1</sup>N.C. - Not Clear; <sup>2</sup>(3)-SL3 (4)-SL4; <sup>3</sup>None in Sayers Dam area.



S190A, Sta. 3, Color IR (0.5-0.88um)

The largest contrast between wooded and cultivated land can be seen in this photography. Minor drainage (second order) can only be identified from accompanying vegetation. The resolution of this photography is poor, and the film is grainy. The presence of slight color variations and streaking in parts of the Great Valley may indicate carbonate material. Some very distinct variations in the color of the Susquehanna River over most of its length are seen. This was seen, to a lesser extent, as tonal variations in the black and white photography. The sandstone ridges and Triassic igneous intrusions appear in sharp contrast to the lowlands and valleys, probably due to this film's sensitivity to vegetation. Quarries can be located, particularly after identifying them on underflight photography.

S190A, Sta. 4, Color Pos. (0.4-0.7um)

This photography may be the most useful of the S190A photographic packages. It is a fine grained film which exhibits very good detail. It is sensitive to farming practice and valley features, and highly sensitive to vegetation. This color positive photography is much sharper in detail than the IR color photography, particularly with respect to valley features and farmland detail. Color variations and streaking provide an indication of the underlying material in the Great Valley as do quarries and drainage patterns, which indicate structural and/or stratigraphic control. Color variations in the Susquehanna River are easily seen. The Appalachian Mountain ridges and the Triassic igneous intrusions stand out sharply. Nothing present in this photography serves to identify distinct soil types or characteristics, although moisture content as a function of proximity to drainage is occasionally indicated.

S190A, Sta. 5, B&W Pan X (0.6-0.7um)

This photography is by far the best black and white coverage of the Skylab package. It is a very fine grained film, providing excellent detail. Both major and minor drainage are distinctly seen, including smaller streams and creeks; although first order drainage cannot be reliably identified. Valley streams and related features stand out well. The photography is sensitive to vegetation, farm, and cultural features. However, water and wind gaps are not visible. The sensitivity of this film to minor drainage patterns lends much to the analysis of the underlying material. Unlike Station 1 and Station 2 photography, which showed the sandstone ridges of the Appalachian mountains but not the ridges and knobs of the Triassic igneous intrusions, this photography shows both features in fine detail. These features are enhanced both by relief and by forest vegetation. The detail of farm and cultural practices in this photography obscures tonal variations which might provide clues to the underlying soil or rock material.

SI90A, Sta. 6, B&W Pan X (0.5-0.6 $\mu$ m)

This photography was probably the most disappointing of all the Skylab photography for the purposes of this study. Nearly every terrain feature compared was either less visible or of poorer quality in the Station 6 photography than its counterpart in the Station 5 photography. Only the contrast between wooded and cultivated land seemed to be somewhat better. (It is known that there was some degree of camera malfunction at Station 6 prior to exposure.)

SI90B, Color Pos. (0.5-0.9 $\mu$ m)

A few minutes spent in examining Table 5 will lead one to the immediate conclusion that the SI90B color photograph is unquestionably the best of the seven film combinations considered. Its resolution is far better than any of the SI90A photographic systems. The detail of valley features is excellent. Major and minor drainage patterns are clearly shown, down to second and sometimes first order drainage. Mountain ridges appear in sharp contrast to lowlands and valleys. There is excellent overall contrast and excellent color separation. Street patterns, buildings, warehouses, factories, and similar structures can be distinguished. A few quarries near Hershey can be identified without the aid of underflight photography. The color variations in the Susquehanna River are also visible. Determinations of soil types at this scale, however, is still very unlikely.

Terrain Analysis Using SI90B Photography

Each test site was studied by an individual student, using SI90B photography. After a description of the site -- obtained from the literature -- the results of the photographic study are summarized.

