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GEOLOGIC LANDFORM ANALYSIS IN THE CENTRAL PIEDMONT OF VIRGINIA AND NORTH CAROLINA

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16. Abstract ERTS-1 imagery in the central Piedmont of Va. and N.C. reveals some geologic structures in the Precambrian and Paleozoic metamorphic terrain. These structures include: 1) a major synform north of Danville, Va., 2) structures in the metavolcanic Carolina slate belt principally near the confluence of the Dan and Roanoke Rivers and near the Albemarle area in central N.C., 3) structures involving the muscovitic Fork Mtn. Formation near Martinsville, Va., 4) post-metamorphic cleavages and faults that are widely distributed, 5) elliptical false structures possibly related to weathering and erosion of coarsely crystalline igneous and metamorphic terrains, and 6) Triassic basins. ERTS-1 immagery in this area yields information on geologic structure generally comparable to 1:250,000 AMS Maps. Doubling the resolution and providing stereoscopic overlap would increase the geologic usefulness of these photographs many fold. Post-metamorphic structures tend to show up better than syn- and pre-metamorphic structures, and ERTS photographs are valuable for scanning large areas for these late structural effects.

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Figure 2. Technical Report Standard Title Page

Contents

Geological Landform Analysis of Lithologic and Structural Units in the Central Piedmont of Virginia and North Carolina

Introduction

This report concerns progress in identifying and interpreting ERTS 1 images of landforms in the region encompassed by the Army Map Service Map MJ17-12, Series V501P, Greensboro, N. C. - Va. 2° sheet. The Greensboro 2° map is bounded by lat. 36° to 37°, and long. 78° to 80°, and is the area of the author's ongoing geologic mapping program. Other landforms in the Albemarle, N.C. area south and southwest of the sheet are also interpreted.

Objectives

The primary objective of the project was geological landform analysis of lithologic and structural units in the Greensboro 2° map area of the Piedmont of Virginia and North Carolina. It was also deemed desireable to determine the potential of ERTS data for speeding up acquisition of structural, stratigraphic and perhaps other kinds of geologic mapping data in this kind of terrane.

Because of deep soil and vegetation cover over 99 percent of the area, lithologic units and geologic structures were considered to be potentially observable only indirectly by ERTS photography. The hope, that soil and vegetation might differ in response to different geologic units underlying them, was realized to only a limited extent through ERTS photography in the area under investigation.

In the Valley and Ridge and Blue Ridge Provinces of the Appalachian mountain system varying resistances of rock units to weathering commonly results in etching out the structural grain of a geologic province so that topographic analysis of remote sensing data can yield a vast amount of structural information. In the Piedmont Province, however, most of the geologic units weather at about the same rate and the topographic expression of geologic units and structures is only very obscurely brought out. Although it was recognized that this would be a most difficult test of ERTS resolution, the added advantage of the synoptic view of a large area, and the fact that the photos would be available in any event made the investigation seem worthwhile. The discrimination of these subtle topographic lineaments reflecting geologic units and structures was accomplished with limited success during the investigation.

Techniques

The approach to interpretation was simple and straightforward visual scanning of MSS imagery for evidence of geologic structure. Apparent enhancement of imagery and improvement in resolution of geologically interesting features was obtained, 1) by stereoscopically viewing areas of overlap between adjacent photos, 2) by "stereoscopically" viewing two photos of the same area each photo taken during different seasons of the year.

Discrimination of topography is enhanced by, 1) shadowing because of low sun angle, 2) cultivation by man (i.e. broad ridges and flat lands are in pasture and crops, whereas steeper hills and stream bottoms are forested, 3) snow or frost capping of ridges, and 4) lighter colored rock and soil (locally) defining the surface distribution of a rock unit.

False color composits were prepared by the Diazo Specialty Co. Process using yellow for band 4, magenta for band 5, and cyan for band 7. The composits were prepared in the U.S.G.S. EROS Project Offices in Washington, D.C. through the courtesy of Dr. William R. Hemphill. Excessive density of many of the original MSS photos precluded using the Diazo Process for most of the imagery obtained. Good results were obtained in the Diazo Process for images E-1244-15321 and E-1243-15262 taken on March 23, 1973. No additional data of use in structural interpretation was gleaned from the Process, and it was not tried again. In my opinion, for the area studied, as much data is derived from visual scanning of the shades of grey in the positive transparency format as can be derived from the Diazo Process.

