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Experimental Application of Landsat to Geobotanical Prospecting of Serpentine Outcrops in the Central Appalachian Piedmont of North America

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EXPERIMENTAL

APPLICATION OF LANDSAT TO GEOBOTANICAL PROSPECTING OF SERPENTINE OUTCROPS IN THE CENTRAL APPALACHIAN PIEDMONT OF NORTH AMERICA

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INTRODUCTION

Geobotanical prospecting is the branch of earth sciences which employs field observation of the distribution of vegetation as a tool for locating mineral deposits. One example of geobotanical prospecting was Isaac Tyson, Jr.'s staking of claims and purchasing of land having potential chromium deposits in the Appalachian Piedmont of the eastern United States during the nineteenth century (Pearre and Heyl, 1960). These chromium deposits, associated with sites having serpentine outcrops, could be easily distinguished from sites containing other rock types by their vegetation. One of Tyson's most productive chromium mines was located within a large Maryland serpentine outcrop called Soldiers Delight. This serpentine outcrop currently supports a stunted tree-flora with an open canopy that is dominated by Virginia Pine (Pinus virginiana), Post Oak (Quercus stellata) and Blackjack Oak (Quercus marilandica). In contrast, the neighboring ultrmafic and schist rock outcrops support a robust tree-flora with a closed canopy consisting of a variety of species and dominated by Chestnut Oak (Quercus prinus) and White Oak (Quercus alba). Prospecting for potential chromium deposits was a matter of searching for the atypical scrubby and open canopied tree-flora among lands supporting agricultural production or dense deciduous forests.

The purpose of this research is to test the use of the United States NASA experimental orbiting multispectral scanning satellite, called Landsat, as a tool for geobotanical prospecting using serpentine outcrops as the focus of study. This paper is divided into two parts. The first part describes Landsat and the steps required for the analysis and production of maps for field work. The second part describes the field work and geochemical analysis that were carried out to test the efficacy of Landsat in geobotanical prospecting of serpentine sites of the Appalachian Piedmont of the Middle Atlantic Region of North America.

PART I. THE PRODUCTION OF VEGETATION MAPS FROM DATA ACQUIRE BY LANDSAT

The overall study site extended along the Appalachian Piedmont from southeastern Pennsylvania through Maryland to northern Virginia and covered an area of 13137 km^2 (5072 mi^2). (See Figure 1). The Pennsylvania and Maryland sector of the study, an area of 7778 km^2 (3003 mi^2), included serpentine outcrops with their well documented occurrences of serpentine mineral deposits (Pearre and Heyl, 1960). The Virginia sector, an area of 5359 km^2 (2069 mi^2), was included because the presence of serpentine outcrops there has not been as well documented as in the sector north of the Potomac. The inclusion of both regions with documented serpentine outcrops as well as an adjacent area provided a means of evaluating the methodology and application of Landsat as a tool for geobotanical prospecting.

Landsat Data Acquisition

The first Landsat began operating during July, 1972 and was followed by a second satellite during January, 1975. Each satellite passes over each point on the earth every 18 days. When both satellites were in operation the entire earth was covered at nine-day intervals. During the course of operation of Landsat to June, 1977, when this study was first begun, relatively few passes took place when atmospheric conditions were uniformly clear over the entire study area. Therefore, the supply of images for study was limited. Computer compatible tapes (CCT's) of the study area were selected among all available images from the Landsat Library at the Goddard Space Flight Center. Two consecutive scenes were required to cover the entire study area. The selected scenes listed in Table I span the seasons of the year.

