DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

AEROMAGNETIC AND GENERALIZED GEOLOGIC MAP OF SOUTHEASTERN PENNSYLVANIA

By

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SCALE 1:125 000

2 0 2 4 6 8 10 MILES

2 0 2 4 6 8 10 KILOMETERS

1967

INTRODUCTION

An aeromagnetic survey of much of southeastern Pennsylvania was made by the U.S. Geological Survey in cooperation with the Commonwealth of Pennsylvania in 1956 and 1957 (see index map) to gain additional information on the regional geology and in the hope of locating iron ore deposits. The generalized geologic map of the region was adapted from the Geologic Map of Pennsylvania by Gray and Shepps, 1960. Only selected magnetic features are discussed with reference to the mapped geology.

INTERPRETATION OF MAGNETIC DATA

The various geologic units tend to have a characteristic aeromagnetic pattern. Paleozoic and Triassic rocks for the most part are nonmagnetic and show only local magnetic anomalies. Small, nearly circular, low-amplitude magnetic anomalies at Harrisburg (C 3) and Allentown (B 8, B 9), and at some of the larger cities such as York (E 4), Lancaster (D 5), Pottstown (C 8), Norristown (D 9), and Lansdale (D 9), are due to industrial plants.

MAGNETIC ANOMALIES ASSOCIATED WITH PRECAMBRIAN ROCKS

The Reading Prong

As shown on the Geologic Map of Pennsylvania (Gray and Shepps, 1960), granitic gneisses are the most abundant Precambrian rocks of the Reading Prong. Hornblende gneisses are second most abundant, and there are lesser amounts of other gneissic rocks; the "bird's-eye maple" magnetic pattern associated with the rocks of the Reading Prong shows no distinct variation of magnetic anomalies by which to distinguish between the two main types. In some places the magnetic anomalies cross contacts between the hornblende and granite gneiss, indicating either that the magnetic anomalies are not directly related to lithologies of the area, or that data are insufficient for interpretation.

Some of the higher-amplitude magnetic anomalies, such as the 11,290-gamma anomaly 1½ miles southeast of Emmaus (B 9), correlate with known magnetite concentrations in the Vera Cruz magnetite district. Other high-amplitude magnetic anomalies to the northeast and southwest of the Vera Cruz magnetic anomaly also indicate magnetite concentrations, for example, 3 miles east of Henningsville (C 8), 2 miles southeast of Macungie (B 8), and 1½ miles east of Hellertown (B 9). Miller (1925) reported that magnetite is abundant and widely distributed throughout the Precambrian gneisses of the area.

The magnetic anomaly 4 miles north of Reading (C 9) and 2 miles south of Maiden Creek (C 9) shows that Precambrian rock extends 1 mile farther west under a thin cover of the mapped basal Cambrian quartzite. The south side of a nearly linear magnetic anomaly between Springtown (B 9) and Riegelsville (B 10), south of the Bucks and Northampton County line, indicates that the Precambrian rocks lie at very shallow depth, approximately ½ mile south of their mapped contact with the Paleozoic rocks. Another area where Precambrian rocks lie at shallow depth is indicated by the anomaly which lies across the mapped geologic contacts, 6 miles northwest of Boyertown (C 8) and 2 miles southeast of Lobachsville (C 8).

The Reading Prong exposes intensely deformed Precambrian crystalline rocks and lower Paleozoic sedimentary rocks. The structure of the Precambrian rocks in the Pennsylvania part of this major uplift is controversial. Hypotheses range from a great overthrust sheet (Stose and Jonas, 1935) to normal faulting, and various combinations of these two ideas (Miller, 1925, and other workers).

