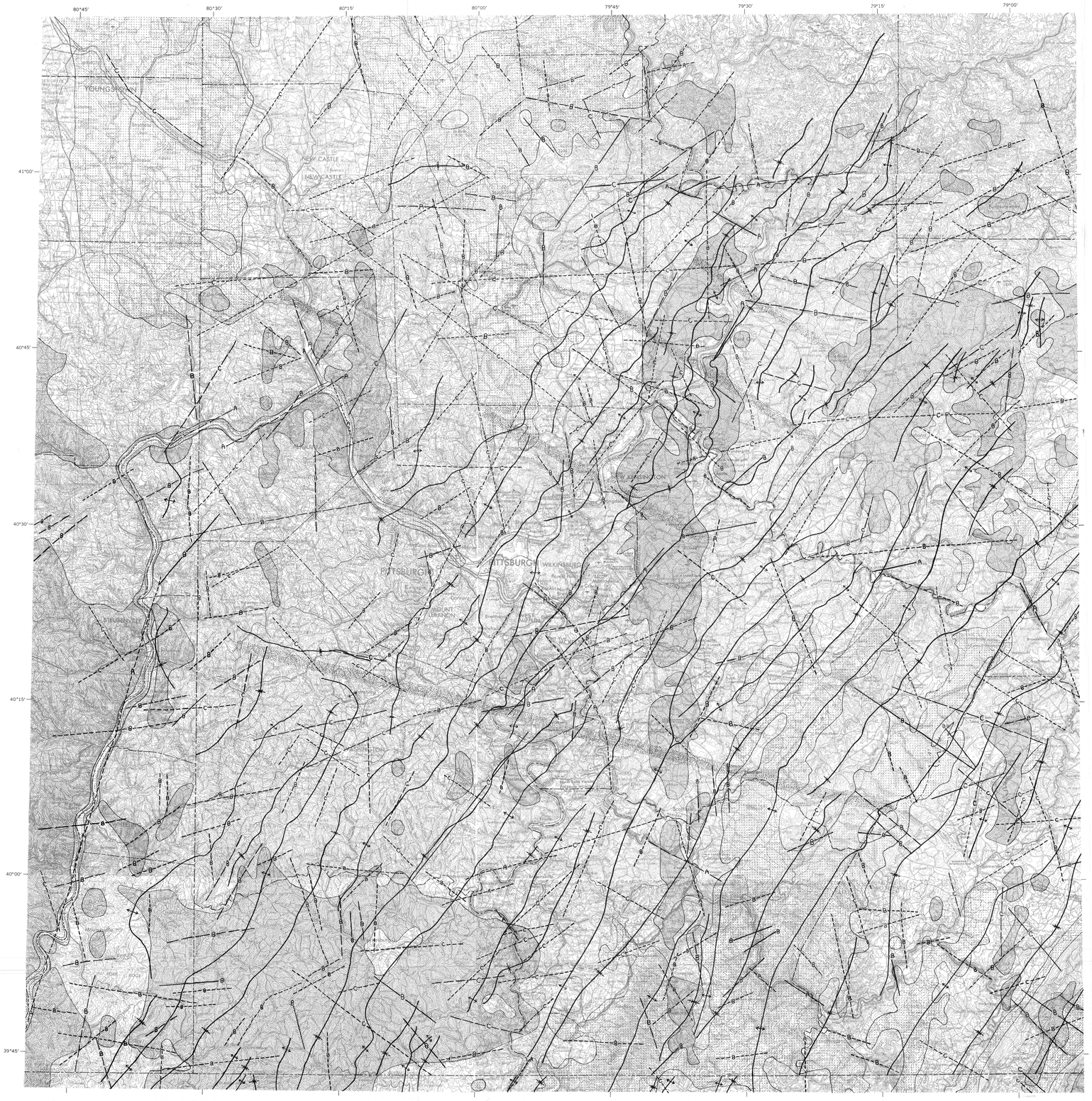
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-815
BRIGGS AND KOHL--CORRELATION OF GEOLOGIC DATA
FROM FOUR SOURCES, SOUTHWESTERN PA. AND VICINITY



Base from U.S. Geological Survey, 1971

LOCATION DIAGRAM

Map showing study area (outlined in heavy black). Greater Pittsburgh region (dot pattern) includes Allegheny, Butler, Armstrong, Westmoreland, Washington, and Beaver Counties.