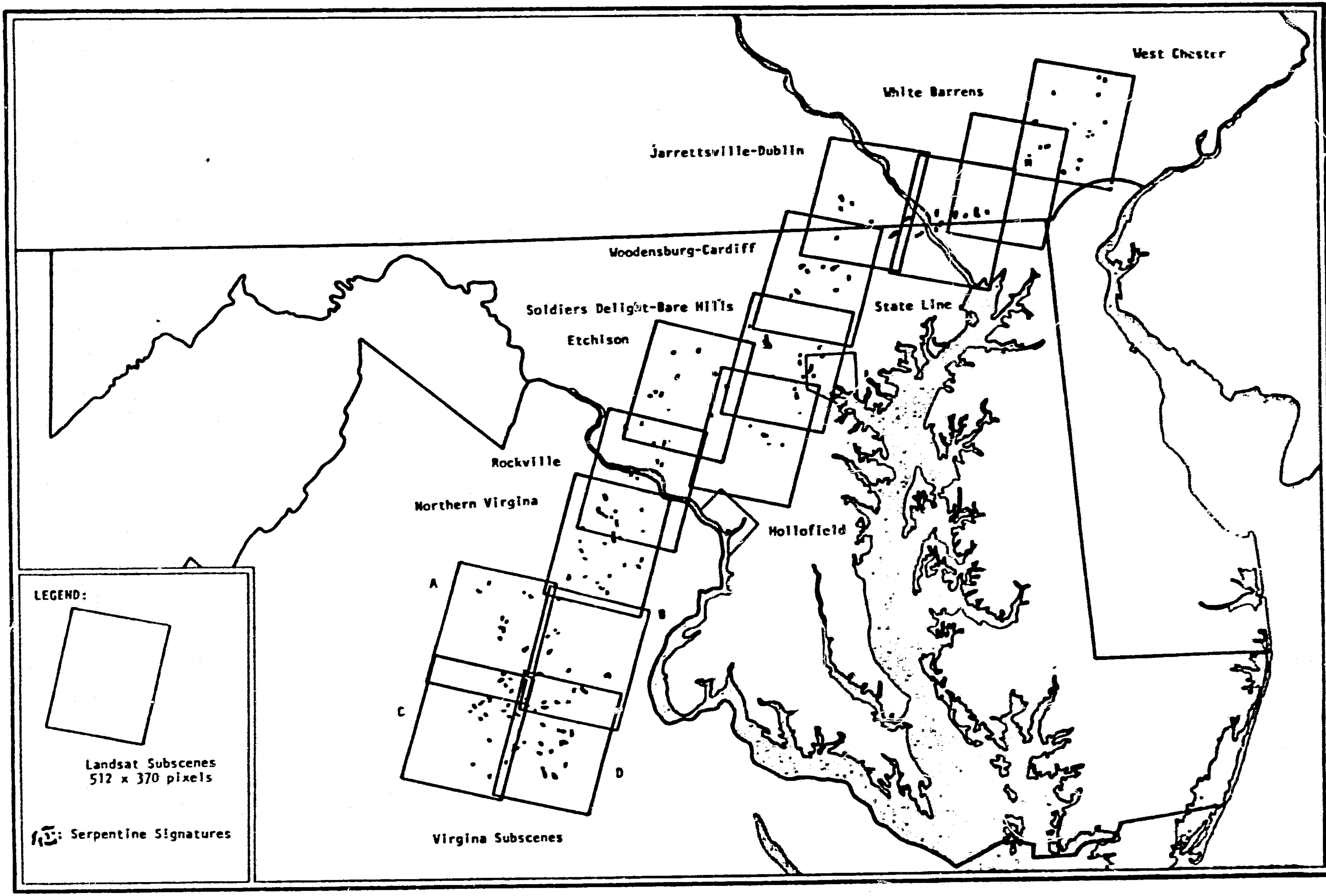

Figure 1. Overall Study Site Extending along the Appalachian Piedmont

TABLE I

LANDSAT SCENE IDENTIFICATION NUMBERS USED IN THIS STUDY

Date	Northern Sector Pennsylvania & Maryland	Southern Sector Maryland & Virginia
February 2, 1977	2742-14532	2742-14534
April 15, 1977	2814-14500	2814-14502
July 19, 1976	2544-15001	2544-15004
October 6, 1973	1440-15172	1440-15175

Analysis of Landsat Images

Analysis of the Landsat scenes was done on Goddard's modification of the GE Image 100 computer called AOIPS (Atmospheric-Oceanic Image Processing System). AOIPS is an interactive computer. The operator can instantaneously see the results of manipulations of the image on a display screen. A subscene of a given Landsat is transferred from the CCT to the memory of the AOIPS computer and viewed on a color cathode ray tube (color CRT). The operator uses a curser on the color CRT which interfaces the computer and the memory banks containing the multispectral data of the subscene. Production of a map requires several modifications which were related to the resolution and operation of the Landsat scanners.

The resolving power of the Landsat image is a function of the area of the nominal instantaneous field of view (also referred to as a picture element or more commonly "pixel"). The smaller the area of each pixel, the greater the resolution of the system. Landsat employs a scanning type sensor which moves perpendicular to the direction of travel of the satellite. Thus, a Landsat image is made up of lines of pixels. The nominal instantaneous field of view (or pixel size) of Landsat is 79 by 79 meters. However, due to overlap between successive scan lines, the effective pixel size is 79 by 56 meters. In practice, correction for overlapping pixels is made on AOIPS by regularly repeating lines of pixels when transferring pixel data from CCT to memory. Thus, a Landsat subscene of 512 by 370 pixels is transferred from CCT to memory in such a way that 370 lines are repeated at regular intervals to fill the CRT display of 512 lines. This correction is essential for production of a map with AIOPS. Because the geometry more closely conforms to the earth, the correction also improves the fit between what is actually present on the surface of the earth and the Landsat image that represents the surface of the earth.

Scene Selection

An important part of Landsat analysis is the judicious selection of scenes to work with. The scenes used in this study are listed in Table I. It was first assumed that early spring, late fall or winter, when deciduous trees are leafless, were the times of the year when conifer sites could be most easily distinguished from deciduous leaf-bearing trees. However, initial analysis of the CCT's revealed that the best time of the year for distinguishing coniferous sites from deciduous sites was in early summer (mid July) when all vegetation was in full leaf. At that time, sun angles are highest, the image is brightest and produces greatest contrast giving maximum resolution. Subtle vegetation differences are most easily observed from Landsat at the height of the growing season. Also, because of the brightness of the summer scene, image enhancement (subroutines which increase contrast) was not required. This is an advantage because each transformation of the image tends to degrade some aspect of its quality.