Harrisburg Area<sup>3</sup>

The Harrisburg study area is located in the south-central portion of Pennsylvania, including portions of Perry, Dauphin, Cumberland, and York Counties. Portions of the Ridge and Valley, the Appalachian Valley, and the Triassic Lowland Sections are represented within the area (See Figure 2). Elevations vary from 400 to 1300 feet. Slopes vary from level to steeply sloping, and the terrain is well drained, with the exception of a few low lying areas and associated streams. The bedrock geology is dominantly sedimentary. In the Ridge and Valley Section the sandstones, shales, and limestones are folded into a major syncline cut by the Susquehanna River. In the Appalachian Valley (the Great Valley), the rocks are generally flat lying shale, limestone and sandstone. The sedimentary rocks of the Triassic Lowland are also relatively flat-lying, with knobs and ridges consisting of igneous basaltic rock. Trellis drainage dominates in the Ridge and Valley Section, whereas dendritic drainage, at times subsurface, characterizes the Appalachian Valley and the Triassic Lowland Sections. Woodlands dominate the rocky ridges, while farmlands in grazing, grains, or fruits are found in the valleys. Much of this farmland is rapidly being replaced by urban and industrial development surrounding cities such as Harrisburg and York.

<sup>3</sup>Studied by Charles Kleeman.

Frame 67 from Roll 88 of Sensor SL90B, SL3, Orbit 44, was chosen for study of the Harrisburg area. The photography was taken in September. The results of this study are described below, and a few features seen on the CL30 photography and the Skylab photography are compared in Table 6.

Landforms and Geology. The sandstone ridges of the Ridge and Valley Section, and the resistant rocks of the Triassic Lowlands, representing relief differences of 700 to 800 feet, are distinct. The rounded hills of the Martinsburg shale cannot be discerned, nor can this shale be differentiated from the limestones of the valleys. Regional strike and dip can be determined in the case of the sandstone ridges.

Drainage and Erosion. A large change in drainage density reflects the underlying geology. On the basis of drainage density, an approximate boundary can be drawn separating the Martinsburg shales from the limestones to the south and the sandstone ridges to the north. All first and most second order drainage cannot be discerned; however, all third and higher orders are easily traced. Large scale erosional features, such as water gaps, are easily identified. First order gully erosion is not visible at the small scale of the Skylab photography.

Color-Tone-Texture. Color, tone, and texture patterns at the Skylab scale do not provide clues for differentiating soils or bedrock in the Harrisburg area. The patterns do assist in classifying general vegetation features. The heavily forested regions reflect a much darker tone than the surrounding developed land. A noticeable tonal variation is seen in the Susquehanna River, most likely caused by increased turbidity resulting from the 4.3 inches of rain which fell over a two-day period prior to the Skylab orbit. It is possible, on occasion, to differentiate between concrete and asphalt highways, from the lighter tone reflected by the concrete.

Vegetation. The tonal contrast between major vegetation types was a prime indicator of slope breaks, drainage, and lithologic formations, in that darker tones were reflected from forested regions and lighter tones indicated other land use areas. Second order streams, which could not be seen in themselves, were sometimes traced out by the aid of vegetation along their courses. Forested areas indicated land which was excessively steep and stony, or where the soil was poor. Using such indicators, it is possible to roughly separate topographic features and to map the igneous rock areas in the Triassic Lowland Section. Agricultural field patterns are clearly seen on this September photography, but it is not possible to discriminate between crops because of the low resolution of this small scale photography.

Cultural features. Urban areas and suburban areas were readily distinguished on the basis of street pattern density. Agricultural areas were easily identified by the field patterns. Limestone quarries are identifiable with the assistance of aerial underflight photography; in a few cases, of quarries several thousand feet in length, some relief could be detected.

