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Landsat Geologic Reconnaissance of the Washington, D.C. Area Westward to the Appalachians*

Conventional published geologic maps of regions can be effectively supplemented by interpreted satellite and aircraft imagery overlays.

KEY WORDS: **Aerial photography; Botany; Geologic maps; Geologic structures; Geomorphology; Infrared photography; Landsat; Lithology; Mapping; Mineral maps; Remotely sensed data; Satellite Photography; Washington, D.C.**

ABSTRACT: The usefulness of satellite remote sensor imagery in the mapping of major geologic structures, boundaries of geologic units and lithologies, and geomorphic provinces in the Washington, D.C. area, westward to the Appalachian Plateau, was investigated. The remote sensor imagery data base consisted of Landsat satellite data and high altitude infrared aerial photography. Both laboratory and field work was utilized in the geologic analysis of the imagery. The imagery was processed primarily by photo-optical techniques and analyzed by conventional interpretation methods. A series of geological and geobotanical overlays were prepared to show the interpreted results. The results showed that conventional published geologic maps of regions can be effectively supplemented by interpreted satellite and aircraft imagery overlays. A special geologic contribution is the additional structural information derived from the imagery which may be useful in the search for new mineral targets in the Appalachians.

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Introduction

The general approach described herein is to apply the concepts of global tectonics, together with remote sensing technology, for the analysis of a broad region in the Appalachians. As the analysis progresses from a broad view afforded by the satellite imagery to local coverage, the remote sensor imagery is supplemented by field observations and comparative analysis of available geophysical data.

The two Landsat scenes interpreted in this report partly describe this research approach (Boegli and Valdes, 1977). These scenes were selected for this report because of their suitability for (1) demonstration of the current Earth sciences/remote sensing training and research programs being conducted at the University, (2) demonstration of the methodology of remote sensor imagery interpretation, and (3) presentation of preliminary results of a continuing National Science

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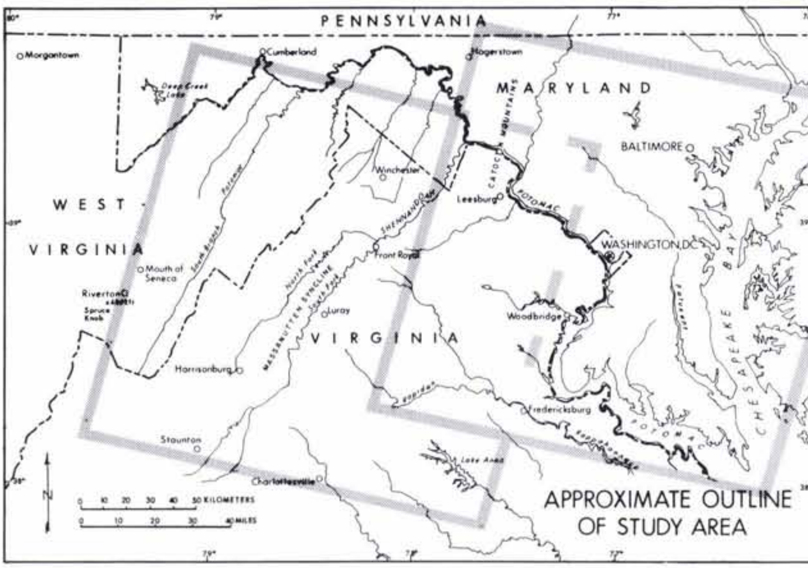

FIG. 1. Geography of the study area and approximate outline of the coverage of two Landsat frames used in the study. See the paragraph, Location of Study Area, for frame identification numbers.

Foundation research project. Of more general interest, the two Landsat scenes were selected because of their geographical coverage of the Washington metropolitan area, the site of the 1978 Annual Convention of the American Society of Photogrammetry (Rabchevsky, *et al.*, 1978).

LOCATION OF THE STUDY AREA

The study site encompasses the Washington metropolitan area and extends west to the eastern front of the Appalachian Plateau in West Virginia. Figure 1 illustrates the geographical boundaries of the study area and its coverage by the Landsat imagery (Figure 2).

The area covers the northern and central portions of the state of Virginia and the east-central margins of West Virginia, stretching across all of the Appalachian geomorphic provinces—the Coastal Plain, the Piedmont and the Triassic Basin, the Blue Ridge and Catoctin Mountains, the Great Shenandoah Valley, the Ridge and Valley province, and the Appalachian Plateau (Figure 3).