Training Sites and Multispectral Signature Acquisition

A training site is a location on the earth's surface where the features of interest to the investigator are well-known. Interactive analysis of Landsat data on AOIPS consists of using a curser to select pixels on the CRT display which represent a training site and obtaining a multispectral signature of the cursered pixels. A multispectral signature defines the training site in terms of the reflection of electromagnetic radiation from the earth at four wavelength bands operating on Landsat. Once a signature is obtained for a training site (consisting of a number of pixels) it can then be applied to the whole subscene as well as subsequent subscenes. All pixels having the same four-band electromagnetic characteristics as the training are electronically tagged (or alarmed) and then displayed on the color CRT. Classification of the subscene involves obtaining several multispectral signatures of different features, coding them and storing them in memory for later recall. The initial map is a digital printout of the results of the classification gathered and stored in the described manner.

Soldiers Delight, Maryland was chosen as the primary training site for this study because vegetation and soil geochemical patterns have been intensively studied there. However, preliminary Landsat data analysis showed that well-documented serpentine sites in the State Line District of Pennsylvania did not match the multispectral signature of the Soldiers Delight training site. For this reason a second training site, Nottingham Park, was selected from the State Line District of Pennsylvania. Both the primary and secondary sites were placed side by side on a single subscene. A refined serpentine signature was subsequently acquired from the combined subscene.

Map Production

In order to produce a serpentine distribution map, the signatures of two other landmarks, water bodies and urban surfaces (a combination of parking lots, highways and building tops, all of which lack extensive vegetation) were also classified. The resulting multispectral signatures of serpentine, water and urban surfaces are shown in Table II. The alarmed areas for each classification were printed as digital maps on a Gould printer. Using a light table, the three classifications were transferred to a single composite map. The resulting maps were first reduced and then, with the aid of a stereo zoom transfer scope, transferred to a United States Geological Survey 1:250,000 base map. The resulting map contained 159 serpentine sites imprinted on four conterminous maps that had topographic, hydrologic, road and urban features of the study area. These final maps placed the extracted Landsat signature for serpentine sites within the context of a road network, thereby making it possible to do field work and to check the proficiency of Landsat as a geobotanical prospecting tool.

PART II. FIELD VERIFICATION OF LANDSAT-DERIVED MAPS OF SERPENTINE SITES

The second part of this investigation involved a field study designed to find and sample the serpentine sites that were mapped from the Landsat images. The purpose of the field work was to determine whether or not the serpentine multispectral signature (Table II) accurately represented serpentine sites within the region of this study.

TABLE II

MULTISPECTRAL SIGNATURES DEVELOPED FOR GEOBOTANICAL PROSPECTING OF SERPENTINE SITES

	Brightness or Grey Levels			
Landsat Band	4	5	6	7
<u>Comparison of the 1° and 2° Training Sites</u>				
Soldiers Delight	9-12	6-13	19-20	21-24
Nottingham Park	8-10	6-12	20-23	20-25
<u>Signatures Used for Mapping Serpentine Sites</u>				
1° plus 2° Training Sites	8-11	6-12	19-23	19-25
Urban Surfaces	12-21	12-27	20-37	14-32
Water	7-12	6-10	3-14	0-10

NOTE: 0-63 Grey Level Range was used on all 4 channels on AOIPS.

Field Sampling Criteria

Field sites in this study were chosen for sampling according to the following size, accessibility and spatial criteria. First, in order to reduce possible sites to a manageable number, only those sites which were 50 pixels or larger were mapped and considered for sampling. All sites fitting this criterion are shown in Figure 1. Secondly, to facilitate sampling only sites accessible by road were chosen. Thirdly, an attempt was made to distribute the sampling of the accessible sites as evenly as possible over the entire study area. The distribution of those sites actually visited is shown in Figure 2. As discussed later, not all sites that were visited were sampled. Sampling consisted of collecting a five-part composite surface soil sample (0 - 10 cm), identifying major tree species, and measuring the tree basal area within each of the sampled sites.

Results

The composite surface soil samples were analyzed for their content of Ni, Ca and Mg using the double acid extraction procedure (CSTPA, 1974). Trees were identified using North American trees (Preston, 1965). The basal area was measured using the Bitterlick method (Grosenbaugh, 1952). The soil chemical results are presented in Table III. The tree species and basal area appear in Table IV.