Data furnished by NASA for this investigation consisted of bulk MSS 9.5 inch black and white positive transparancies and paper prints in NDPF spectral bands 4, 5, 6, and 7 when less than 30 percent cloued cover existed. Additionally a strip of 70 mm (bands 4, 5, 6, 7) black and white transparancies was flown by U-2 out of Ames Airforce Base along the Virginia-North Carolina line in the Greensboro 2° quadrangle. The 70 mm strip revealed nothing of importance to the structural and stratigraphic geology of the region, because it passed over areas of minimum relief. Existing color IR and thermal IR imagery from NASA Mission 121, Site 125 covered a small area over the Roxboro Reservoir in the central Greensboro 2° map. The color IR and thermal IR revealed nothing of geologic importance.

Eleven days of field work was spent in the Greensboro 2° map area primarily in verifying the existence of the Republican Grove Synform (described below), checking out the "false structures" (described below), and the areas of lineations (F) shown in figure 1. Four days were spent in transit and visiting the EROS Project Office of the U.S.G.S in Washington, D.C. There I conferred with experts on the project about problems of interpreting ERTS data and employed their Diazo Process machine.

As explained in the following pages I consider the MSS ERTS data to have significant though limited utility in studying areas similar to the central Piedmont of Virginia and North Carolina. The general utility lies in scanning the photos for major structural features over large areas before beginning regional mapping projects. Post-metamorphic structures are generally more prominent in the photos than pre-metamorphic structures.

Republican Grove Synform

This is a newly discovered major structure (Fig. 1, A) in the Piedmont named for the community of Republican Grove near its northern terminus. It exceeds five miles in width and 20 miles in length, closure being apparent only on the northern end. The term synform is herein used as a descriptor, rather than syncline, because it is presently indeterminate whether the youngest or oldest rocks occur in the center of the structure. Geometrically, however, it is a downfold of synclinal shape. Field work supported by this project has demonstrated the synformal nature of the structure, and has revealed that the metamorphic rocks in the fold have compositional layering generally parallel to schistosity. Schistosity and compositional layering curve around the northern nose of the fold, and a well developed axial plane cleavage of the synform has not been found. Thus the synform appears to result from a late folding event that refolded already metamorphically deformed and schistose rocks.

Subtle reflection in the topography of compositional layering in the structure is primarily responsible for its appearance in the ERTS 1 imagery on photo 1243-15262-6 taken on 23 March 1973. The image of the structure is enhanced by land clearing, road building, and culture which are located preferentially on the higher and flatter portions of the ridge crests.

The structure can also be seen on the Greensboro 2° map (1:250,000 scale) where its topographic expression compares favorably with that on the ERTS-1 photos. The topographic map of the Riceville, Va. area (1:62,500) also shows the structure well expressed in topography, and culture location. The ERTS-1 image does not yield as much information about the structure as does the 1:62,500 map. ERTS data has focused attention on the area and led to the discovery of this structure by the geological community. However, the structure could easily have been discovered from existing 1:62,500 maps, and it might have been discovered from existing 1:250,000 maps.

False Structures

On photographs E-1243-15262 and E-1243-15265-6 taken on March 23, 1973, four circular to elliptical lineation patterns have been recognized (fig. 1).

Feature I on photo E-1243-15265-6 (fig. 1) is underlain by a heterogeneous sequence of generally coarse grained metavolcanics and metaintrusive rocks that strike northeasterly through the feature. Land clearing and cultural features contribute most to the production of the false structure image, and in this case bear complex (or random) relations to the geology. The drainage pattern is subparallel northward through the feature and is crossed by a crude annular component near the southern margin. The annular component is convex southward and parallels the general strike of schistosity and compositional layering.

Feature B on figure 1 is another false structure of elliptical pattern. Field checking demonstrated that the lineation pattern is underlain by uniform granitic rock whose contacts and structure are not reflected in the topography.