Over 90 percent of the land surface in this region is covered by woodland, forests, grasslands, and croplands, making direct interpretation of the imagery difficult. Deciduous hardwood forests and cultivated land prevail in the climatically temperate zones of central and eastern Virginia, while the folded Appalachians in West Virginia are covered by mixed deciduous and coniferous forest communities, more common to high latitudes and altitudes.

The rugged terrain of the folded Appalachians has made this region more difficult to develop than the other, topographically more subdued areas. For example, soils in the Valley and Ridge province tend to be thin and rocky and subject to continuous and at times intense erosion. On the other hand, the peneplained Great Valley and the Piedmont, including the Triassic Basin, are mantled by a thicker soil cover which support cultivated land, grassland, and patches of young woodland, almost totally covering this area.

The area is drained by the Potomac River Basin, with the South and North Forks of the Shenandoah River being the major tributaries of the Potomac (Figure 1). A consequent drainage pattern is developed over the peneplained Piedmont province, with structurally controlled trellis and rectangular drainage being prominent in the Ridge and Valley province. The flat-lying strata of the Appalachian Plateau are characterized by dendritic and pinnate drainage patterns.

REMOTE SENSOR IMAGERY PRODUCTS

Prior to ordering any types of imagery for the study area, the following sources were consulted for imagery availability: (1) EROS Data Center, Sioux Falls, South Dakota; (2) EROS Program Office, Reston, Virginia; (3) The National Cartographic Information Center, Reston, Virginia; (4) NASA, Landsat Browse Facility, Goddard Space Flight Center, Greenbelt, Maryland; (5) Biology Department, Imagery File, The American Uni-

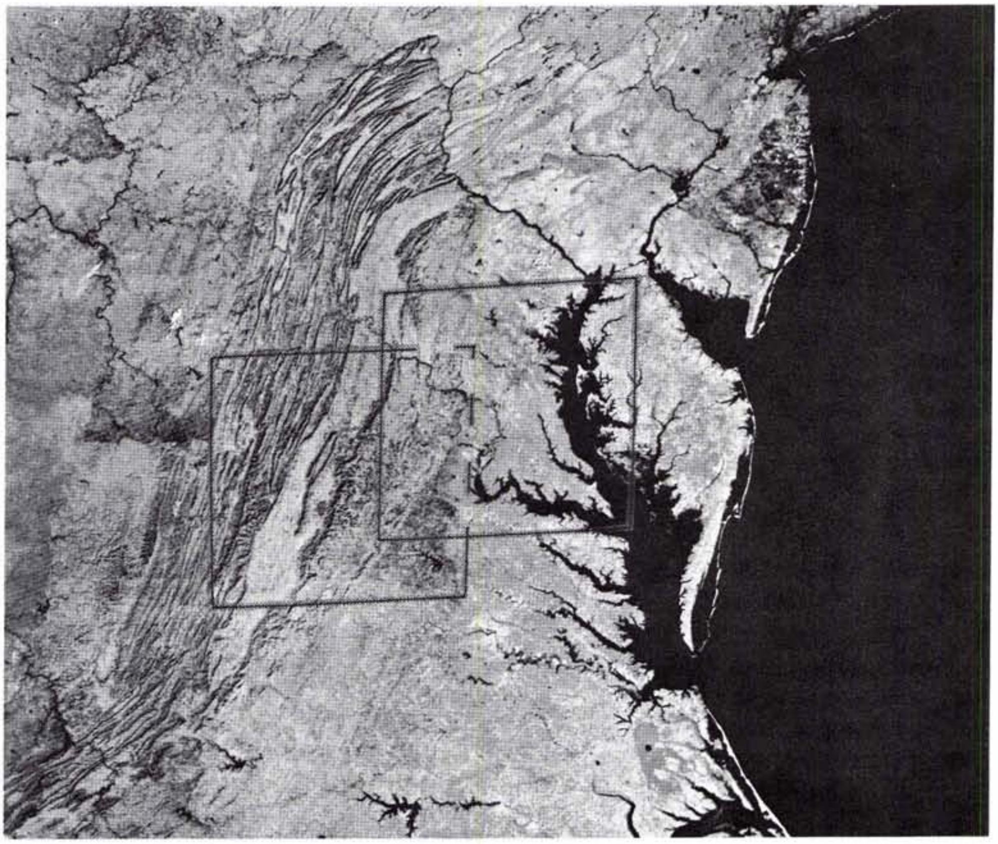

FIG. 2. Landsat color mosaic, black-and-white rendition, of the Appalachians, sheet 5 of the "Portrait U.S.A." mosaic (Bishop, 1976). Courtesy National Geographic Society.