Serpentine and Non-Serpentine Soils of the Primary Training Site

The chemical nature of serpentine and non-serpentine soils was established from a study of the soils and vegetation at the primary training site, Soldiers Delight, Baltimore County, Maryland (Mielke, Munns and Chaney). Table V presents the chemical characteristics of soils from a variety of sites in Soldiers Delight. The first four sites, Group I in the chart, represent locations in Soldiers Delight which have serpentine soils and bear the tree-flora commonly recognized as characteristic of serpentine outcrops. The last two sites, Group IV in the chart, are soils associated with schist bedrock adjacent to Soldiers Delight and support the usual deciduous tree-flora of the Maryland Piedmont. Comparison of the

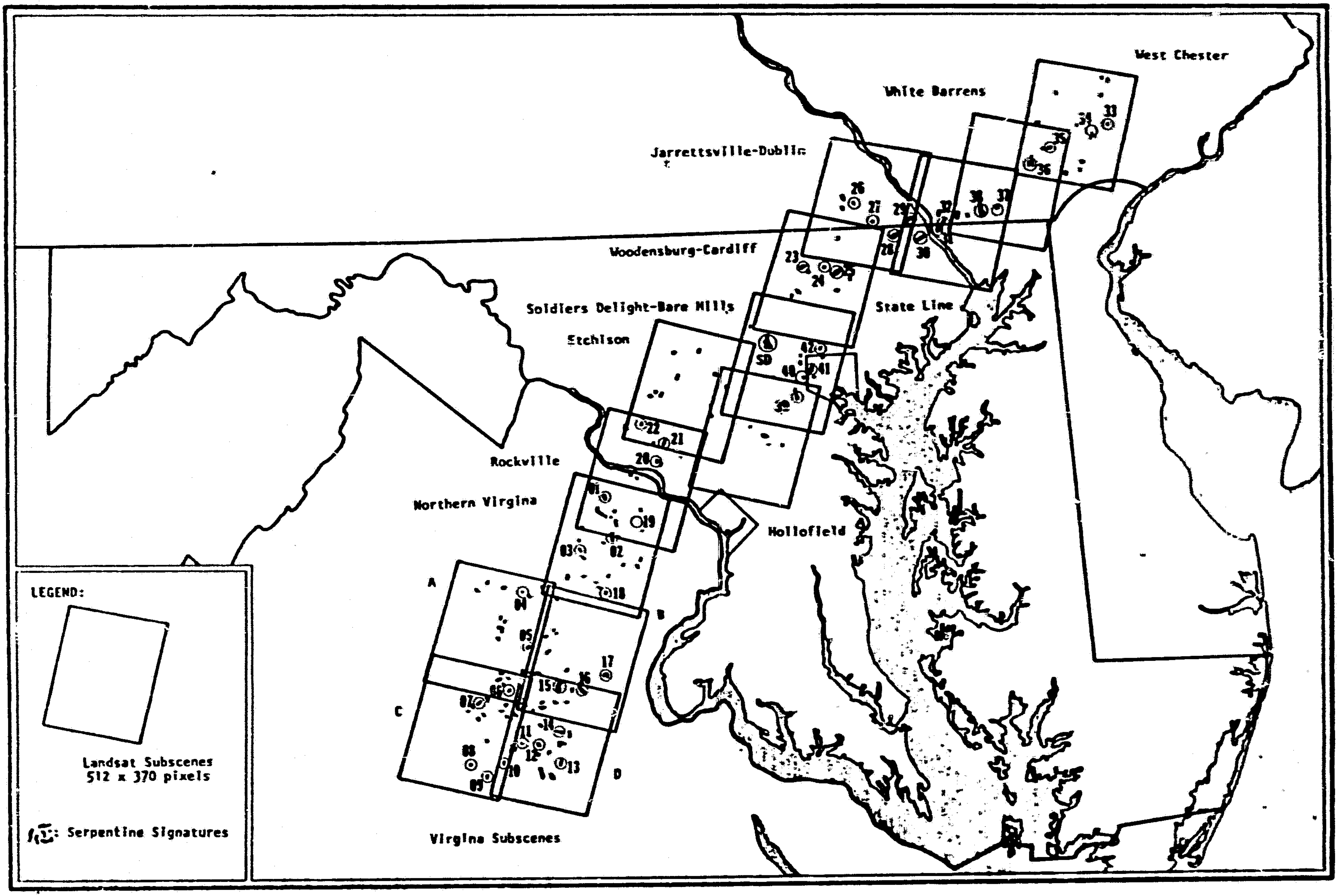

Figure 2. Distribution of Field Sites Actually Visited

TABLE III

RESULTS OF THE SOIL CHEMICAL ANALYSIS

Sample Location (Nearest Number, Town or Landmark	Ca (ppm)	Mg (ppm)	Ca:Mg Ratio	Ni (ppm)	pH.
001 Herndan, VA	706	49	15.50	< 1	5.7
002 Centreville, VA	95	22	4.30	< 1	4.4
003 Manassus, VA	150	39	3.80	< 1	4.4
006 LaGrange, VA	157	36	4.40	< 1	4.1
007 Batna, VA	150	83	1.80	1	4.8
010 Saint Just, VA	28	4	7.00	< 1	4.0
011 Locust Grove, VA	74	10	7.40	< 1	4.2
012 Brockroad, VA	24	2	12.00	< 1	4.3
015 Goldvein, VA	78	27	2.90	< 1	4.4
016 Glendie, VA	81	8	10.10	< 1	4.6
017 Roseville, VA	46	22	2.10	< 1	4.4
*019 Rt. 50 - Fairfax, VA	186	147	1.30	3	4.8
020 Travilah, MD	133	106	1.30	5	4.7
022 Boyds, MD	704	227	3.10	2	5.8
023 Evna, MD	342	51	6.70	< 1	5.1
025 White Hall, MD	251	105	2.40	1	5.3
027 New Park, PA	176	14	12.60	1	4.0
028 Cardiff, MD	95	12	7.90	1	3.9
031 Camp Shadowbrook, MD	53	116	.46	13	4.5
032 US 222, York Co, PA	95	106	.90	12	4.7
035 Embreeville, PA	13	2	6.50	< 1	4.0
037 Chrome, PA	17	40	.43	6	4.3
038 Nottingham Park, PA	130	685	.19	46	5.8
042 Bare Hills, MD	44	138	.32	10	4.8

*Undersized. See Discussion.

TABLE IV

BASAL AREA AND TREE SPECIES OF THE SAMPLED SITE

	Site	Basal Area (m^2/ha)	Pinus virginiana L	Pinus taeda L	Pinus rigida Mill	Pinus strobus L	Juniperus virginiana L.	Thuja occidentalis L	Tsuga canadensis (L) Carr	Quercus velutina Lam	Quercus marilandica Muenchh	Quercus rubra L	Quercus alba L	Quercus bicolor Willd	Quercus stellata Wangenh	Quercus prinus L.	Liriodendron tulipifera L	Acer rubrum L	Fraxinus americana L	Cornus florida L	Platanus occidentalis L	Liquidambar styraciflua L	Sassafras albidum (Nutt.) Nees	Ulmus rubra Muhl.	Ailanthus altissima (Mill.) Swingle	Robinia pseudoacacia L	Populus tremuloides Michx	Fagus grandifolia Ehrh.	Nyssa sylvatica Marsh	Tilia americana L	Prunus sp.
	001	8.7 ± .06		X			X	X		X							X														
	002	7.8 ± .09	X				X			X	X							X													
	003	9.8 ± .07	X				X				X	X						X	X												
	006	7.1 ± .16	X				X			X									X												
	007	9.7 ± .05	X				X						X																		
	010	11.7 ± .08	X				X						X				X	X													
	011	11.7 ± .09	X							X			X	X		X			X												
	012	10.8 ± .09	X		X								X					X	X												
	015	11.0 ± .06	X				X			X								X		X	X										