INTRODUCTION

The purpose of this map is to compare major naturally occurring rectilinear and elongate features that are expressed at the surface of the earth. The four types of information shown were mapped originally at a variety of scales on different formats. The features are here combined at a uniform scale to allow interpretation of relations and significance. Descriptions are in order of history of discovery or time of effective delineation.

FOLD AXES

The existence of folds in rock layers of the area has long been recognized (for example, Maps of relevant counties in Lesley, 1885). The axial trends of anticlines and synclines shown on the present map are from maps by: Ashley (1926); Butts (1904); Campbell (1902, 1903); Cardwell, Erwin, and Woodward (1968); Flint (1965); Phalen (1910); Richardson (1904, 1934); Shaffner (1958); Shaw and Munn (1911); Stone (1905, 1932); and Wagner and others (1975).

In the eastern part of the map, rock layers are folded into a well-organized pattern of anticlines and synclines with well-defined axial traces that trend northeasterly with relatively minor deviation. Progressively from southeast to northwest, however, folds become broader and gentler making precise definition of axial zones more difficult; the sinuosity of axial traces increases from southeast to northwest.

LINEAMENTS INTERPRETED FROM SATELLITE IMAGERY

The subdued trellis pattern of drainage in southwestern Pennsylvania has long been plain from many maps of the area. Only with the availability of imagery from the Landsat (formerly ERTS--Earth Resources Technical Satellite) experiments, however, has systematic investigation of larger features associated with the pattern been feasible. By interpretation of 1972 and 1973 Landsat-1 imagery, W.S. Kowalik prepared a map for the Pennsylvania State University showing lineaments in Pennsylvania and adjacent areas. This map was published at the scale of 1:3,125,000 (1 cm equals 31.25 km) (Kowalik and Gold, 1976, fig. 1), and D.P. Gold of the University's Department of Geosciences kindly made available to us a larger scale (1:1,000,000; 1 cm equals 10 km) version, as well as copies of the imagery interpreted and annotated by Kowalik. We transferred to the present map all lineament information relevant to the map area, with a minimum of adjustment. Kowalik's lineament classification is retained on map and explanation (Kowalik and Gold, 1976, p. 238).

Most lineaments shown are reflections of topographic features, continuous or segmented river or stream valley reaches. Others are based on differences in tonal density of the imagery; their nature is less certain, but they also are thought to be related to drainage (W.S. Kowalik, written commun., 1976). Most lineaments identified by tonal differences are classed as "marginally linear."

A few lengthy straight or only slightly curvilinear topographic features which are clear from examination of the topographic base map were not included in the Landsat-1 interpretation. Notable examples are the essentially north-south 30-km-long lineament formed by Little Chartiers Creek and a southward extension in Washington County and the 25-km-long northwest-trending lineament formed by Breakneck Creek and a northwestward extension in southwestern Butler County.

These and other drainage features probably were not mapped as lineaments owing to a combination of several factors listed by Kowalik and Gold (1976, p. 238-241), including operator variability, bias owing to sun azimuth, operator fatigue, and single-season imagery used in the interpretation. The essentially straight northeast-trending folded mountains and intervening parallel valleys and their streams in the southeastern part of the map also largely were not included in the Landsat-1 interpretation owing to an effort to avoid linear features chiefly reflecting differential erosion along the strike of outcropping rocks (Kowalik and Gold, 1976, p. 238). The satellite-imagery lineaments presented here, therefore, represent a conservatively mapped sample of actual lineament distribution.