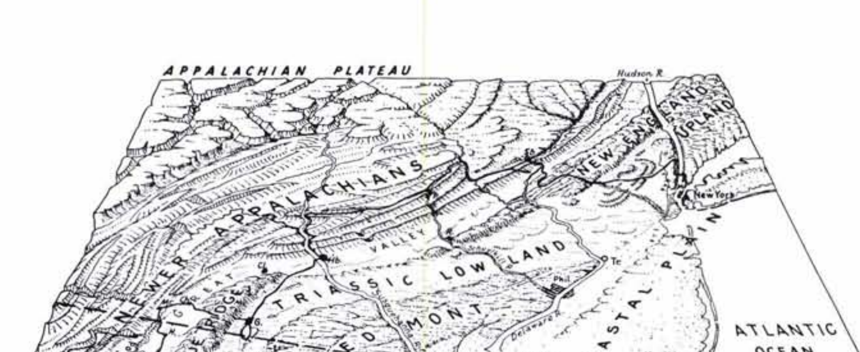

FIG. 3. Block diagram of the geomorphic provinces of the central Appalachians and the Atlantic Coastal Plain (Eardly, 1962).

versity, Washington, D.C.; (6) The World Bank, Cartography Division, Washington, D.C.; (7) The National Geographic Society, Cartographic Division, Washington, D.C.; and (8) various private companies and individuals. The imagery was evaluated by personal review when possible or on the basis of written descriptions. An attempt was made to acquire imagery other than Landsat that would be useful for the study, such as conventional aerial photography, high-altitude color infrared imagery, thermal infrared imagery, passive microwave imagery, side-looking airborne radar (SLAR), imagery from manned space missions, meteorological satellites, and airborne geophysical data. Due to either the lack of areal coverage or to the lack of response from the various imagery sources, this attempt was unsuccessful. Of all the various types of imagery mentioned, only the high-altitude aircraft color infrared was used in the study as a complement to the Landsat imagery. In conclusion, the availability of various types of imagery was not as good as would be expected over such a well-known area as the one described in this report.

The following remote sensor imagery and products were used:

(1) Landsat Satellite Imagery (EROS)
  (a) Winter Season Coverage:
  Washington, D.C. frame ID Nos.:
  1080 - 15199, 4 Oct. 72
  1440 - 15175, 6 Oct. 73
  1080 - 15192, 11 Oct. 73
  1854 - 15065, 24 Nov. 74
  1170 - 15193, 9 Jan. 73
  2742 - 14534, 2 Feb. 77

  West Virginia frame ID NO.:
  1495 - 15225, 30 Nov. 73

  (b) Spring Season Coverage:
  Washington, D.C. frame ID Nos.:
  2076 - 15080, 8 Apr. 75
  2814 - 14502, 15 Apr. 77
  2094 - 15075, 26 Apr. 75

  West Virginia frame ID Nos.:
  1243 - 15260, 23 Mar. 73
  2473 - 15081, 9 May 76

  (c) Landsat Mosaic, Sheet 5 of the Landsat Mosaic of the United States (Figure 2), published by the National Geographic Society (Bishop, 1976).

(2) High-Altitude Aircraft Imagery
  (a) Spring Season Coverage:
  Washington, D.C. frame/photo ID Nos.: (EROS)
  8166/5740017088166, 25 April, 74
  8187/5740017188181, 25 April, 74

  (b) Fall Season Coverage:
  Washington, D.C. frame ID Nos.:
  (Biology Department, American University)
  223 - 235, 20 Sept. 70
  (Job Order 1002 TF, Site 244, Mission 144, Flight No. 5)

The Landsat imagery was available in the following products and formats: black-and-white prints and transparencies, standard false color composites and transparencies, optically enhanced color composites and transparencies, and computer processed color composites.

Imagery Processing and Interpretation Approach

All Landsat imagery was purchased from the EROS Data Center and was in the 70-mm format, black-and-white positive transparencies (chips), at the scale of 1:3,369,000. Black-and-white prints and false color composites and transparencies were then produced at various scales directly from the chips. The conventional Kodak color processing/printing procedure and the Cibachrome method, (White *et al.*, 1973; Rabchevsky, 1976) were used in the production of Landsat false color composites. In most instances, the International Imaging System (I^2S) Multispectral Viewer was used to preview the imagery and to determine the selection of the band/filter combination best suited for the interpretation. Some of the composites were produced directly from the viewer, using the photo-head attachment.