	016	10.6 ± .10	X				X											X	X	X		X	X								
	017	9.3 ± .07	X				X						X					X				X	X								
	019	7.8 ± .11	X				X											X													
	020	8.0 ± .11	X							X								X	X	X										X	
	022	8.4 ± .08	X				X						X					X	X	X				X	X						
	023	5.9 ± .06	X							X							X	X		X											X
	025	8.9 ± .05	X			X												X								X					
	027	15.1 ± .03				X																									
	028	9.3 ± .05	X							X								X			X					X	X				
	031	6.9 ± .08	X				X											X										X			
	032	7.4 ± .03	X				X											X	X							X	X				
	035	12.8 ± .07							X								X				X										
	037	5.8 ± .06	X				X				X				X			X					X						X		
	038	5.4 ± .07			X								X					X					X								
	042	6.0 ± .06	X								X				X													X			
Totals	24		20	1	2	2	14	1	1	8	4	1	7	1	2	1	4	17	8	5	3	2	4	1	1	3	2	2	1	1	1

chemical features of these groups of soils reveals several distinctive characteristics of soils derived from serpentine outcrops. First, the serpentine-derived soils have levels of magnesium, calcium and nickel that are substantially higher than the schist derived soils. Secondly, the serpentine soils generally have a higher pH than the schist soils. Thirdly, serpentine soils have a nickel content that is generally higher than 10 ppm. Another common feature of serpentine soils is their calcium to magnesium ratio is generally below 1 (Kruckeberg, 1954; Loew and May, 1901; Lyon et al, 1971; Walker et al, 1955). However, that alone is not a reliable indicator here because both groups of soils in Table V have similar Ca-Mg ratios.

Comparison of the Primary and Secondary Training Sites

Comparison of the soil characteristics of the serpentine soil of Soldiers Delight (Table V) with the soils of State Line District's Nottingham Park (Sample 038, Table III) reveals striking similarities between the two sites. The soils of both sites have high levels of magnesium and calcium, relatively high pH's, high quantities of nickel and low Ca-Mg ratios. The similarity between the two training sites enchances confidence in applying the serpentine signature to other sites in the study.

One important floral difference should be noted (see Tables IV and VI). The conifers in Nottingham Park are Pinus rigida instead of Pinus virginiana. The difference in species helps to explain the difficulty discussed earlier, of establishing a single multispectral signature from pixels of Soldiers Delight which would also pick up the electromagnetic signal and indicate the location of other known serpentine sites such as Nottingham Park. More than one species of pine is capable of becoming established on serpentine outcrops and slight differences in electromagnetic reflection between species, as shown in Table II, produces variations in multispectral signature. In this study, multispectral signatures of the two training sites having different pine species were combined to produce the experimental signature (see Table II). The final multispectral signature as demonstrated in Table IV, covered wavelengths that included at least four species of pines.