Table 6: Comparison of Skylab S190B Photography of the Harrisburg Area with Aircraft Photography of the Same Area

<u>Cl30 Aircraft Mission 271</u> <u>Photography</u>	<u>Skylab S190B Photography</u>
Paxton Creek visible to Wildwood Lake and through Harrisburg until it joins the Susquehanna River.	Paxton Creek visible only to Wildwood Lake --not at all through the city of Harrisburg.
Minor streams -- Spring Run and Hogestown Run -- visible to the Conodoguinet from the south.	Minor streams -- Spring Run and Hogestown Run -- visible, but due only to vegetation along them.
Well dissected hills visible rising to 500 ft just north of Steelton and just south of Harrisburg terrace.	Hills just north of Steelton are not visible. Only indication is drainage in that area.
Deep-cutting Spring Creek and other short running streams visible dissecting the hills above Steelton.	Spring Creek and other parallel streams are visible mainly from vegetation on the stream banks.
A terrace of glacial outwash along the Susquehanna River on which Harrisburg is built is visible.	Harrisburg terrace visible from relief and city street and building patterns.
Elevated hills rising 100 ft above stream level between meanders of Conodoguinet Creek indicate shale joint control.	100 ft relief not visible between meanders of Conodoguinet Creek.
Hilly terrain typical of Great Valley south of railroad at Rutherford Heights is visible.	Hilly relief south of railroad at Rutherford Heights not visible.
Grid-type pattern of minor (1st and 2nd order) drainage on Spring Creek above I-83 in Harrisburg is visible.	1st order drainage not visible; 2nd order drainage visible in some parts.
Grid-type pattern of minor (1st and 2nd order) drainage and topography just south of the Conodoguinet near the Susquehanna River is visible.	1st order drainage not visible; some 2nd order drainage visible. Relief not visible.

(continued)

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Table 6 (continued)

<u>C130 Aircraft Mission 271</u> <u>Photography</u>	<u>Skylab S190B Photography</u>
Bethlehem Steel quarries and slag pits at Steelton on east bank of Susquehanna River visible.	Relief visible in larger quarries. Slag pits visible after locating on C130 photography.
Water filled quarries at I-83 in Harrisburg and NE of Hershey visible.	Both sets of quarries visible with aid of C130 photography.
Nuclear reactor and cooling towers at Three Mile Island power generating facility visible.	Nuclear reactor building and four cooling towers visible.
Farmland and plowed fields in the Great Valley visible.	Individual plowed fields and cultivated fields visible.

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Soils. Soil associations could only be identified on a regional basis, and no sharp boundary could be drawn separating soil associations. It is believed that the reddish tonal variation observed in the Great Valley area reflects the underlying limestone.

#### Sayers Dam Area<sup>\*</sup>

The Sayers Dam study area is located in the center of Pennsylvania and includes portions of Centre and Clinton counties (see Figure 2). Portions of the Ridge and Valley and the Allegheny Mountain Sections are represented within the area. Elevations vary from 550 to 2,200 feet. In the three broad valleys traversing this region the slopes are gentle to moderate, whereas they are moderate to very steep in the mountains. The bedrock, which is entirely sedimentary, varies from nearly horizontal in the Allegheny Mountain Section to tilted and folded in the Ridge and Valley Section. Sandstones form the higher elevations of the mountains, while limestones and dolomites (with some shales) are the dominant feature of the valleys. Sinkholes and limestone quarries are common valley features. In areas of surface drainage, the streams exhibit a trellis pattern. Locally, the groundwater table is seasonably high; evidence of this is seen as a mottled soil pattern on aerial photographs. Trees, originally covering the area, are now limited to steep and stony mountain slopes and valley regions of soil too poor for cultivation or urban development.

Frame 324 from Roll 91 of Sensor S190B, SL4 Orbit 73, was chosen for study of the Sayers Dam area. There is a light snow cover on this January scene. The results of this study are described below.

Landforms and Geology. The landforms are detectable on a regional basis only. They can be related to the underlying geology, but no sharp boundary line can be drawn separating them. In the stereoscopic model of the area, the resistant sandstone formations of the Ridge and Valley Section (where greater than approximately 800 ft in relief) stand out. However, no detectable slope break can be observed between the ridges and the valleys. Relief features of a lesser order of magnitude than the sandstone ridges can be observed in the dissected shale hills of the Allegheny Front. Effective shadows, produced by the combination of the low sun angle and topographic relief, assisted in differentiating the shale hills. Separation of individual members within the shale formation was not possible. A detectable break in terrain is seen separating the Catskill formation from the Chemung-Portage shale formations and the Pocono sandstone.