Two relatively broad valleys underlain by Paleozoic sedimentary rocks lie along the south edge of the Precambrian belt of the Reading Prong, one along the valley of Saucon Creek south of Bethlehem (B 9) and the other along the valley of Manatawny Creek located 6 miles east of Reading. Low-amplitude magnetic anomalies associated with a line of hills of Precambrian rocks along the southern border of the easternmost valley, south of Bethlehem, suggest that the magnetic rocks are relatively thin slivers or that their magnetic susceptibilty is low compared with most of the other Precambrian crystalline rocks of the area (Bromery, 1960). Magnetic patterns along the western, northern, and eastern perimeters of the valley east of Reading (C 7, C 8) suggest that Precambrian crystalline rocks lie at extremely shallow depths along these borders and probably closely underlie the entire northern part of the valley. The lack of magnetic anomalies in the southern part of this same valley suggests that Precambrian crystalline rocks here may lie at great depth.

Mapping in the valley 6 miles east of Reading indicates that the strata thicken from east to west. However, the magnetic gradients at the contact between Paleozoic rocks in the valley and the surrounding Precambrian rocks suggest that in the northern part of the valley, these contacts dip toward the valley, forming a saucer along an east-west profile. In the southern half of the valley, the magnetic data indicate that these contacts dip away from the valley.

The broad low-amplitude magnetic anomalies in the extreme northeast part of the mapped area of the Reading Prong are interpreted to be caused by buried Precambrian crystalline rocks similar to those exposed in the area. North of Easton (B10) and at Bethlehem (B 9), a series of folded and faulted lower Paleozoic strata and Precambrian crystalline rocks crop out in a thin discontinuous line of low hills. A high-amplitude magnetic anomaly is associated with the hill at Easton; no magnetic anomaly is associated with the hills north of Bethlehem. This contrast in magnetic expression may indicate differing lithologies, or that the Precambrian rocks forming the hills north of Bethlehem are extremely thin slivers.

The pronounced magnetic anomaly associated with the hill at Easton is probably caused by a south-dipping rock slice of high magnetic susceptibility. Analysis of the anomaly gradients also indicates that the anomaly is composite; the part having the steeper gradient correlates well with the exposed Precambrian crystalline rocks. That part of the anomaly terminates abruptly at the fault mapped at the western end of the hill. The second part of the anomaly, which has a more gradual gradient, continues west past the fault to Hecktown (B 9), where it trends north and then southwest around the broad magnetic anomaly north of Bethlehem. The two distinct magnetic gradients indicate that magnetic Precambrian rocks lie at two separate stratigraphic levels. The broad magnetic anomaly north of Bethlehem is interpreted as being caused by Precambrian crystalline rocks buried approximately 1 mile below the surface (Bromery, 1960). This anomaly correlates with an anticlinal structure mapped in lower Paleozoic sedimentary rocks of the area (Gray and Shepps, 1960). The steep magnetic gradient along the eastern boundary of this anomaly is interpreted as being caused by a fault. The westernmost Precambrian rock hills along the southern flank of this anomaly are probably structurally related to the buried Precambrian rocks.

The rather uniform gradient along the north flank of the broad magnetic anomaly north of Bethlehem is offset to the south just north of Allentown. The magnetic gradient then becomes less steep and continues uniformly to the southwest where it merges abruptly with the "bird's-eye maple" magnetic patterns associated with the exposed Precambrian rocks of the Reading Prong. The magnetic gradient does not steepen where it intersects the exposed Precambrian rocks, indicating that the buried Precambrian rocks producing the gradient do not change depth, and that the exposed Precambrian rocks must lie stratigraphically above the buried Precambrian rocks, with an intervening thickness of nonmagnetic Paleozoic sedimentary rocks.

This magnetic gradient then trends southeast from a point near the town of Lyons Station (C 7) through the anomalous magnetic pattern associated with the exposed Precambrian rocks of the Reading Prong to a point 8 miles north of East Greenville (C 9) where it is interrupted by the magnetic anomalies associated with diabase rocks of the Quakertown area. Farther to the east, a south sloping magnetic gradient in the area between Springtown (B 9) and Pipersville (C 10) indicates that the Precambrian rocks of the Reading Prong dip south at a relatively low angle and closely underlie the north part of the Triassic basin in this area.