The winter/fall-summer/spring coverage was selected to aid the interpretation of this heavily vegetated area. There are a number of advantages in using multiseasonal coverage for geologic interpretations:

> (1) *Direction of the Sun.* Solar elevation and azimuth both change seasonally. At any given hour of the day, the angle of the sun above the horizon is lower in winter than in summer, providing longer shadows which accentuate topographic forms and relief. This winter enhancement of relief is especially helpful to interpretation if the surface morphology is flat or subtle.
>
> Interpretation is also made easier and more reliable by the changing direction of shadows. Because of the seasonal variations in the astronomical relationship between the Earth and the sun, the sun moves progressively clockwise (southward) on the Landsat coverage of the area between summer and winter. The azimuth changes from approximately

118° in the summer to approximately 150° in the winter.

The changing solar elevation and azimuth also have a photogrammetric and spectral reflectance effect on topography and surface cover materials, but these will not be discussed in this report.

(2) *Look Direction.* Small changes in the orbit and attitude of Landsat provide a stereoscopic effect due to parallax when winter and summer frames of a given area are viewed simultaneously. This effect is enhanced by the changes discussed in Item 1 above.

(3) *Vegetation.* Summer vegetation cover is at times also useful in mapping lithological and soil boundaries. For example, the summer coverage showed spectral signature differences in the Triassic basin area which were not so apparent as the winter coverage. Such a geobotanical prospecting approach may be well adopted to the Landsat seasonal coverage, especially for computer classifications of surface covers.

In addition to the multi-seasonal coverage, the Landsat imagery was also processed at various scales: 1:2,5000,000; 1:1,000,000; 1:500,000; and 1:250,000. It is now well known that multi-seasonal and multi-scalar interpretations are useful for regional geologic applications (Rabchevsky, 1970).

All remote sensor imagery was interpreted following conventional photo-interpretation procedures (Von Bandat, 1962; Bowden and Pruitt, 1975), with a few new approaches as described above. As mechanical aids, various stereoscopes, scale-changing equipment, a multispectral viewer, and a density slicing system were used during the imagery analysis. Computer classification programs and digitally enhanced imagery were too costly and thus not used in the study.

In parallel with the direct interpretation of the imagery, correlative overlays were prepared, each overlay displaying a distinct set of information such as lithologic boundaries, structural features, geomorphology, drainage, cultural features, and so forth. Most of this information was transferred from published maps using either a Kargl scale-changing projector, a Mapograph, a Zoom-Transfer Scope, or by photographic means. The correlative overlays thus produced served not only as guides in the geologic interpretation of the imagery, but also as reference and orientation guides during the field verification of the interpreted results.

Following the image interpretation phase, field work was planned to verify the interpretations and check anomalous areas. As is usual, geologically well-known localities were also visited for comparison purposes and referencing. Field notes and observations, sample collections, and ground photography were the types of information/ground truthing data assimilated at each field station. Most of the field stations were selected from the imagery; other stops were made on an as-needed basis while in the field and then cross-referenced back to the imagery.

Direct interpretation of the imagery, without the correlative overlays prepared from existing published sources as well as field work, would have been very difficult in this study area. All interpreted Landsat overlays were thus a result of multi-stage approach, proceeding from known and published data to the new interpreted products.

Results of Interpretation

Delineation of Geomorphic Provinces

Not all of the Appalachian physiographic provinces were easily identifiable on the Landsat imagery. For example, the Coastal Plain boundary was least easily identified on the imagery; the provinces most readily recognized on the imagery are the Appalachian Plateau, the folded Appalachians—the Ridge and Valley province, the Ordovician Great Valley, the Blue Ridge Mountains, and even portions of the Triassic Basin stand out well and are easily recognized. The winter season coverage was best for the delineation of the different geomorphic provinces. Within the Great Valley, the synclinal Devonian/Silurian Massanutten Mountain can be easily outlined directly from the imagery, on both the winter and the summer season coverage.

The boundary between the Coastal Plain and the Piedmont is least evident and can be delineated only by correlation with existing geomorphological maps. The Triassic Basin, located within the Piedmont province, can be delineated only in some places, its eastern boundary being the most easily identifiable.

In conclusion, the geomorphic provinces most readily identifiable from the Landsat imagery corresponded directly with (1) abrupt changes in topography and structural geology, (2) abrupt changes in lithologies, and (3) vegetational and land-use patterns. Seasonal coverage was useful in identifying geomorphic boundaries more precisely in that vegetation changes tended to highlight the topography and land-use patterns.