AERORADIOACTIVITY ANOMALIES

During 1960, an airborne radioactivity survey of the area (Bates, 1966) was made at a mean ground clearance of about 150 m. According to Bates, aeroradioactivity at that altitude has three chief components: (1) cosmic radiation ("determined twice daily.... and removed from the radioactivity data prior to recording"); (2) radionuclides in the air ("if inversion conditions are avoided.... considered to be fairly uniform on a given day in a particular area"); (3) radionuclides in "approximately the upper few inches of the ground." The pattern of an aeroradioactivity-survey map, therefore, probably chiefly reflects conditions at ground surface. On the present map, a striking elongation of some areas with relatively high radioactivity (mean level greater than 550 counts per second) and some with low radioactivity (mean level less than 400 counts per second) is evident.

WAGNER-LYTLE LINES

In the course of revision of the structural geology of the Greater Pittsburgh region, the late W.R. Wagner and W.S. Lytle (1976) identified west-northwest-trending

> "lines of structural discontinuity...[which] represent narrow zones or trends along which fold axes terminate, diminish, or change direction. These lines.... particularly the southern one and the two through Butler and Armstrong Counties, appear to influence the distribution of the oil fields. The line.... in Washington County defines the southern border of the McDonald oil field; in Butler County the southern line.... truncates the Little Creek and Renfrew-McCalmont fields; and the northern line... terminated the Bullion-Clintonville and the Cherry Valley oil fields."

With the lines superimposed on the regional oil and gas fields map (Lytle and Balogh, 1975), this influence on oil production is clear.

For reasons of brevity and recognition, these lines of structural discontinuity are here termed Wagner-Lytle lines.

Based upon surface and subsurface information, Wagner-Lytle lines were mapped only in the six counties of the Greater Pittsburgh region, Armstrong, Allegheny, Beaver, Butler, Washington, and Westmoreland; so their extent on the present map is limited to those counties. Further investigation probably would extend identified lines into adjacent areas and might identify new lines. For example, truncated and irregular fold axes in central and eastern Greene County suggest a northwest-trending line, and similar relations in Indiana County also are suggestive.

Wagner (oral commun., 1974) speculated that the lines may be the expression of long-lived, very slowly and intermittently moving strike-slip faults in crystalline basement. Flexures and apparent offsets chiefly, but not exclusively, suggest left-lateral movement along Wagner-Lytle lines.

Earlier, Gwinn (1964, p. 890-891) defined "lineaments" in a large area that includes the Greater Pittsburgh region, using criteria generally similar to those of Wagner and Lytle. Only three of these lines of discontinuity occur in the area of the present map. They are not shown because the relatively small scale of Gwinn's map and its lack of base-map detail (Gwinn, 1964, plate 1) make accurate positioning impossible. In general terms, though, one Gwinn lineament trends due east from the area south of Kittanning in Armstrong County to a point outside the map area; another trends due east from south-central Indiana County also to a point outside the map area; and the third trends northwest, approximately between Somerset in Somerset County and Latrobe in Westmoreland County. The two that are within the Greater Pittsburgh region neither coincide with Wagner-Lytle lines nor appear well defined by the geologic structure of the region. However, in Indiana County there are structural discontinuities that can be interpreted as reflections of the two east-trending Gwinn lineaments.