Feature D is another area of obscure annular topographic lineation. Drainage is crudely radial away from the center. Coarse grained biotite and hornblende gneiss underlie feature D according to the Geologic Map of Virginia (1963).

Feature E is the largest of these areas of annular lineation within the boundaries of the Greensboro 2° map. According to the Geologic Map of Virginia, and confirmed in part by reconnaissance during this investigation, it is underlain by a complex of coarse grained granite, granite gneiss, "greenstone", and schistose volcanics. The eastern boundary of the feature, shown by a dashed NNE trending line on figure 1, is well within the area of Carolina slate belt volcanics shown on the Virginia Geologic Map. Reconnaissance in the area suggests that the map is quite generalized because granitic gneisses as well as coarse grained metavolcanic rocks of amphibolite facies occur over much of the area mapped as "volcanic". Thus coarse grained gneisses appear to be the dominant rock type underlying this as well as the other elliptical lineation false structures. The drainage pattern over the feature is dominantly radial with minor annular components.

From the foregoing it seems that crudely radial drainage patterns with intertributary ridges and streams contributing an annular component to the topographic expression create the false structures of this part of the Piedmont. They are not related to any single geologic unit or large structure. They tend to form where coarse grained rocks of metamorphic and igneous origin crop out. Thus they may be more nearly an indicator of coarse grain size and indirectly therefore of intermediate to high grade metamorphic terrains.

Triassic Basins and Adjacent Gneisses

Three Triassic basins (feature C) are recognized on photograph E-1243-15262-7 of figure 1. The two easternmost are recognized by uniformly low reflectance. The third and westernmost basin is not as easily distinguished from adjacent rock by tonal value. It does however have a conspicuous ridge of sandstone within it striking NE parallel to the trend of the feature. Assymetry of the ridge indicates gently westward dipping strata.

The relatively featureless area G on figure 1 is underlain by coarse grained gneisses of very complex structure. The gneisses are coarse grained biotite-quartz-feldspar, hornblende-feldspar, and intermediate biotite-hornblende-quartz-feldspar rocks that exhibit little tendency to weather according to compositional variations. The minor schistose layers have insignificant topographic expression, therefore the complex structure of the area is not revealed.

Carolina Slate Belt

Structures in the volcanic-rich Carolina slate belt are conspicuous only near the confluence of the Dan and Roanoke Rivers in the southeastern part of photograph E-1243-15262-7. In this area the greenstones (Gs), metamorphosed basaltic volcanic rocks, underlie low topographic ridges that are generally about 50 feet higher than the surrounding metamorphosed mud-stones and sandstones (As). The greenstones were mapped by Laney (1917) as the Virgilinia greenstone (Gs on figure 1) and the mudstones as Aaron slate (As). Fine grained and thinly bedded argillite (Arg) occupies the low lying axial region of this synclinorial feature. Metamorphosed rhyodacitic pyroclastic rocks (Hy) occur along the flanks of the synclinorium and they are the rocks mapped as Hyco quartz porphyry by Laney (1917). Coarse grained granitic and gabbroic intrusive rocks (Pl) occur at the confluence of the river. Only the boundaries of the greenstones could have been mapped on this photograph without reference to existing geologic maps. A much more accurate job could be done using existing topographic maps at 1:62,500 and larger scales.

In the southeastern corner of photograph E-1243-15262 shown on Fig. 1, the area F contains a moderately conspicuous pattern of NNE-trending lineations. This area is not mapped geologically. The lineation is parallel to both the dominant strike of compositional layering and to schistosity in nearby areas of better known geology.

An area lying south of 36° lat. and centered on 80° long. (figure 2) shows remarkable reflection of geologic units and structure in photograph E-1099-15261-7 taken on 30 October 1972. Although the area lies outside of the Greensboro, N.C. 2° AMS quadrangle, of principal concern to the investigator, it was studied because the results could be checked by detailed geologic maps already in existence (Conley, 1962, Stromquist, et al, 1971). This is one of the rare cases near the project area where tonal differences directly related to rock type are manifest. Abundant very light colored rhyolitic volcanic rocks here are resistant to weathering. The combination produced topographic ridges and hills on which light colored soil (?) and rock produce a higher reflectance. A number of structural lineaments and part of the Triassic basin are also evident.