The steepness and location of the magnetic gradients at the western end of exposed Precambrian rocks at Reading and the lack of magnetic anomalies farther west indicate that the Precambrian rocks do not plunge west under the Paleozoic rocks, but that the west contact dips to the east under the Precambrian rocks. Anomalies at the northern half of the valley of Manatawny Creek 6 miles east of Reading are interpreted as showing that lower Paleozoic rocks overlie buried, relatively near surface Precambrian rocks.

Low-amplitude magnetic anomalies are associated with the Precambrian crystalline rocks near Wernersville and Womelsdorf (C 6). The pattern associated with these Precambrian rocks contrasts with the high-amplitude pattern of the Precambrian rocks exposed to the east. A regional survey by Bromery shows low-amplitude gravity highs associated with the exposed Precambrian rocks in this area, in contrast to gravity lows associated with the Precambrian rock east of Reading. Analysis of the magnetic and gravity data indicates that the Precambrian rocks of the Wernersville-Womelsdorf area (C 6) are in a relatively thin slice. The contrast between magnetic and gravity anomaly patterns for this area and those east of Reading indicates a marked difference in the physical properties of the rocks. No near-surface buried connection between the rocks of these two areas is indicated.

Eastern Piedmont

The linear magnetic anomaly patterns in the extreme southeast part of the mapped area north and northeast of Philadelphia are underlain by granitic gneisses and hornblende gneisses of Precambrian age. The higher amplitude magnetic anomalies of that area correlate well with the hornblende gneisses, and the lower amplitude magnetic anomalies are associated with the granitic gneisses. The higher-amplitude anomalies extend northeast across the contacts into the area of sedimentary rocks of the Triassic basin where they can be traced more than 7 miles, to the vicinity of Newtown (D 11). Depth calculations by Zietz and Gray (1960) indicate that the Precambrian rocks in the vicinity of Newtown are 3,000 feet below the surface. To the west, in the vicinity of Norristown (D 9), another northeast-trending linear magnetic anomaly lies within the Triassic basin. The anomaly starts at Norristown and extends northeast through Ambler (D 10), across a gap in the data coverage, and terminates at the Bucks County line 4 miles north of Willow Grove (D 10); it is interpreted as being caused by a mass of hornblende gneiss of Precambrian age buried less than 1,500 feet below the surface.

Somewhat linear, low-amplitude anomalies are in general associated with the gabbroic rocks of West Chester (E 8) and Conshohocken (D 9). Approximately 3 miles southeast of West Chester is a local area of higher-amplitude, nearly circular magnetic anomalies associated with a patch of Wissahickon Formation. These anomalies lie across a fault and indicate that magnetic rocks are associated with the fault. McKinstry (1961) shows this small area of the Wissahickon Formation as being slightly larger in areal extent and continuous with the larger region of the same formation to the southwest. These nearly circular magnetic anomalies are superimposed on a broader, more extensive magnetic anomaly. The gradients along the north and south sides of this broader magnetic anomaly indicate that the north and south sides of the magnetic rock unit dip south. In these places relatively nonmagnetic gneiss may overlie a more or less tabular body of more magnetic Wissahickon Formation.

Between Newtown Square and Media (E 9), high-amplitude magnetic anomalies and gradients extend across the contact between the Precambrian gneisses and the Wissahickon Formation. At this locality the Wissahickon has been intruded by serpentinite masses, but additional geologic mapping is necessary to explain the geophysical data.

South of Malvern (D 8) and south of St. Davids (D 9), along the northern boundary of the area linear magnetic anomalies associated with the Wissahickon Formation extend, without any evident change, into areas underlain by Precambrian rocks. This may indicate that the contacts at these places dip south at a low angle, or the magnetic anomalies may be associated with serpentinite masses that have intruded across the contacts.