RELATIONS BETWEEN TYPES OF LINEAR OR ELONGATE FEATURES

Fold axes versus aeroradioactivity anomalies.--In the southeastern part of the map, aeroradioactivity lows in general parallel fold axes and are centered over anticlines. Bates (1966) concluded that the rocks exposed in the anticlinal cores have a lower level of natural gamma radioactivity than do younger rocks exposed on the flanks of the anticlines; there is a suggestion of a similar relation in the vicinity of Waynesburg, Greene County, where an anticlinal axis approximately coincides with a zone of moderate radioactivity surrounded by areas with relatively high aeroradioactivity. An irregular syncline in western Armstrong County coincides generally with an aeroradioactivity high, and similar relations are apparent locally along short segments of synclinal axes in Armstrong and Indiana Counties. In the southwestern part of the map, fold axes and aeroradioactivity distribution show no clear correlations; the large area of relatively high aeroradioactivity in the area probably chiefly expresses conditions in outcropping rock of the Permian Greene Formation (Pennsylvania Bureau of Topographic and Geologic Survey, 1960). Elsewhere on the map, fold axes and elongate aeroradioactivity highs cross each other at angles approximating 45 degrees.

Fold axes versus satellite-imagery lineaments.--Many lineaments that represent valley traces (classified A and B on the map) are parallel or normal to fold axes. This can be explained as an expected structural correlation; patterns of jointing in this region largely are parallel or normal to trends of Appalachian fold axes (Nickelsen and Hough, 1967; Parker, 1942), and a not unreasonable corollary is that the many similarly oriented valley segments are entrenched in zones of rock weakness caused by the presence of joints parallel to the valley segments. H.P. Ferguson (1967), however, has demonstrated that bedrock of valley bottoms rarely is jointed. His evidence indicates that joints in valley walls rather are results of release of stress parallel to thalwegs owing to downcutting, and recent work by Kohl (unpub. data, 1976) provides support for this theory. Though the question of ultimate origin of straight valley segments thus is open, orientations of the valley segments plainly suggest some relation to Appalachian folding.

Numbers of the lineaments identified by tone (classified C on the map) show similar relations to fold axes. The well-expressed northeast-trending tonal feature through eastern Washington County coincides with a synclinal axis.

Many satellite-imagery lineaments are at various angles to fold-axis orientations, but locally some bear an apparently systematic relationship to axes; note the "chevron" relation of short lineaments to the anticlinal axis along Laurel Hill in the zone centering about 16 km east-southeast of Connellsville, Fayette County, in the southeastern part of the map.

Fold axes versus Wagner-Lytle lines.--Wagner-Lytle lines are defined on the basis of flexures and discontinuities in fold axes, and the lines for the most part trend at angles approximately normal to trends of undeformed segments of the principal fold axes.

Aeroradioactivity anomalies versus satellite-imagery lineaments.--Where elongate anomalies parallel fold axes, the anomalies also modestly relate to lineaments normal to the axes. Where aeroradioactivity highs trend north-south, however, there is no consistent relationship, either in lineament orientation or in the incidence of lineaments. For example, northern and southern parts of the north-south zone of high anomalies in the east-central part of the map coincide with areas where many lineaments are identified, but the central part of the zone is relatively free of lineaments. On the other hand, lineaments that trend approximately north-south are fairly common in much of the area of the map, but they are about as common in parts where anomalies have other trends than north-south or have no strong trends as they are where anomalies are alined north-south.

Aeroradioactivity anomalies versus Wagner-Lytle lines.--Although very tenuous relations between Wagner-Lytle lines and anomalies might be speculated upon locally, such relations probably are coincidental. Most Wagner-Lytle lines cross anomalies without apparent mutual cause.

Satellite-imagery lineaments versus Wagner-Lytle lines.--Many lineaments trend northwest and west-northwest, and all Wagner-Lytle lines have this general orientation. Though Wagner-Lytle lines have been defined only in the Greater Pittsburgh region, lineaments suggest possible continuations of the lines. For example, the long B-type lineament through the town of Indiana in the eastern part of the map is suggestive of an extension of the northernmost Wagner-Lytle line in Armstrong County; this speculation is reinforced by the fact that the lineament traverses an area with a number of apparent structural discontinuities.

DISCUSSION

With the exception of the north-south trending aeroradioactivity anomalies, linear features in southwestern Pennsylvania largely are consistent with structural origins. The anticlines and synclines are geologic structures by definition, and the Wagner-Lytle lines may reflect basement faulting that has offset anticlinal and synclinal axes. The fact that no surface faulting has been recognized along the lines suggests that deformation took place in broad zones over long periods of time during which the rocks were able to adjust to stress with many minor fractures rather than mappable faults. The resulting deformation style is analogous to plastic movement.