Discrimination of Major Lithological Units

The general geology of the study area partly corresponds and correlates with the

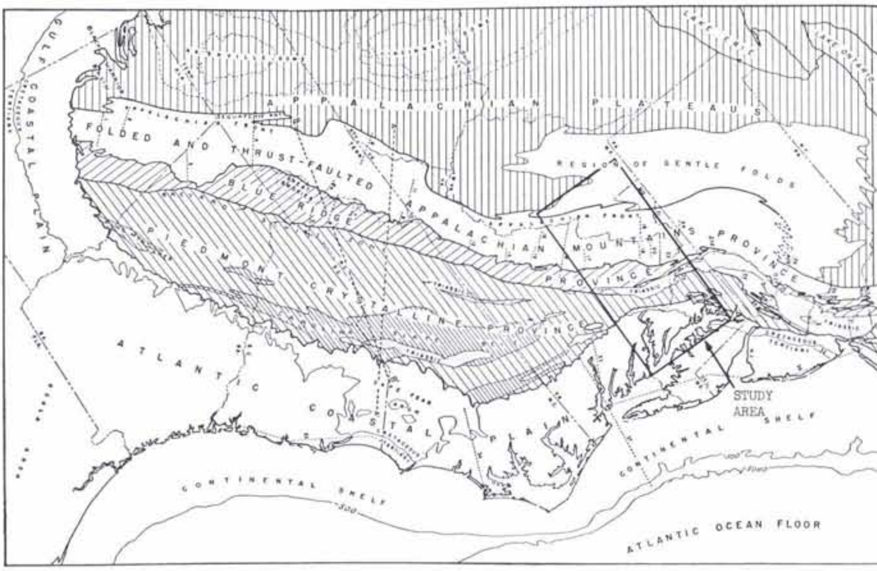

FIG. 4. Index map of the structural systems of the eastern margin of the United States (Eardly, 1962).

geomorphological provinces (Figure 4): The youngest unconsolidated Tertiary sediments are confined mostly to the Coastal Plain; the Piedmont is underlain by Precambrian metamorphic and igneous complexes; the Blue Ridge is supported by resistant Precambrian metavolcanics and the well known "Skyline Greenstones," the Catoctin Mountains being part of this same complex; and the Triassic sandstones and intrusives are located within the Piedmont province but cannot always be directly identified on the imagery. Within the Triassic Basin, denser vegetation generally correlates with the diabases, while pastures and croplands correspond to the Triassic sandstones and shales.

Because of their lesser resistance to erosion, the Ordovician Trenton limestones and Martinsburg shales highlight the Great Valley. The more resistant Silurian sandstones form the ridges of the Massanutten syncline and can be easily outlined. The outcropping Ordovician limestones in the Great Valley form hogbacks (Figure 5) that are clearly discernible in the imagery as northeast-southwest trending dark linear features. The Ridge and Valley province stands out distinctly on all scales and seasonal renditions of the Landsat imagery. This is because this province has a prominent topographical break with the Great Valley and consists of a series of tightly folded anticlines and synclines. These folds are made up of a series of resistant lithological sequences such as limestones and sandstones, ranging in age from Ordovician to Pennsylvanian. For example, the Mississippian Pocono sandstones and the Pennsylvania Pottsville conglomerates top most of the highest ridges, the Silurian Clinton/Medina/Tuscarora sandstones and the Devonian Helderberg limestones and Oriscany sandstones support the flanks of the ridges, while the Devonian shales and Ordovician limestones underlie most of the valley bottoms.

In our study it was almost impossible to directly identify the various lithological types, except that the ridges correlated with the more resistant rocks and the valleys were underlain by less resistant ones, such as shales; limestones occurred both as ridge

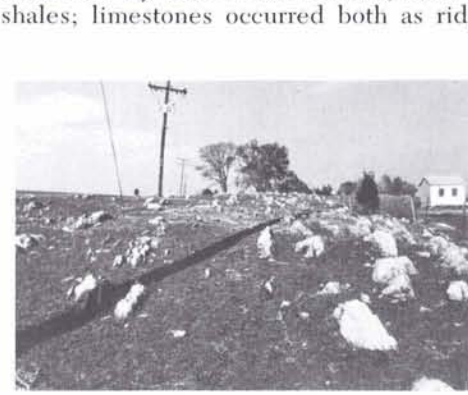

FIG. 5. Northeastward view, just east of Harrisonburg, of Ordovician limestone hogbacks exposed in the Shenandoah (Great) Valley of Virginia. These limestone ledges appear as a series of parallel dark bands on the Landsat imagery.

makers in the Ridge and Valley province and as valley floors in the Great Valley province; sandstones always supported the flanks of ridges or capped them. The Triassic diabase dikes and sills could also not be directly identified either in the Ridge and Valley or Great Valley province, perhaps simply because of poor exposures and small dimensions, too small to be discerned by the Landsat sensors. The same diabase, however, could be correlated to some extent with the vegetation patterns in the Piedmont province, because of their greater areal extent and weathering characteristics. The eastern slope of the Appalachian Plateau roughly correspond to the snow lines on the winter imagery and to a vegetation boundary on the spring imagery, but little could be said about its lithological character.