Buckingham area

The linear magnetic anomaly near Buckingham (C 10), is underlain by Cambrian and Ordovician rocks. Bedding in the Paleozoic sedimentary rocks in general dips northwest. In one small area float of amphibole gneiss indicates presence of Precambrian basement rocks (Zietz and Gray, 1960). Those authors indicate that the anomaly is composite and is caused by two distinct magnetic masses: Part of the anomaly is due to a fault block, tilted to the north, involving the Precambrian rock surface; on the south side of the fault, this surface has been downdropped about 3,000 feet and slopes gently southeast away from the fault. The other part of the composite anomaly is attributed to a tabular magnetic body buried approximately 1,000 feet below the surface, parallel with and 1,000 feet northwest of the fault, as indicated by the higher amplitude and steeper gradients associated with its northeast part.

The attitude and depth of the Precambrian rock surface, computed from the Buckingham anomaly, the Newtown anomaly, and the points where the Precambrian is exposed, have been linearly extrapolated. This indicates that the Triassic rocks are 7,000 feet thick in the vicinity of Buckingham and Pineville, and that this is the thickest section of Triassic rocks south of the Precambrian locality near Buckingham (Zietz and Gray, 1960).

Phoenixville-Honeybrook area

Crystalline rocks of Precambrian age are exposed in a major uplift in the vicinities of Phoenixville (D 8) and Honeybrook (D 7). The area in general is characterized by a pattern of low-amplitude magnetic anomalies. Although these anomaly patterns do not indicate the boundaries of felsic and mafic gneisses, and there are no obvious differences in the amplitude or areal extent that correlate with the geology, the trends of many individual anomalies are parallel to the trends of mapped contacts. However, the elliptical mass of mafic rocks in the central part of this area is composed of anorthosite and is characterized by a pattern of rather flat magnetic anomalies rimmed by magnetic highs.

A broad magnetic high extends west along the projected trend of these Precambrian rocks, through an area of Paleozoic sedimentary rocks to within 2 miles of Lancaster. A similar magnetic anomaly west of Lancaster extends from Columbia (D 5), west through York and Hanover (E 5), to the Adams County line (E 3). Whether there is a continuity between the magnetic anomalies east and west of Lancaster is not clear, in part because of the local industrial magnetic disturbance at Lancaster.

Hanover-York area

The high-amplitude magnetic anomaly that extends from the west bank of the Susquehanna River near Wrightsville (D 4) toward York is associated with mafic volcanic rocks of Precambrian age exposed in the center of an anticline. The magnetic data indicate that the magnetic rock unit, and presumably the anticline, has a steep northern flank and that the south flank dips less steeply to the southeast. The crest of this anomaly is offset to the south at Hallam (D 4), suggesting a fault. From Hallam the magnetic anomaly extends southwest through Hanover to the south edge of the mapped area, as previously mentioned. The magnetic anomaly gradients northeast of Hanover (E 3) indicate that the magnetic rocks are buried 3,000 to 4,000 feet below the surface; west of Hanover the anomaly gradients become less steep, indicating that these same rocks plunge to the southwest to a considerable depth. The metabasalt of Precambrian age north of Hanover has no associated pronounced magnetic anomaly. The magnetic anomaly north and northeast of Hanover, therefore, must be caused by magnetic rocks buried below the metabasalt.

South Mountain area

Pronounced magnetic anomalies are associated with the Precambrian metabasalt and metarhyolite exposed at South Mountain. A magnetic anomaly extends east from approximately 1 mile north of Bendersville (E 1) across the contact of the Precambrian and Triassic rocks to a point 3 miles into the Triassic basin. The magnetic gradient becomes slightly less steep toward the east, indicating that the magnetic rocks causing the anomaly lie at shallow depth.