Gold, Alexander, and Parizek (1974, p. 52) speculate that some satellite-imagery lineaments "are underlain by zones of fractured and jointed rocks," and traverses across the traces of lineaments in an area northeast of the present map yielded results that support this theory (David P. Gold, oral commun., 1975). Kowalik and Gold (1976, p. 241-245; fig. 6) relate some satellite-imagery lineaments to lineaments defined by Gwinn (1964, p. 890-891). Because Wagner-Lytle lines and Gwinn lineaments are based on generally similar criteria, some satellite-imagery lineaments and Wagner-Lytle lines may be essentially the same.

The fact that Wagner-Lytle lines largely were not recognized as satellite-imagery lineaments may, in part, be a function of size; the lines are broad and may not have the linear expression identifiable in narrower zones. However, at least one Wagner-Lytle line generally coincides with a satellite-imagery "megalineament" that was illustrated by Gold, Alexander, and Parizek (1974, fig. 1); it is not shown on the present map. Very long lineament assemblages in southern Butler County lie between and parallel to Wagner-Lytle lines, and one can speculate that these lineaments may represent incipient or poorly developed Wagner-Lytle lines. This explanation of lineaments is inconsistent with Ferguson's (1967) valley stress-release theory, mentioned earlier.

The evidence for the Wagner-Lytle lines is suggestive of strike-slip movement, which provides a possible explanation for many of the lineaments that are neither parallel nor normal to principal structural directions. These lineaments may result from stresses analogous to those that yield second-order and third-order faults in many structural contexts.

Not shown on the map are a number of north-northeast-trending highs and lows of total aeromagnetic intensity in the northern part of the map area that can be interpreted as truncated southward against a west-northwest-trending line approximately through Pittsburgh (Popenoe and others, 1964), parallel to but not coincident with the Wagner-Lytle lines. Beck and Mattick (1964) have interpreted aeromagnetic anomalies in this area largely as expressions of magnetism of rocks in crystalline basement. Their theoretical basement-contour map (Beck and Mattick, 1964, fig. 2) thus is fairly smooth, but it does include a depressed zone extending west-northwestward from the approximate middle of the east edge of the present map about halfway across the map, generally on line with the Wagner-Lytle line through southern Armstrong County. Beck and Mattick (1964, p. 7) suggest that this zone may be a remnant of Precambrian drainage.

In contrast to the other features, the segmented line of elongate aeroradioactivity highs extending from south-central Fayette County due northward into Armstrong County, and similar trends of anomalies to the west and east, can be explained neither by the distribution of outcropping rocks nor by structure. In general, the regional geologic structure is an irregular monocline dipping gently southward, made complex in the eastern part of the map by folding of the rock layers. Accordingly, rocks exposed at the surface range generally from older on the north, chiefly Mississippian and Early Pennsylvanian in age, to younger on the south, chiefly Pennsylvanian and Permian (Pennsylvania Bureau of Topographic and Geologic Survey, 1960). The outcrop pattern thus is roughly east-west, at right angles to the strong north-south trend of these anomalies.

Flight directions during the aeroradioactivity survey also were north-south, but it is difficult to relate the north-south anomalies to this fact or to possible faulty performance of instrumentation for two reasons: (1) anomalies locally exceed 13 km in east-west dimension, whereas flight lines were about 1.6 km apart and 190 km long; at airspeeds of about 320 km/hr, instrumentational or procedural lapses of as much as 4 hrs would be required if such anomalies were false; and (2) only the Fayette County-Armstrong County anomaly and, to a lesser degree, the anomaly at the east edge of the map persist across most of the area overflown. The north-south anomalies probably cannot be laid to diurnal or other periodic variations in cosmic radiation because safeguards were taken to avoid such effects (Bates, 1966). One can say only that the north-south aeroradioactivity anomalies appear natural but their trends currently are unexplained.