These features are described in order below.

Unit A on the overlay (figure 2) shows abundant light-toned hills that are underlain by rhyolitic material. It comprises the Uwharrie Formation of Stromquist (1971). The formation is folded into an anticline whose axis plunges gently SW, and the nose of the fold is clearly evident on the photograph. Another anticlinal nose to the SE is suggested on the photograph and is confirmed by the Geologic Map of North Carolina (1958). This latter anticline appears to be faulted along its SE margin, as suggested by lineations marked f? on the overlay. Other lineations marked f? also lie to the NNE along the main fold axis, although those could be caused by the axial plane cleavage. Lineations marked S_1 and S_2 are also probably structural cleavage, those in the nose of the fold correspond to a set observed by Conley (1962). The distribution of the rhyolitic rock as suggested by the photo pattern indicates that it may grade downward stratigraphically into less resistant and perhaps less rhyolitic material, alternatively there may be a lateral facies change toward the east.

Unit B overlies unit A and this comprises the Tillery and Cid Formations of Stromquist (1971). Easily weathered volcanogenic mudstones and tuffs make up much of unit B but irregularly shaped masses of rhyolitic material (C) are evident as light-tones topographic highs roughly conformable with the strike of unit B. This conformity of rhyolites (C) with unit B is evidence that C is part of B and not unconformable upon B as Conley (1962) thought. This is a contribution from ERTS that is not evident from topographic maps alone, because tonal distinction is a necessary adjunct to topography in the interpretation.

Unit D is the Flat Swamp Member of the Cid Formation (Stromquist, A.A., et al, 1971). Resistant rhyolitic and andesitic pyroclastic rocks of this unit form hills. Topographic relief and generally high reflectance mark this unit on the photograph. Unit D conspicuously marks the SW plunging nose of an anticline.

Unit E is the Millingport Formation of Stromquist (1971). Easily weathered volcanogenic sandstone and mudstone produce a rather featureless pattern on the photo. Unit E is bounded on its western side by the Gold Hill-Silver Hill fault zone (G-H) which produced some topographic lineation shown on the overlay (figure 2). Other prominent lineations of the Gold Hill-Silver Hill fault set are seen in the southwestern parts of unit E and along strike to the northeast in unit B. This is consistent with an age of faulting that is younger than the folding.

North of 36° lat. the Gold Hill-Silver Hill fault zone lineations die out (?) in a more easterly trending zone of topographic lineations S. These lineations (S_1) appear to be parallel to the regional foliation in this area, which in turn is generally parallel to lithologic layering.

Triassic Basin South of Durham, N. C.

The Triassic basin is easily distinguished in the east central part of the photograph (figure 2) and as far east as a little beyond 79° long. These are unmetamorphosed sediments in partially fault bounded depressions in the metamorphic complex. Low relief and a distinctive dark tonal pattern, probably related to the vegetation cover, appear to distinguish it.

Fork Mountain Formation

In the SE corner of photograph E-1244-15321-7 (figure 3) taken on March 24, 1973, topographic expression of rock units is seen. The area in this photograph south of 37° lat. and 80° long. is encompassed in the Greensboro, N.C., AMS 2° quadrangle. This area is extremely complex (Conley and Henika, 1973), and only the very muscovite-rich schists of the Fork Mtn. Formation produce topography that can easily be related to the geology as mapped by Conley and Henika. A fault of large displacement, the Bowen's Creek fault, bounds the western body of Fork Mtn. Formation as shown on the overlay (figure 3). The southeastern body of Fork Mtn. Formation underlies Turkeycock Mtn. The northward termination of this mountain is possibly a synclinal nose by projection of the structure of Conley and Henika, although the easternmost straight margin of the mountain also suggests a fault. Other boundaries of the Fork Mtn. Formation are with rocks of the Bassett Fm. (Conley and Henika, 1973) or with the intrusive rocks of the Rich Acres or Leatherwood Formations (Conley and Henika, 1973). Both of these formations underlay areas of relatively low relief and probably are not separately distinguishable.