TABLE V

SUMMARY OF SOLDIERS DELIGHT SOIL CHEMICAL ANALYSIS

Group Description	Site	Ca	Mg	Ca:Mg	Ni	pH
Group I Classical Serpentine Sites						
Scrubby pines and oaks on serpentine outcrops.	A	42	241	.17	13	4.6
	B	181	484	.37	36	5.3
	G	495	874	.57	123	4.8
	H	399	1430	.24	89	6.6
Group II Serpentine Sites dominated by deciduous trees and grasses.						
Scrubby maples and oaks.	I	435	821	.53	76	6.4
Alluvial soils on serpentine outcrops.	J	795	972	.82	65	5.9
Residual soils supporting grasses and pine saplings.	E	562	854	.66	104	6.2
Group III Intermediate Soil Sites.						
Barrens supporting brush and scrubby deciduous trees. Mixed serpentine and schist alluvial soils.	C	760	186	4.09	9	4.9
Mixed pine and broadleaf deciduous plants	F	260	42	6.19	6	4.7
Group IV Non-serpentine Soils.						
Chestnut oak dominated sites adjacent to serpentine outcrops.	D	3	5	.40	< 1	4.3
	K	10	16	.63	1	4.3

Source: Mielke, Munns and Chaney

Site	Basal Area (m^2/ha)	Pinus virginiana L	Acer rubrum L	Quercus marilandica Muenchh	Quercus stellata Wangenh	Quercus prinus L	Quercus imbricaria Mich.	Quercus velutina Lam.	Quercus rubra L	Quercus alba L	Kalmia latifolia L	Prunus serotina Ehrh	Rhus copallina L	Rhus typhina Tomer	Liriodendron tulipifera L	Populus grandidentata Mich.	Alnus rubra Bong	Castanea dentata (Marsh.) Borkh.	Sassafras albidum (Nutt.) Ness	Cornus florida L	Corya glabra (Mill.) Sweet
Group I																					
A	7.4 ± .8	X	X	X	X						X										
B	6.7 ± 1.2	X	X	X	X																
G	7.8 ± .8	X	X	X	X														X		
H	7.6 ± .6	X	X	X	X														X		
Group II																					
I	4.7 ± .9	X	X	X				X													
J	4.3 ± .8	X	X	X				X													
E	saplings	X																			
Group III																					
C	2.6 ± 1.1		X									X	X	X	X	X	X				
F	6.7 ± .6	X	X				X					X				X			X	X	
Group IV																					
D	10.8 ± .6		X		X	X	X	X	X									X			
K	12.4 ± .5		X		X	X	X	X		X									X	X	X

Table VI

Summary of Basal Area and Tree Species In Soldiers Delight

Comparison of Training Sites With Other Sampled Sites

Applying the chemical criteria found in Tables III and V to all sites in the study area, the multispectral signature had varying degrees of effectiveness in identifying serpentine sites. Three sites had soil characteristics remarkedly similar to the training sites. Sites 031, 032 and 042 had the requisite chemical features of serpentine soils. They also had tree species and basal area similar to the training sites.

Five sampled sites had only a limited chemical resemblance to the training sites. For example, sites 019, 020, 022 and 025 have elevated calcium and magnesium levels and relatively high soil pHs. Sites 019, 020, 022 and 037 have a moderately elevated nickel content. Site 037 has a low Ca to Mg ratio. Sites 019 and 037 have the most similar vegetative characteristics to the training sites. The other sites, 020, 022 and 025, are vegetatively more dense than the training sites.

The remaining fifteen sites sampled in this study had none of the chemical criteria that identified them with the serpentine soils of the training sites. These sites include the following: 001, 002, 003, 006, 007, 010, 011, 012, 015, 016, 017, 023, 027, 028 and 035. All of these sites were dominated by pines. They had an average basal area of 10.1m^2 compared with an average basal area of 7.0m^2 for the training sites. Thus, they either supported a stand of trees with larger diameter trunks or more numerous trunks than the training sites.

Evaluation of Landsat for Geobotanical Prospecting of Serpentine Sites

Using the serpentine multispectral signature, a total of 159 sites with 50 pixels or more were identified in the study area. The field research included 41 sites, or about 26 per cent of the total number of sites with a serpentine signature. About half of the sites (23 sites) or 14 per cent of the total number of sites with serpentine signatures were actually sampled. One undersized site, 019, was sampled and the results of this site will be discussed separately.

Of the sampled sites, eight (including Nottingham Park) had many chemical features similar to the soils of the primary training site. The overall rate of success in geobotanical prospecting was eight positive identifications out of 23 samples or about a 35 per cent success rate in identifying serpentine sites. One factor which contributes to the successful use of geobotanical prospecting is the distribution of natural vegetation.