The sinuous low anomaly west of Pittsburgh coincides with the valley of the Ohio River, which is formed at Pittsburgh by the confluence of the Allegheny and Monongahela Rivers. The anomaly may combine influences of topography with lower aeroradioactivity over water and alluvial areas, which are broader on the Ohio River than along the tributaries.

APPLICATIONS

Fold axes have proved valuable guides to oil and gas traps (Wagner and Lytle, 1976). Additionally, re-examination of trends of folds on existing maps may lead to definition of more Wagner-Lytle lines. Wagner-Lytle lines apparently are indicators of oil and gas fields, so further testing of the concept may result in a useful tool for petroleum exploration in southwestern Pennsylvania and elsewhere.

Concerning certain satellite-imagery lineaments, Gold, Alexander, and Parizek (1974, p. 52-53) wrote the following. The parenthetical insertions are theirs.

> "If the lineaments observed overlie fracture zones (as suspected) and prevail to depths corresponding roughly to the same order as their length (as implied by theory), then these implications are important to (1) stream and river control and the evolution of landscape, (2) ground-water movement, (3) oil and gas migration and leakage, (4) underground gas storage, and (5) engineering foundation exploration, analysis, and design."

Other potential applications include identification of areas where fracturing may cause unusual roof failure and water problems in mining and tunneling (Overbey and others, 1973).

The suggested applications may prove useful along a single lineament, and it is reasonable to expect that stronger correlations may be found where two or more lineaments cross or cluster. For example, ground-water yields from bedrock aquifers in southwestern Pennsylvania generally are low, but drilling in areas where satellite-imagery lineaments intersect may find enhanced yields.

The original intent of the aeroradioactivity survey (Bates, 1966) was to provide a data framework against which changes in radioactivity could be measured; the data is still used for this purpose. In addition, Lundberg (1952) and others suggest that aeroradioactivity in some settings may be a guide to concentrations of petroleum. A few oil and gas fields in the Greater Pittsburgh region have irregular north-south elongations in areas roughly coincident with north-south aeroradioactivity anomalies (Lytle and Balogh, 1975), lending support to this potential application.

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EXPLANATION

Axial trace of principal anticline

Trough of principal syncline

greater than 550 | 400-550 | less than 400

Radioactivity units

Numbers indicate mean of gamma radioactivity levels in counts per second (Bates, 1966).

A
B
C

Satellite-imagery lineaments

Interpreted by W.S. Kowalik from 1972 and 1973 ERTS-1 (Landsat-1) imagery (unpublished information)

Solid lines: best expressed and most linear features
Long-dashed lines: features of intermediate linear expression
Short-dashed lines: marginally linear features
A: alinements of segments of rivers, streams, or impoundments with water evident
B: alinements of segments of streams without evident water
C: alinements of tonal features not fitting criteria for A or B

Wagner-Lytle lines

Lines of structural discontinuity shown only in Allegheny, Armstrong, Beaver, Butler, Washington, and Westmoreland Counties (Wagner and Lytle, 1976)

Scale 1:250,000

5 0 5 10 15 20 Statute Miles
5 0 5 10 15 20 25 30 Kilometers
5 0 5 10 15 Nautical Miles

CONTOUR INTERVAL 200 FEET

TRANSVERSE MERCATOR PROJECTION

MAP SHOWING MAJOR FOLD AXES, SATELLITE-IMAGERY LINEAMENTS, ELONGATE AERORADIOACTIVITY ANOMALIES, AND LINES OF STRUCTURAL DISCONTINUITY, SOUTHWESTERN PENNSYLVANIA AND VICINITY

By
Reginald P. Briggs and William R. Kohl

1976

Pennsylvania (Southwest) Structure. 1:250,000. 1976.
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