MAGNETIC ANOMALIES ASSOCIATED WITH ROCKS OF THE GLENARM SERIES

The northern border of the area of Glenarm Series east of Hanover is characterized by few magnetic anomalies, except locally. South of this magnetically flat border zone, which is 1 or 2 miles wide, these same rocks are characterized by pronounced northeast-trending linear magnetic anomalies, except in the area south of Coatesville (E 7), where the northeast trend is abruptly interrupted. In this area the magnetic anomalies trend north and are associated with a local area in which fold axes trend north. Near the Susquehanna River, the linear magnetic anomalies roughly follow the offset in the north contact of the Wissahickon Formation, suggesting that this north contact is stratigraphically controlled. In the vicinity of Glen Rock (E 4), some anomalies correlate with the mapped metavolcanic rocks. However, most anomalies correlate with the topographic lows, probably because the magnetite tends to be concentrated in the more easily eroded schistose unit rather than the more resistant sandy beds. In general, the north edge of this belt of linear magnetic anomalies across the southern border of the area is characterized by steep-gradient magnetic highs and closely associated magnetic lows, indicating that the north contacts of the magnetic rock units dip south. In the area west of Philadelphia and about 3 miles northeast of West Chester (E 8), the linear magnetic anomalies associated with the Glenarm Series trend northeast back and forth across the contact with the mapped gabbroic rocks, without pronounced changes in the magnetic gradients, indicating that the magnetic rocks lie at shallow depth below the gabbroic rocks.

MAGNETIC ANOMALIES ASSOCIATED WITH PALEOZOIC ROCKS SOUTH OF THE TRIASSIC BELT

Paleozoic strata trend northeast across the southern part of the mapped area from south of Hanover to northeast of Philadelphia. In general, these sedimentary rocks are nonmagnetic; they are characterized by flat magnetic anomalies or somewhat linear magnetic anomalies of moderate amplitude that probably are associated with buried crystalline rock masses. A good example is the anomaly trending northeast from a point south of Hanover (E 2) to a point east of Columbia (C 5).

Smaller, steep-gradient magnetic anomalies are associated with anticlinal exposures of the Lower Cambrian(?) Harpers Phyllite or the Lower Cambrian Antietam Quartzite, and areas where some of the basal Cambrian Chickies Slate is exposed. These anomalies are 3 miles north of Quarryville (E 6), at Safe Harbor (E 5), 1 mile south of Columbia (D 5), 4 miles southeast of York, and 2 miles south of Spring Grove (E 3), respectively. In these areas it is difficult to differentiate between the Harpers and Antietam Formations (Cloos and Hietanen, 1941), so the magnetic anomalies cannot be directly correlated with a specific formation. However, Griscom (1959) found that the magnetic anomalies north of Quarryville and at Safe Harbor are associated with magnetite-rich schists within the upper part of the Antietam Quartzite as mapped by Knopf and Jonas (1929). This magnetite-rich schist is found near the crests of anticlines and may be the metamorphosed equivalent of the topmost Antietam of other areas.

The restricted location of these magnetic anomalies is probably the result of regional metamorphism. The anomalies north of Quarryville (E 6) and southeast of York (E 4) continue to the southwest and southeast, respectively, across the contact with the Wissahickon Formation, indicating that these magnetic rocks extend beneath the Wissahickon. Depth determinations made by Griscom (1959) indicate that the magnetic rocks causing the anomaly plunge gently southwest and extend beneath the Wissahickon Formation a horizontal distance of more than a mile. This is in agreement with previous geologic mapping in these areas, which has shown the Wissahickon Formation to be a relatively thin and flat-lying sheet.

The pronounced northeast-trending linear magnetic anomalies associated with the Glenarm Series in the vicinities of West Manheim (F 3), Glenville (E 3), and Glen Rock (E 4) have restricted zones of markedly lower amplitude anomalies readily shown northeast and southwest of Glenville (E 3) and not so readily shown, owing to lack of data, southeast of Red Lion (E 4). The zones of lower-amplitude anomalies roughly coincide in areal dimensions and location with the two linear magnetic anomalies associated with the Paleozoic rocks south of Spring Grove (E 3) and southeast of York (E 9). This indicates that magnetic rocks similar to those associated with the magnetic anomalies in the vicinities of West Manheim, Glenville, and Glen Rock are offset 4 miles to the north.