General Distribution of Vegetation in the Study Area

Geobotanical prospecting relies on the ability to discriminate between vegetation differences in order to identify rock outcrops. The distribution of natural vegetation in the Middle Atlantic Region of the Appalachian Piedmont is illustrated in Figure 3. North of the Potomac the broad leaf deciduous forest dominates, but south of the Potomac the natural vegetation is dominated by needle leaf evergreen coniferous species. In the study sites north of the Potomac, a multispectral signature based on conifers facilitated discrimination of anomolous vegetation when compared to the background vegetation. However, south of the Potomac the target sites were indistinguishable from the natural background vegetation.

There are several indications of the difficulty in applying a single multispectral signature to too large an area. First, although the area south of the Potomac included only about 41 per cent of the total study area, it contained about 56 per cent of the total number of sites with the serpentine signature in the study. Secondly, south of the Potomac none of the 11 sampled sites identified using the multispectral signature were, in fact, serpentine. In contrast, north of the Potomac eight of 12 or 67 per cent of the sampled sites had soil chemical features which linked them with serpentine outcrops.

One exceptional site, 019, was found south of the Potomac which did have serpentine soil characteristics. The sample was collected from an undersized site of one or two acres (i.e., one or two pixels). It was spotted along the road and sampled because it bore a close physical resemblance to serpentine sites at Soldiers Delight. While there were no actual

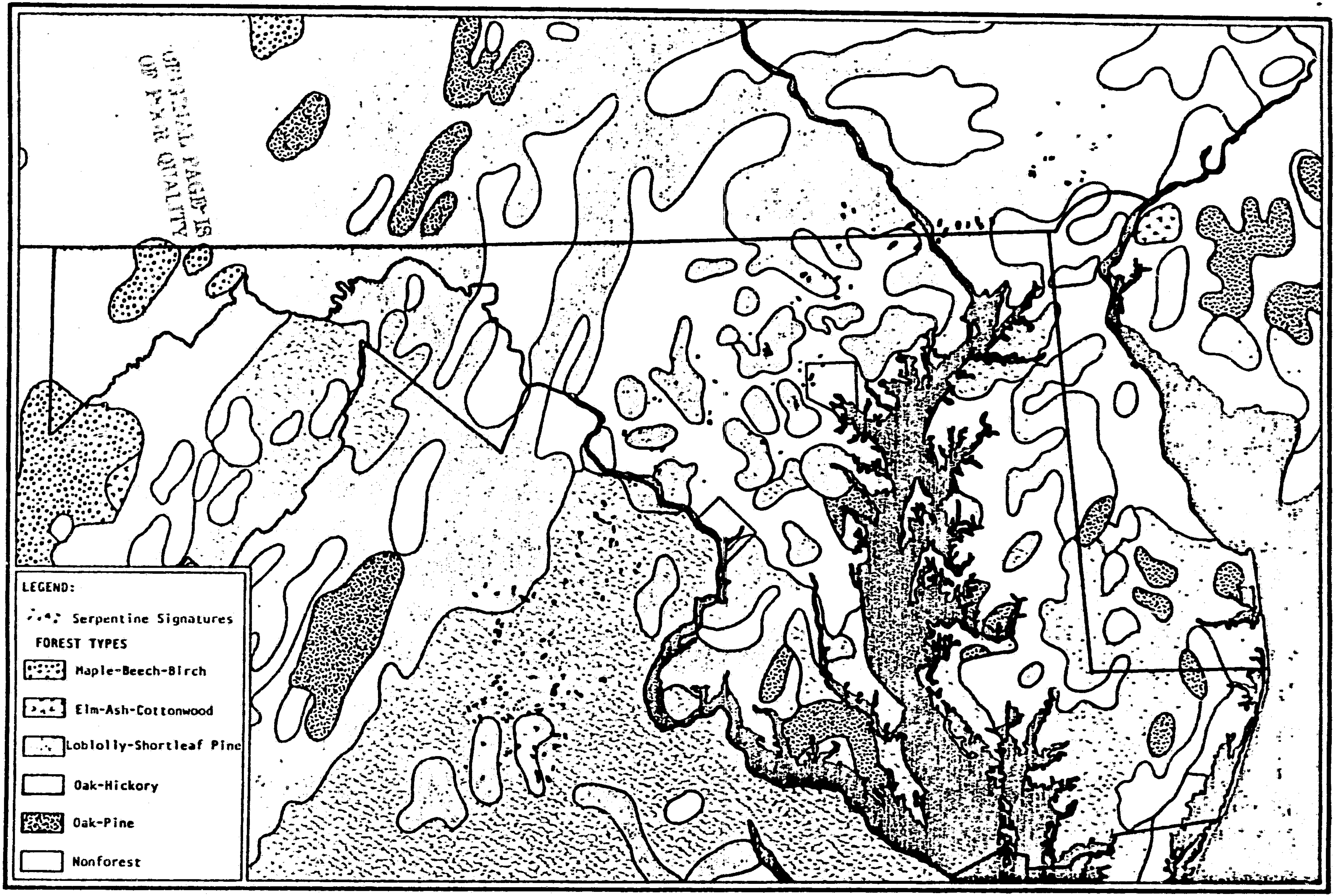

Figure 3. Distribution of Natural Vegetation in The Middle Atlantic Region of the Appalachian Piedmont

serpentine sites among those located by multispectral signature having 50 pixels or more south of the Potomac, the finding of 019 suggested that other serpentine sites may also exist, and that an alternate signature would make it possible to locate them.