Post-metamorphic Structures of the Piedmont

Early pre- and synmetamorphic structural lineations in the Piedmont tend to be obscured in ERTS photographs except where they coincide with lithic units that weather differentially because of mineralogical differences. However, as in the case of the Gold Hill-Silver Hill fault zone, late structural deformation (post metamorphic) usually produces topographic lineation because granulation and cleavage in rock units reduces the weathering resistance parallel to the structure regardless of rock composition and mineralogy. ERTS photos are valuable for scanning large areas in searching for those late structural effects. Because of this these photos will undoubtedly find increasing use in analysing post metamorphism tectonics of the Piedmont. This subject is of intense current interest in relating present earthquake distribution to existing structure, and to siting dams and atomic power plants. It will also doubtless become of importance in analysing Piedmont (and therefore Coastal Plain basement) tectonics during the Mesozoic and Tertiary while the Atlantic Coastal Plain sediments were accumulating. These sediments and their offshore extensions may contain a large percentage of the U. S. petroleum reserves. The author is currently engaged in an analysis of these structures.

Utility of ERTS MSS Data for Geologic Mapping

From the foregoing it seems that in an area of low relief, deep soil cover, heavy vegetation, complex multideformed metamorphic rocks, and little contrast of weathering resistance in the underlying rocks, ERTS MSS imagery will have significant but minor utility in geologic mapping. This conclusion is based only on the experience gained during this investigation in the Greensboro 2° quadrangle. It is suggested that the primary utility of the MSS imagerylies in early photoreconnaissance of large areas like these. ERTS data provides information on features of possible geologic significance that can be checked in the field during the course of the project.

Conclusions

(1) ERTS 1 imagery yields data on geologic structure comparable to 1:250,000 AMS Maps in the central Piedmont, U.S.G.S. topographic maps at 1:62,500 scale are often superior to ERTS imagery for structural interpretation.

(2) False structures appear on these photographs that are unrelated to mappable geologic frameworks. These are elliptical patterns of lineation possibly formed during weathering and erosion in response to coarse grained textures in gneisses and granitic rocks that occur in areas of medium to high grade metamorphism.

(3) Post-metamorphic structures of the Piedmont tend to show up better than syn- and pre-metamorphic structures in some parts of the region studied. ERTS photographs are valuable for scanning large areas for these late structural effects. Current interest in relating late structures to the pattern of earthquake zones is of importance to siting large dams and atomic power plants. Knowledge of post-metamorphic structures in the Piedmont of Mesozoic and Tertiary age may eventually define the tectonic framework of accumulation of offshore shelf sediments. These Coastal Plain and shelf deposits are believed to contain a large percentage of U.S. petroleum reserves.

(4) Doubling the resolution and providing stereoscopic overlap would increase the geologic usefulness of these photographs many fold.

References

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Appendix

ERTS Mss Data Furnished During This Investigation

Format: bulk MSS, 9.5 inch, black and white positive transparancies and paper prints in NDPF spectral bands 4, 5, 6, and 7.

Photo No.	Date
E-1081-15255	12 Oct. 72
E-1099-15261	30 Oct. 72
E-1099-15255	30 Oct. 72
E-1208-15322	16 Feb. 73
E-1242-15204	22 Mar. 73
E-1242-15211	22 Mar. 73
E-1243-1562	22 Mar. 73
E-1243-15265	23 Mar. 73
E-1244-15321	24 Mar. 73
E-1244-15323	24 Mar. 73
E-1260-15204	9 Apr. 73
E-1261-15265	10 Apr. 73
E-1279-15264	28 Apr. 73
E-1280-15323	29 Apr. 73
E-1280-15320	29 Apr. 73

Other Data Furnished or Available

NASA Mission 121, Site 125 color IR

U-2, 70 mm. black and white transparancies in MSS bands 4, 5, 6, 7. A strip across the Greensboro 2° Map along the Va. - N. C. line.