MAGNETIC ANOMALIES ASSOCIATED WITH TRIASSIC ROCKS

Within the sedimentary rocks of the Triassic lowland are four major diabase intrusions (see geologic map). These intrusions and their associated magnetite-bearing hornfelses have characteristic magnetic patterns. In general, the more linear anomalies are associated with steep diabase dikes (or) with contact-metamorphosed rocks. The blotchy, less linear magnetic patterns in these four zones are associated with almost horizontal diabase sills. The nearly circular high-amplitude magnetic anomalies are caused by local magnetite concentrations. Each of the major intrusions has a distinctive magnetic character.

These Triassic rocks are economically the most important within the mapped area because of the association of extensive magnetite ore deposits with the diabase. The larger iron mines are all in the narrowest part of the Triassic lowland between Pottstown (CD 8) and Middletown (D 4).

Quakertown-Boyertown area

The Quakertown-Boyertown area contains the easternmost intrusion of diabase in the Triassic basin in Pennsylvania. The circular area of diabase near Ferndale (B 10) is part of the same diabase body but is isolated in a broad syncline by erosion. In the eastern part of the area, the low-amplitude, nearly circular magnetic anomalies are underlain by flat-lying diabase sills, and the linear magnetic anomalies are associated with the hornfels rim at the upper contacts of the sills (Socolow, 1959). In the western part of the Quakertown-Boyertown area (C 8, C 9), the magnetic anomaly pattern becomes more linear and of higher amplitude, reflecting the changes in attitude of the diabase rocks. At the extreme western end of the diabase intrusion at Boyertown (C 8), the broad, nearly circular magnetic anomaly is associated with the Boyertown iron mine.

Reading-Morgantown area

The Reading-Morgantown area is characterized by linear magnetic anomalies underlain by diabase rocks, most of which are steep dikes. The high-amplitude, nearly circular magnetic anomaly on the inner edge of the diabase body north of Morgantown (D 7) is associated with a large economic deposit of magnetite ore (Jensen, 1951). Another smaller magnetic anomaly south of Hopewell (D 7) having a similar favorable geologic setting is interpreted as indicating a magnetite concentration.

Cornwall-Middletown area

The linear magnetic anomalies of the Cornwall-Middletown area are underlain by structurally complex diabase rocks. The southern diabase band is a north-dipping sill and the northern band is a dike (Spencer, 1908). The Cornwall (C 5) magnetite mine, the largest of several magnetite mines along the northeast margin of the diabase dike group, still produces magnetite ore, but the magnetic anomaly associated with the mine is relatively small. Preliminary measurements of the magnetic properties on unoriented samples of ore from the Cornwall mine show a large component of remanent magnetization. This property of the ore may in some way account for the lack of a pronounced magnetic anomaly over this magnetite ore body.

Gettysburg-Dillsburg area

The southwesternmost area of diabase rocks is distinguished from the other three by abundant magnetic anomalies within the intrusion. The magnetic pattern suggests that in the central part of the Gettysburg-Dillsburg area, diabase in general is close to the surface. However, in the vicinity of York Springs (D 2), the magnetic anomalies trend east, with slight gradient changes across the contact with the Triassic rocks, indicating that the pre-Triassic rocks may also lie at shallow depth and cause some of the anomalies.

Two anomalies warrant further investigation as magnetite indicators: (1) along Route 15 approximately 2 miles south of Heldlersburg (E 2); (2) south of Gettysburg (E 2) between Route 116 and 140. The gradients of these anomalies indicate that the top of the magnetic body in the Heldlersburg area is less than 1,500 feet below the surface. The low-amplitude anomaly at Cornwall indicates that other low-amplitude magnetic anomalies may also be worth closer examination.

Buckingham area

Two small crescent-shaped belts of linear magnetic anomalies near Buckingham (C 10) at the east end of the Triassic basin are underlain by diabase. A gravity traverse (Zietz and Gray, 1960) shows that the northernmost diabase sheet dips north, nearly concordant with the Triassic strata.