An Alternate Approach for Multispectral Analysis of Serpentine Sites South of the Potomac

Examination of the chemical and vegetation features of Soldiers Delight (Tables V and VI) reveals an alternate method of using Landsat for geobotanical prospecting. Several Soldiers Delight sites had characteristics that, as discussed previously, would classify them as serpentine by their chemical makeup, but their vegetation does not match the stereotype for the classifical description of Maryland serpentine sites. For example, maples dominate several alluvial sites (see Table V, Group II). Also, grasses dominate some residual soils that had serpentine chemical features (see Table V, Group II). While both of these types of sites had serpentine soil chemical characteristics because of their plant cover, neither of them were included in the multispectral signature used in this investigation. Therein lies the basis for the development of an alternative multispectral signature which might improve the ability to discriminate between vegetation and enhance the use of Landsat as a tool for geobotanical prospecting south of the Potomac.

Miscellaneous Field Observations of Sites and Conclusions

There were some difficulties in using Landsat for geobotanical prospecting. As listed in Table VII, discrimination problems occurred at a number of sites. For example, several sites, both sampled and unsampled, were actually tree plantations instead of being serpentine sites. The sampled plantations included sites 001, 006 and 027. Unsampled plantations included sites 005, 009 and 030. Also, one association involving slate was frequently observed. The sampled site of Cardiff (028) was an old slate quarry. Several unsampled sites also had slate associated with them. Rural site 029 and several urban sites (034, 049 and 041) consisted of various combinations of deciduous and coniferous trees plus slate piles (029) or slate-covered roofs.

Table VII

Field Notes For The Unsampled Sites

Site	Location (Nearest Town or Other Landmark)	Field Observations
004	Wanenton, VA	Pine stumps. Logging operations recently cleared out mature trees.
005	Bealeton, VA	Cedar plantation. Slightly off-mapped location. No road into site.
008	Unionville, VA	Very small area of conifers.
009	Vulcan, VA	Tree plantation.
013	Alsop, VA	Unable to find any conifers.
014	Chancellorsville, VA	Mixed forest of conifers and hardwoods.
018	Lake Jackson, VA	Could not get into site to sample it. Pine and Red Cedar visible from road.
021	Corner of Route 28 and Quince Orchard Road, MD	Shopping center was being completed on the site.
024	Prettyboy Reservoir, MD	Unable to cross stream to get to site.
026	Stewartstown, PA	Unable to find the site.
029	Peach Bottom, MD	Slate slag piles mixed with deciduous and coniferous species.
030	Conowingo Dam, MD	Pines planted on steep slopes west of Broad Creek
033	Goshenville, PA	Pines located on back field of private property.
034	West Chester, PA (residential location)	Large lots with several species of conifers including White Pine, Red Pine, Blue Spruce and Eastern Hemlock. Homes had slate roofs.
036	Cockranville, PA	The road on the map did not correspond with those on the site. A pine plantation was present at approximate location.
039	Catonsville, MD (residential location)	Conifers abundant in the neighborhood. Blue Spruce and hemlocks present. Homes had slate roofs.
041	Baltimore, MD West Forest Parkway (residential location)	Older homes with planted spruce, hemlocks, cedar and juniper trees. Homes had slate roofs.

A very positive aspect of Landsat is its timeliness. Some of the sites had undergone change so recently between the field work (late July, 1978) and the scan date (July 19, 1976) that the reason for change was immediately recognized. Site 004 contained freshly cut pine stumps and other signs of being recently logged. Also, the finishing touches were just being completed on site 021 as a shopping center and parking lot.

Table VII lists the 18 sites which were field checked, but not sampled in the study. Four sites, or 10 per cent of the total 41 sites, that were sought could not be found. There are several possible reasons for failure to find a site. Small errors in the alignment of digital printout and transfer to base maps in the production process could displace the sites from their actual location. Also, the USGS 1:250,000 series maps contain rural roads, but do not identify roads by number. Sites could have been missed because of navigation error. Nevertheless, in view of the fact that the area of the study was 13,137 km^2 (5072 mi^2), the 90 per cent success rate in finding sites was itself considered to be a remarkable achievement. While the study demonstrated that south of the Potomac another multispectral signature should be developed, on the 7778 km^2 (3003 mi^2) sector north of the Potomac this study established the effectiveness of the multispectral imaging satellite as a tool for quickly and accurately locating mineral sensitive vegetation communities over vast areas of land.

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