Drainage and Erosion. Although relief features separating the Pocono from the Pottsville sandstone formations of the Allegheny Mountain Section cannot be seen, as the slope differences are not readable at the Skylab scale, the separation of lithologies, from the Pocono and Pottsville sandstones through the Catskill formation and to the shales, is made possible by the noticeable change of the surface

<sup>\*</sup>Studied by Scott Daelhausen.



drainage patterns, reflecting the change in the underlying bedrock. The Juniata formation, separating the Tuscarora and Oswego formations, is identifiable; however, no sharp erosional boundary is discernible. Large-scale erosion features, such as water and wind gaps, are easily seen. First order drainage gullies cannot be seen at this scale. One minor erosional feature was observed. The Catskill formation is believed to be exposed along the slopes north of the West Branch of the Susquehanna River. The south-facing slopes permit early snow melt, exposing the Catskill formation underlying the Pocono and Pottsville sandstones. An example of this may be seen in the vicinity of North Bend and Renovo.

Color-Tone-Texture. Color, tonal, and textural patterns, which provide valuable assistance in detecting and identifying geological features on aircraft photography, are almost completely obscured on winter Skylab photography of the Sayers Dam area due to the 3 to 4 inches of snow on the ground. Only the Catskill formation, described above, is revealed by a reddish color on the photograph.

Vegetation. In January the vegetation is dormant; however, a sharp tonal contrast between forested and other land use categories was provided by the light snow cover in this scene. Forested regions (darker in tone) indicate areas of poor soils or steep terrain, and thus are a clue to the underlying geology. The Gatesburg formation, defining an area of scrub oak known as "the Barrens," is easily identified as a forested area in the center of Nittany Valley. The snow cover prevented significant identification of agricultural vegetation.

Cultural features. Urban areas are easily separated from surrounding land uses. The street patterns in the medium sized towns of State College, Bellefonte, and Lock Haven are identifiable. Snow cover prevented identification of agricultural field patterns. Major highways can be seen when not obscured by snow. Railroad rights-of-way, large industrial buildings, and limestone quarries can be identified with the aid of aircraft underflight photography.

Soils. The snow cover at this time of year prevents identification of soil associations.

#### Reading Area<sup>5</sup>

The Reading area is located in the southwestern portion of Berks County. It includes parts of the Appalachian Valley and the Triassic Lowland Sections (see Figure 2). Elevations vary from 140 to 1120 feet. Slopes range from level to very steep. A considerable variety of bedrock types is found in the area. The Appalachian Valley Section (the Great Valley) consists of gently dipping limestones and shales, with the highlands of Reading (the Reading Prong) composed of granitic and gneissic rocks. In the Triassic Lowlands to the south, several

<sup>5</sup>Studied by Gary Hesler

high ridges of diabase rock are surrounded by limestones, shales, and conglomerates. In the Reading highlands, drainage is structurally controlled by a complex fault system, whereas in the remainder of the Appalachian Valley Section and in the Triassic Lowlands Section the drainage has a trellis pattern on folded shale. Just northwest of the Highlands area, drainage in a limestone valley is subsurface to the Schuylkill River. Forest lands are largely confined to slopes too steep for agricultural use, with the exception of a few cultivated lots of conifers found on moderate slopes. The large areal extent of deep, productive soils has led to the development of a large variety of agricultural activities. Chief among these is dairy farming, grains, truck crops, and orchards. Growth of the suburban areas around the city of Reading is encroaching on the agricultural land to some extent. A few limestone quarries are found in the area.

From the comparisons described earlier, it was determined that the S190B color positive film was the most promising for analysis. Accordingly, Frame 69 from Roll 88 of Sensor S190B, SL3 Orbit 44, was chosen for study of the Reading area. The photography was taken in September. The results of this study are described below.