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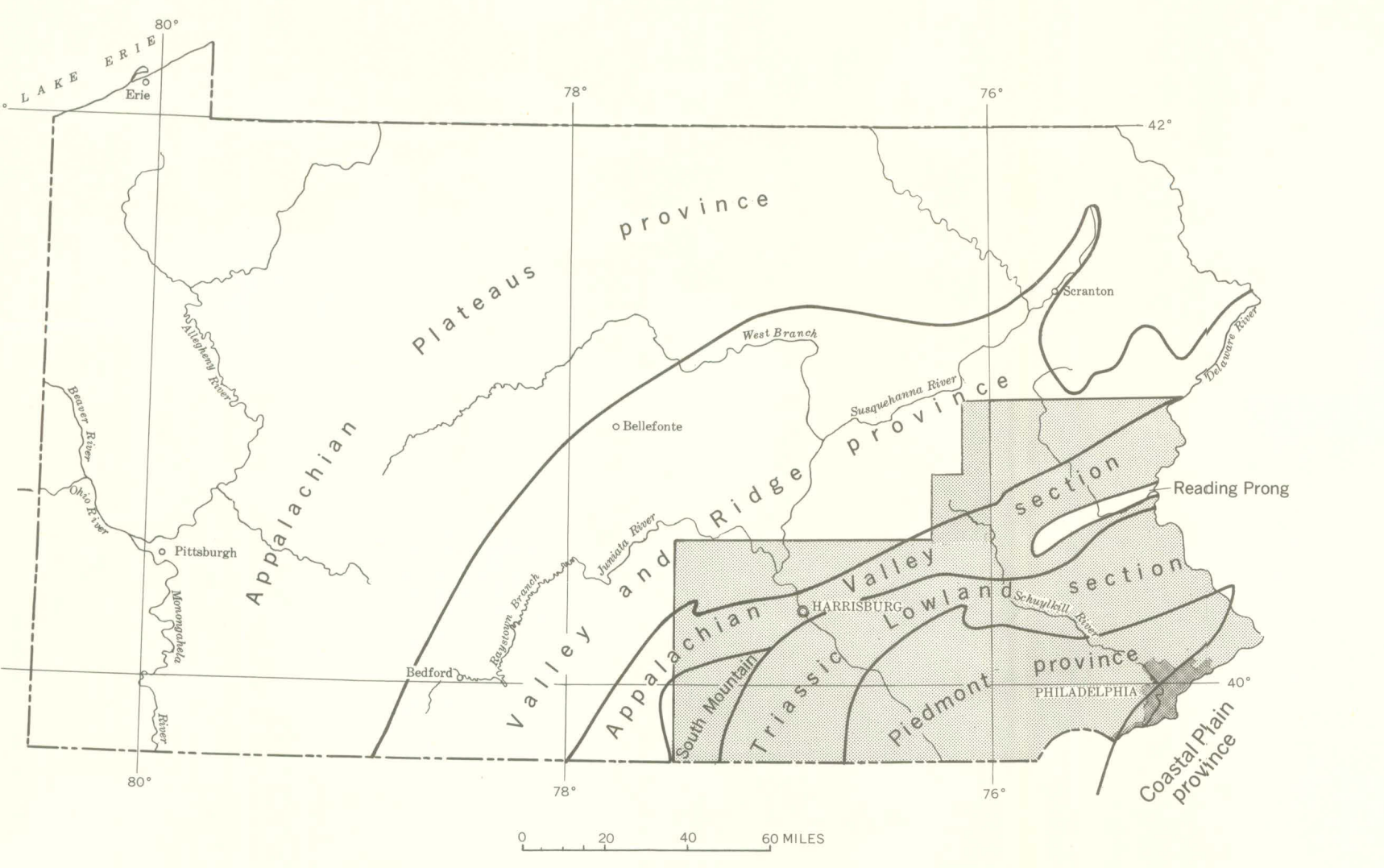
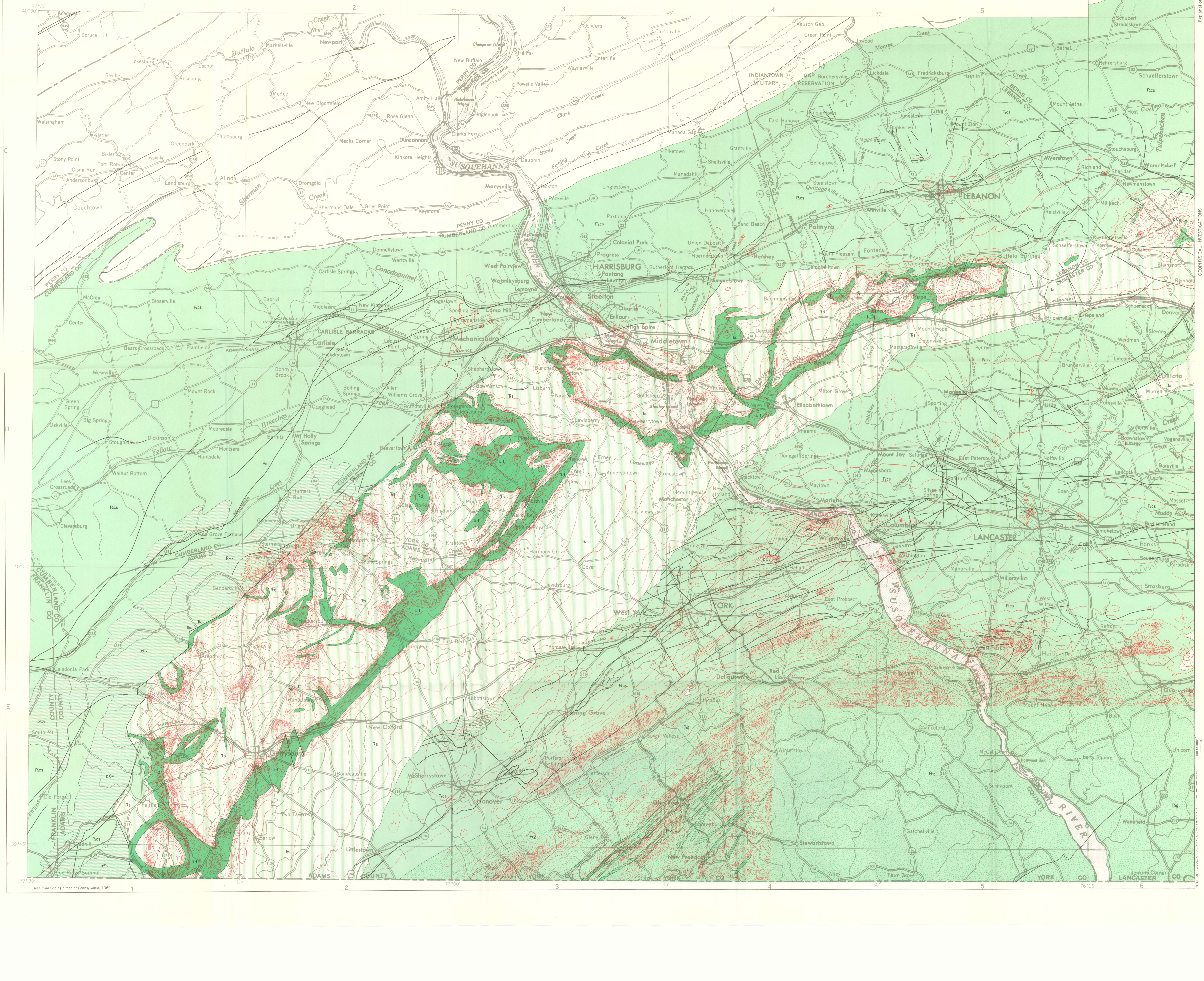


INDEX MAP OF PENNSYLVANIA SHOWING AREA OF THIS STUDY (STIPPLED) IN RELATION TO PHYSIOGRAPHIC PROVINCES



Explanation on east half

GEOPHYSICAL INVESTIGATIONS
MAP GP-577 (WEST HALF)