Identification of Major Structural Geological Features

As briefly discussed in the previous sections, the regional multi-scaler perspective and seasonal coverage afforded by the Landsat imagery were effective in delineating all of the geomorphic units within the study area. The synoptic view of the entire Appalachian system, as partly illustrated in Figure 2, provided a unique look at this region in relation to its surroundings. Not only was it possible to identify the various Appalachian provinces as described, but the entire Appalachian orogen could be visualized, stretching from New England to the Georgia-Alabama borders (Figure 6). Such a regional perspective is extremely useful in the formulation of the structural history and geologic evolution of basins and uplifts. For example, the major regional bends in the Appalachian chain, its major structural entities such as the Adirondacks, the Great Valley, the Blue Ridge, the Cumberland Overthrust block, the Great Smokey Mountains, etc., and major fractures and folds could be easily mapped directly from the imagery.

Prior to the preparation of new structural overlays for the study area, overlays were prepared showing the occurrence of known structural features such as anticlines, synclines, and faults. The multi-scale and multi-season imagery was then interpreted for the purpose of identifying other lineaments. The interpreted lineaments were then correlated with the known fracture patterns and checked in the field, when possible.

It is generally accepted by most geologists that many of the lineaments identified from Landsat imagery cannot always be verified

FIG. 6. Tectonic sketch of the Appalachian Mountains in the United States (Spencer, 1969).

on the ground and can be seen only from the air. In our study some lineaments were substantiated on the ground, especially where they intersected regional strikes of formations. At such locations, the following field geologic data was observed and recorded: (1) dip and strike of formations; (2) presence of dislocations within formations; (3) presence and orientation of water and wind gaps; (4) stream dislocation and trends; and (5) the topographic relation of the locality to other areas through which the same lineament was expected to continue.

The interpreted imagery generated many previously unmapped lineaments. Most of those were of regional extent crossing at times many geomorphological provinces and geological units and structures. Because of their magnitude many could not be effectively verified on the ground. In our preliminary study we were able to find concrete evidence of dislocations that corresponded to the interpreted lineaments only at few localities.

Our preliminary study shows that (1) Landsat imagery is useful for the mapping of transverse fractures and strike-slip (transform) faults or lineaments that cut across the regional trend of major structural features and geologic units; (2) the identification and mapping of longitudinal faults is difficult without secondary or tertiary evidence; (3) because of the East-West scanlines present in Landsat imagery, the East-West lineaments are difficult to map or recognize with certainty; (4) because of the direction of the sun's illumination, some interpreters may tend to "overemphasize/overinterpret" the Northeast-Southwest trending lineaments, and to neglect the East-West and the Northwest-Southeast trends; (5) Landsat imagery is more suited for the mapping of regional structural trends than for mapping small fractures; and (6) the structural information obtained from the interpretation of Landsat imagery adds significantly to the formulation of concepts pertinent to the determination of local and regional stress fields, contributing directly to an understanding of the geologic history and evolution of the study area.

Correlation of Mineral Occurrences with Interpreted Data

The Appalachian region is geologically complex and contains a great variety of mineral resources. Each Appalachian physiographic province features a variety of rock types and mineral deposits of different ages and modes of formation. For example, the Piedmont and Blue Ridge provinces are underlain by Precambrian and Triassic igneous intrusive and metamorphic rocks which host a large number of ore and mineral deposits, including barite, copper, zinc, gold, etc. (U.S. Geological Survey and U.S. Bureau of Mines, 1968), while the Ridge and Valley province consists of folded and faulted sedimentary rocks containing sedimentary deposits as well as residual and low temperature hydrothermal metalliferous deposits such as lead, iron, manganese; and the Appalachian Plateau province is underlain by flat-lying sedimentary rocks ranging in age from Mississippian to Permian, containing large bituminous coal measures and even some hydrothermally deposited uranium resources.

A number of ore deposits are known or are suspected to be localized along lineaments, or along intersections of lineaments, or to be near the perifery of circular features that may be of igneous origin. Because Landsat is extremely useful in mapping regional lineaments, it is now being used more frequently as a first step in mineral exploration. Our interpretations concentrated on the intersections of major Landsat lineaments and the correlation of these lineaments with known or suspect ore deposits or mineral occurrences.

For the purpose of this presentation, overlays were prepared of the occurrence of only a few mineral types, which were then compared to the trends of the interpreted Landsat lineaments. The two minerals discussed are fluorite and manganese, because of their occurrence in the study area and because of their distinctly different modes of formation and association.