Landforms and Geology. Separation of the varied lithologies within this area can only be done on a regional scale. The igneous formations of the Reading Prong are roughly delineated from the surrounding lowlands (representing a relief of approximately 700 ft). The dissected shale hills cannot be seen, nor can the limestones be separated from the shale formations.

Drainage and Erosion. Changes in drainage density can be effectively used as indicators of changes in bedrock lithology. For example, a change in drainage density indicates the approximate boundary between the Martinsburg shales and the bordering limestones in the area. First order drainage cannot be seen. Some second order drainage is discernible; however, aircraft underflight photography was not available to verify the mapping of these. All drainage of higher order than second was easily traced. First order gully erosion cannot be detected.

Color-Tone-Texture. In this area, darker tones generally indicate limestones and lighter tones indicate underlying shales. In some instances a mottling effect appears to be observable, further substantiating the presence of limestone. Drainage features show up as a dark color tone, and a reservoir just northwest of Reading shows a tonal variation similar to that seen in the Susquehanna River in the Harrisburg area. The lighter water tones occur only at the inlet to the reservoir and, as in the Susquehanna River, these are probably an indication of turbidity resulting from the 3.8 inches of which fell in the Reading area two days prior to the Skylab pass. Tonal variations are not detectable in the smaller streams of the area. Forest vegetation can be separated from other land uses on the basis of tone. It is also occasionally possible to differentiate concrete and asphalt highways, on the basis of the lighter tone of the concrete.

Vegetation. Vegetation, in the form of tonal contrasts, is a prime indicator of differences in lithology. Forested areas, dark in tone, form a rough boundary separating igneous intrusions from the surrounding sedimentary formations, as the forests are largely confined to stony and steep slopes. This characteristic, in turn, leads to the determination of an approximate boundary between slope breaks. Agricultural field patterns are clearly visible, but discrimination between crop types is not possible at the scale of the Skylab photography. Vegetation is occasionally of aid in tracing second order drainage.

Cultural features. Differentiation between urban, suburban, and agricultural areas is comparable to that found in the Harrisburg area, and considerably better than that found in the January, snow-covered, scene of the Sayers Dam area.

Soils. It is possible to roughly identify regional soil associations. The variety of soils series present and the small scale of the photography prevented more detailed discrimination.

### Summary of Results

#### Sensor/Film/Filter Analysis

In terms of film grain texture and object definition, the S190B color positive film is distinctly superior to the S190A films, when both are compared in the 9 x 9 inch format. Within the six S190A films, the panchromatic black and white films are superior to the infrared black and white, and the color positive film is superior to the color infrared.

1. The following features were visible on all of the photography:

- a. Major drainage, such as rivers and their tributary creeks.
- b. The sandstone ridges of the Appalachian Ridge and Valley region.
- c. Limestone quarries (with the aid of aircraft photography).

2. The following features were visible on all photography with the exception of S190A Stations 1 and 2 (0.7 to 0.8 and 0.8 to 0.9 micrometers, respectively):

- a. Differences in vegetation (forest versus agricultural land).
- b. Second order drainage (from vegetation differences).
- c. Color/tone variations in the water bodies.
- d. Cultural features, such as railroad rights-of-way, large industrial buildings, and roads (some with the aid of aircraft photography).
- e. The hills formed by the Triassic igneous intrusions.

3. The following features were visible only on photography from Stations 1 and 2 of the S190A and on the S190B color positive photography:

- a. Reservoirs and lakes.
- b. Water and wind gaps.

4. The S190B color positive photography was clearly superior for interpretative purposes to any of the S190A photography.

5. Some inconsistency in performance between S190A camera Stations 5 and 6 was detected.

#### Terrain Analysis

Landforms and Geology. Minimum relief differences on the order of 500 to 100 feet could be detected by stereoscopic study, however, it is not possible to determine to what extent vegetation and cultural practices assist in such delineations. The line of separation between highs and lows could not be consistently mapped. Secondary clues, such as shadows on winter photographs, led to an interpretation of relief in some instances. Gentle rolling relief related to limestone, dolomite, and shale in the valleys could not be detected. The igneous rock highs of the Reading Prong in the Great Valley were easily seen, in part due to vegetation and in part as a function of relief. Regional geologic features could be delineated, using topography, drainage patterns, vegetation, and cultural patterns. However, specific lithologic members of a formation could not be differentiated. Strike and dip could be determined on a regional basis, but verification from ground truth was needed.