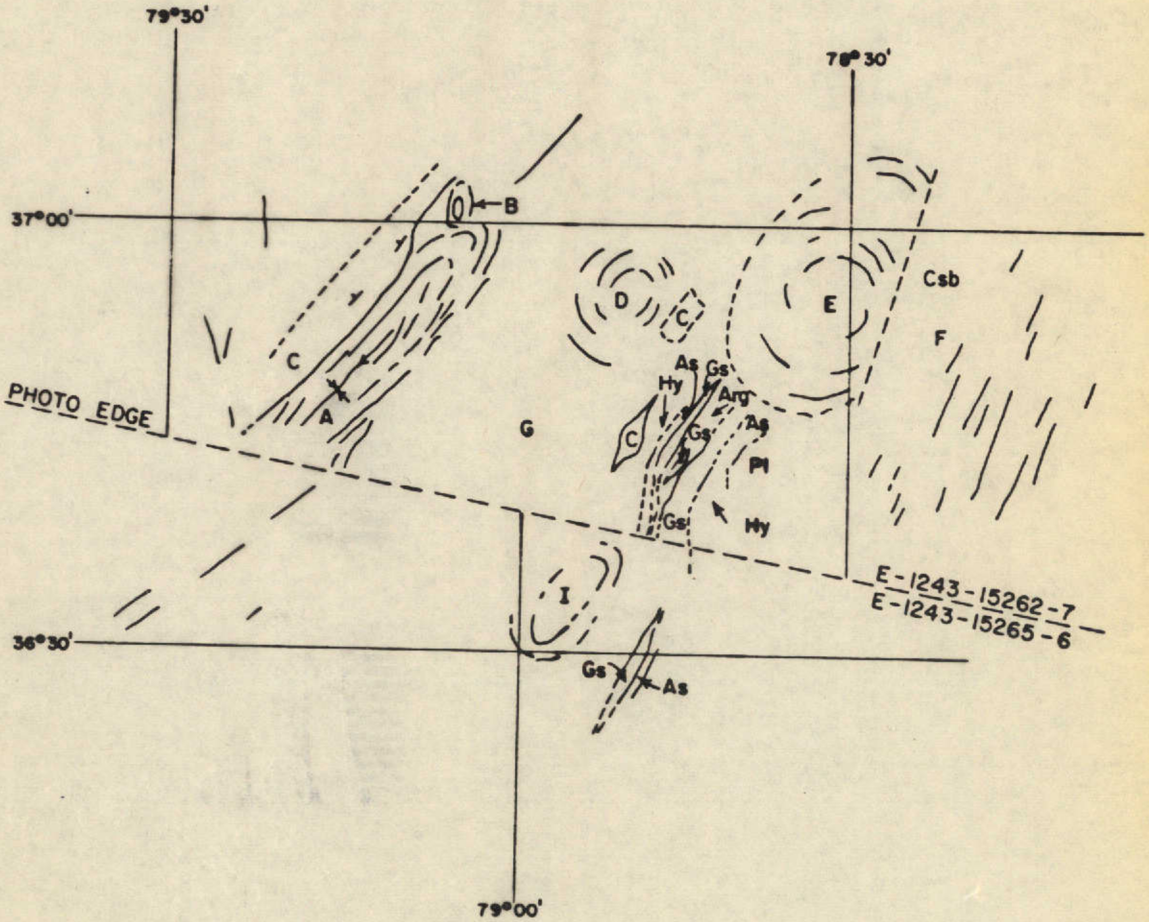

Figure 1. Overlay for photograph Nos. E-1243-15262-7 and E-1243-15265-6.