Fluorite. Fluorite occurs in fissure veins and as replacement beds in limestone and dolomites. In the area of study it occurs in association with calcite and perhaps galena (presently under investigation) in veins injected into the Ordovician Trenton limestone. Fluorite is usually a hydrothermal mineral and may be found both in igneous rocks as well as in carbonates. The Illinois-Kentucky mining district of the Appalachians is the largest and most productive fluorspar district in the world (Bateman, 1959). This mineral is well suited for Landsat lineament analysis, because the fluorite-bearing fissure veins may have been intruded through a thick stratigraphical column along fracture zones that now have a surficial expression and can be identified on the imagery.

During the field verification phase of this study, a fluorite occurrence was visited that was not previously mapped (Worl *et al.*, 1974). That locality was observed in the field, samples of fluorite were collected, and readings were recorded of the major joints in the area along which mineralization also

FIG. 7. Germany Valley Limestone Company quarry, north of Riverton, West Virginia. The horizontal Ordovician beds shown here form the core of this anticline, with thick flourite and lead (?) bearing calcite veins occurring between the bedding planes.

FIG. 8. Westward view from the Germany Valley quarry, showing the gap in the Silurian sandstone ridge in the background and the vertical calcite veins intruded along the joint through the Ordovician limestone. Field measurements of the joints indicated a compressive stress (sigma 1) of approximately north 70° west to southeast with the complementary extension (fold) axis (sigma 3) running in a north 20° east to southwest direction.

seems to be occurring (Figures 7 and 8). This fluorite calcite locality occurs in the Germany Valley Limestone Company quarry, north of Riverton, West Virginia (Teleki, 1977) (Figure 1). From the preliminary analysis of the Landsat imagery and geologic field work, the direct relationship between the fluorite occurrence and its location along interpreted lineaments cannot be established with certainty. Some of the fluorite occurrences are concentrated at the intersection of the Appalachian orogen by transverse fractures, but others could not be directly related to any lineament pattern (Figure 9).

Manganese. Manganese occurs primarily in three types of deposits in the Appalachians: (1) in veins or beds; (2) in residual clays and weathered sedimentary rocks; and (3) in schists, as manganese silicates. In the area of study the occurrence is primarily in clays and weathered sedimentary rocks. However, the manganese-bearing formations are poorly exposed and occur at erratic intervals, so that systematic sampling or prospecting is difficult. For example, it is still not known if the occurrence of manganese in carbonates is relatively constant along strike. It is obvious that buried deposits could be more easily located if their distribution was constant along strike.

Because some of the manganese deposits occurring in clay are buried under talus and are covered by colluvium, the published map of manganese localities in the study area (U.S. Geological Survey and U.S. Bureau of Mines, 1968) was compared to the distribution of Landsat lineaments (Figure 9). Most of the interpreted lineaments pass through areas of structural offset zones of weakness, producing either water/wind gaps or accumulation of debris such as talus and colluvium fans. The preliminary correlation of manganese occurrences with Landsat lineaments shows that (1) it is possible to locate at least one lineament passing through a mapped manganese locality; (2) most such

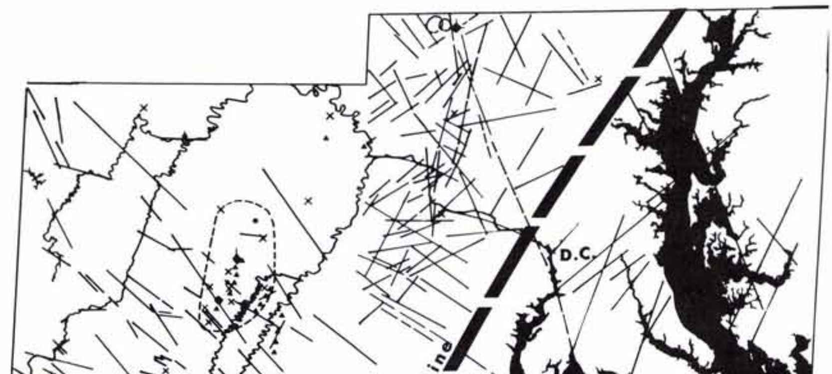

FIG. 9. An interpretive overlay showing the relation of the Landsat lineaments and the occurrence of fluorite (crosses) and manganese (triangles). The heavy dashed northeast-southwest line shows the approximate location of the Fall Line. See Figure 1 for the location map.

lineaments are short and may not be the direct cause of the concentration/formation of the deposit through fluid/mineral migration; (3) almost none of the occurrences were aligned along any of the long lineaments or a fracture trend; and (4) the published map used for correlation was inadequate and a large-scale detailed map is needed for more definitive conclusions.