Drainage and Erosion. Water and wind gaps through major ridges were easily seen. Streams of third order and larger were clearly visible and easy to trace. Second order streams could sometimes be identified and traced, but not with consistency. First order streams and gullies, on which much erosion analysis depends, could not be detected. Changes in drainage density frequently could be used as an indicator of differences in lithology. Shadows, especially on the winter scene, and vegetation were of assistance in tracing drainage.

Color-Tone-Texture. Differences in color, tone, and textural patterns rarely supplied clues for differentiating soils or bedrock. In some instances, darker tones indicated underlying limestones and lighter tones indicated shales. Rarely, mottling substantiated the presence of limestone. In one instance it was thought that a reddish tone indicated the presence of the Catskill formation; in another, that it indicated limestone in the Great Valley. Tonal variations were detected in the Susquehanna River and in one reservoir. It is suspected that this was a function of suspended silt from a heavy rain. Forest vegetation was easily separated from other land uses on the basis of tone, and developed land was separated from agricultural land on the basis of the textural pattern of streets. Concrete and asphalt highways were occasionally separable on the basis of the lighter tone of the concrete.



Vegetation. The separation of naturally forested areas from areas of cultivation and pasture was effective and a valuable clue to the underlying geology. It was possible to separate large plantings of conifers from deciduous trees, especially on winter scenes. Field patterns were not seen on the snow covered winter scenes, but were readily seen on the September scenes, although crops could not be identified. Vegetation was frequently a valuable clue in tracing second order drainage.

Cultural features. Suburban and industrial developments were clearly differentiated from urban areas and surrounding agricultural fields. Street patterns, field patterns, reservoirs, highways, and large bridges were identifiable. Utility and railroad rights-of-way, quarries, and large industrial buildings could occasionally be identified of themselves, but most often had to be verified from underflight photography and/or ground truth.

Soils. Soil associations could be identified on a regional basis, but no sharp boundary could be drawn separating soil associations. Occasional tonal variations seemed to indicate the presence of particular soils, but again no sharp boundary could be drawn. No soils information was obtained from the January snow covered scene.

#### CONCLUSIONS AND RECOMMENDATIONS

It is clear from this study that the S190B color positive film in the 9 x 9 inch format is superior to any of the S190A films in the same format. It is possible, however, that this is a function of the fact that the original S190B film is 5 x 5 inches, whereas the original S190A film is 70 x 70 mm. Thus, the S190B film has been magnified to a lesser extent than the S190A to obtain the same size transparency.

Within the S190A films, the panchromatic black and white is generally superior to the infrared black and white, although water feature definition and that of water and wind gaps are distinctly clearer on the infrared film. The color positive film of the S190A is superior to the color infrared film. This may be a function of the fact that the three wavelengths registered by the emulsion of the color IR film are longer than those of the color positive film. As the photography is enlarged, the distortion brought about by this difference is accentuated.

In terrain mapping from the S190B photographs, it is clear that drainage pattern mapping is a key to identification of many features. Drainage to the level of third order streams can be consistently mapped, and second order streams are frequently discernible with the aid of vegetation and shadows. Vegetation at the level of forests versus agricultural land can be consistently mapped, and in some cases larger areas of conifers can be differentiated from deciduous trees, especially on winter scenes.

On the basis of street patterns, suburban and industrial land can be differentiated from urban areas and from surrounding forest and agricultural land. Field patterns are easily seen, but crops cannot be determined. Reservoirs, highways, and large bridges can be mapped, and concrete highways can occasionally be differentiated from asphalt. With the assistance of ground truth or underflight photography, utility and railroad rights-of-way, quarries, and large industrial buildings can be located.