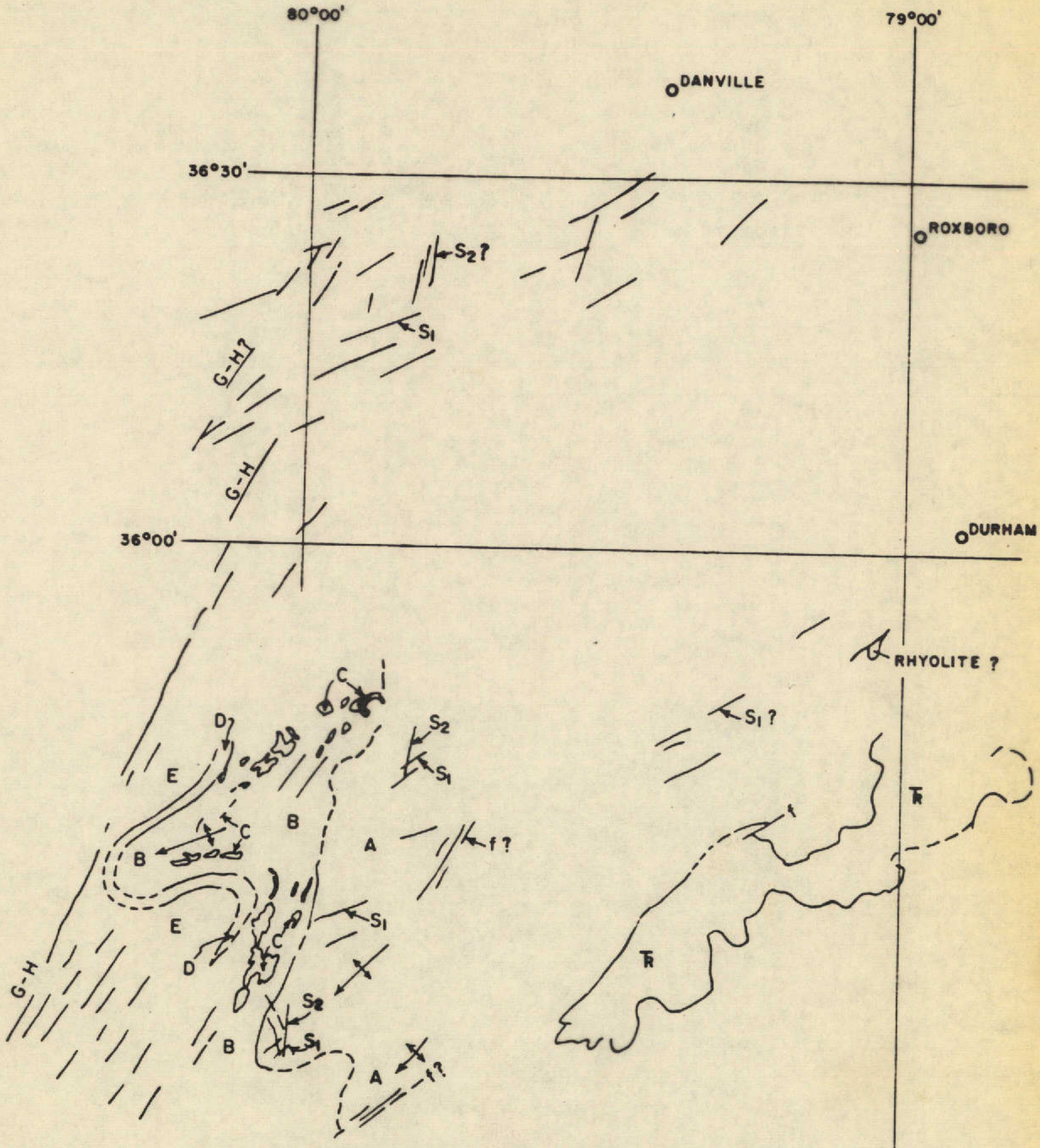

Figure 2. Overlay for photograph No. E-1089-15261-7.

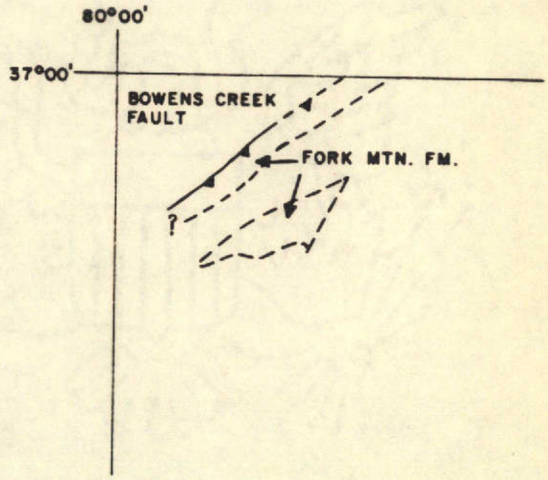

Figure 3. Overlay for photograph No. E-1244-15321-7.