As in the case of fluorite, the sole criterion of coincidence of a manganese mineral occurrence along or at the intersections of Landsat lineaments may be insufficient for the location of new mineral targets in other areas along the lineament. Other criteria need to be considered for their usefulness, such as (1) the relative ages of the Landsat identified lineaments; (2) the vertical extent (depth) of the interpreted lineaments; (3) the relationship of regional stress fields and plate motion to the present distribution of the deposits; and (4) the stratigraphic relationship of localities to the regional geologic history of the entire area. Another consideration may be that not all mineral and ore deposits can be directly correlated with lineaments identified on Landsat imagery. Mineral-bearing fluids that tend to migrate along veins, especially along the deep seated vertical faults, or minerals of magnatic origin, may be more suited for such a prospecting approach than are minerals of sedimentary or even replacement origin.

Conclusion

As pointed out in several instances throughout this presentation, Landsat imagery is definitely useful for regional geologic reconnaissance, provided the user is familiar with the subject matter, the Landsat system, and imagery specifications. Field verification of interpreted results is definitely an integral part of the imagery interpretation task. For example, illustrating the occurrence of Landsat lineaments in the study area and their correlation with known or suspected mineral occurrences is as yet inconclusive. The few instances in which there is direct correlation between lineaments and mineral occurrences may be only of local significance and the regional picture has yet to be determined.

All of the imagery used in this study consisted of Landsat data. Unfortunately, other types of imagery were non-existant, of poor quality, expensive, or inadequate for the study. The Landsat imagery provides information only in the reflected region of the electromagnetic spectrum and at a resolution insufficient for detailed prospecting requirements. Interpretations of such imagery will result in information in only the "horizontal" plane, such as lineaments, without any depth penetration. Thermal, passive microwave, SLAR, and other types of imagery must be examined together with Landsat imagery for a conclusive evaluation of such technology to mineral exploration potentials.

Acknowledgment

This preliminary report describes research currently being conducted at the American University as part of a National Science Foundation (NSF) grant. The NSF study is entitled "Application of Plate Tectonics to the Location of New Mineral Tergets in the Appalachians." Drs. Jan Kutina and George Rabchevsky (1977) are the principal investigators of the study. The co-authors, Messrs. Ulrich Boegli and Juan Valdes, are graduate students at the University enrolled in the remote sensing program being directed by Dr. Rabchevsky. Under his direction they assist the principal investigators, as graduate student research assistants, in the performance of the subject study.

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BOOK REVIEWS

Forest Inventory with Landsat, by Roger A. Harding and Robert B. Scott. State of Washington, Department of Natural Resources, Olympia, Washington, 221 pages, 65 illustrations, paper cover, 1978, no charge.

THIS BOOK is a report of the Landsat Multistage Forest Inventory portion of a contract to the Pacific Northwest Regional Commission entitled, *Washington Forest Productivity Study, Phase II*. The 88-page text is organized in 11 sections beginning with an Introduction summarizing the steps and processes followed in developing the inventory project. The text ends with a summary of observations, knowledge, and experience gained during the three-year study. These are cleverly presented by posing questions which the authors answer. Although this section is well done, there are instances where the authors seem carried away by their own optimism in view of the statistical results of their project.

Sandwiched between the Introduction and Summary are nine sections which take the reader through Project Planning and Development Tests, Test Areas, Landsat Data and Signature Development, Sample Allocation and Selection, Ground and Air Photo Data Collection, Digitizing Ownership, Availability of Image Analysis Equipment, Statistical Summary, and Numerical Analysis and Statistical Results. The authors have done a fine job in providing the reader with details of an unorthodox forest inventory with a minimum of errors. It is unfortunate that large errors in acreages by land ownership categories reported in the results could not be adequately explained. These discrepancies put other statistics in doubt. However, the authors admit that "Operationally, the inventory project left something to be desired, but as a demonstration it was a smashing success."

This book illustrates the complexities of digital image analysis of a Landsat-based large-area resource inventory, and gives recommendations for improving statistical estimates. Following the text are several Appendixes detailing procedures used. A 38-page Glossary of statistical, remote sensing, and image processing terms and terminology will help the reader make the transformation from a conventional forest inventory to a Landsat digital-based multi-stage forest inventory.

Despite some reservations regarding the statistical results and summary statements, I feel this book will be a valuable addition to the libraries of remote sensing, photogrammetry, and resource inventory specialists.

—Robert C. Aldrich
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