The level of generalization at which soils can be mapped compares well with the soil association maps prepared by the Soil Conservation Service.

Photoanalysis techniques applied to Skylab S190B photography can yield a regional map of considerable value. Landforms with minimum relief differences of 500-800 ft can be mapped relatively consistently, and lesser relief differences can be discerned in some instances, with the assistance of shadows and vegetation differences. Clues such as topography, drainage pattern differences, vegetation, and cultural patterns reveal the regional geology on the formation level, and regional structural orientation can often be determined.

Extensive ground truth, underflight photography, and information from the literature were used during the course of this study to verify the identification of features seen on the Skylab photography. However, the consistency with which three operators have identified features in three different geographic areas seems to indicate that regional mapping on the level herein described, using S190B photography, is feasible for areas for which little or no ground truth is available.

This study was conducted using the Old Delft Scanning Stereoscope and the Bausch and Lomb Zoom Transferscope. It is believed that mounting the Bausch and Lomb Zoom 95 Stereoscope on an X-Y stage would make it an instrument superior, for this type of analysis, to the Old Delft.

#### REFERENCE

- Weeden, H. A. (1975) Photointerpretative Analysis for Engineering Purposes, ORSER-SSEL Technical Report 17-75, Office for Remote Sensing of Earth Resources, The Pennsylvania State University.



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**SUMMARY**

ORSER-SSEL Technical Report 16-75

**PHOTOINTERPRETATION OF SKYLAB PHOTOGRAPHY**

H. A. Weeden, C. Kleeman, S. Daelhausen, and G. Hesler

Skylab scenes from three different areas in Pennsylvania were studied for their usefulness in terrain analysis. The study was conducted in two parts. First, photography from the S190A and S190B sensors were compared, with the result that the S190B color positive film was selected as the best in overall quality for terrain analysis. Terrain analyses of the three study areas were then made, using the S190B photography. The summarized results are as follows:

Sensor/Film/Filter Analysis

1. The following features were visible on all of the photography:
  - a. Major drainage, such as rivers and their tributary creeks.
  - b. The sandstone ridges of the Appalachian Ridge and Valley region.
  - c. Limestone quarries (with verification from underflight aircraft photography).
2. The following features were visible on all photography with the exception of that from S190A stations 1 and 2 (0.7 to 0.8 and 0.8 to 0.9 micrometers, respectively):
  - a. Differences in vegetation (forest versus agricultural land).
  - b. Second order drainage (from vegetation differences).
  - c. Color/tone variations in silted water bodies.
  - d. Cultural features, such as railroad rights-of-way, large industrial buildings, and roads (some with verification from underflight aircraft photography).
3. The following features were visible only on photography from stations 1 and 2 of the S190A and the S190B color positive photography:
  - a. Reservoirs and lakes.
  - b. Water and wind gaps.
4. The S190B color positive photography was clearly superior, for interpretive purposes, to any of the S190A photography.
5. Some inconsistency in performance between S190A camera stations 5 and 6 was detected.

Terrain Analysis

1. Relief differences of 600 to 800 feet could be detected, with some indications of lower relief features from shadows and vegetation.
2. Regional geological features could be delineated from topography, and from patterns of drainage, vegetation, and cultural features. Regional strike and dip was indicated, but should be verified by ground truth.
3. Water and wind gaps, and drainage larger than second order were clearly visible. Changes in drainage density were an important indicator of geology.
4. Color and tonal changes gave inconclusive evidence of soil and underlying bedrock. Tonal differences clearly differentiated forest vegetation from cultivated fields. In some cases, concrete highways could be differentiated from asphalt on the basis of tone. Tonal differences in water bodies indicated the presence of silt.
5. Textural differences were used to identify urban, suburban and industrial, and agricultural land uses. The presence of utility and railroad rights-of-way, quarries, and large industrial buildings required aircraft underflight photography for verification.
6. Field patterns could easily be seen, although crops could not be identified. The level of generalization at which soils can be mapped compares well with the soil association maps prepared by the Soil Conservation Service.