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Article III.— PRE-CAMBRIAN AND TRIASSIC DIABASE IN EASTERN PENNSYLVANIA.

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With Map.

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I. Introduction.

Location and general relations.— The region to be discussed occupies part of two adjoining quadrangles, the Boyertown and the Quakertown, contained in parts of Montgomery, Berks, Lehigh, and Bucks counties, Pennsylvania. The area of these quadrangles lies in the Piedmont Plateau and the Appalachian Mountains which is the eastern geographic division of the Appalachian Province. In Pennsylvania these mountains have been called the Reading and Durham hills. They enter northern New Jersey from Dutchess County, New York State, and form the Highlands of New

Jersey. Crossing the Delaware River near Easton, they extend southwestward past Bethlehem and Allentown to Reading. The Piedmont Plateau lies to the east of the Reading and Durham hills. The boundary between the two, in the area of the Boyertown-Quakertown quadrangles, extends in a curving and generally northeastern direction from west of Boyertown in the southwestern part of the quadrangle of that name, northeastward across the northwestern corner of the Quakertown quadrangle. The Reading and Durham hills occupy the whole northwestern half of the entire area of the Boyertown quadrangle but only a part of the northwestern ninth of the Quakertown quadrangle. The area southeast of this boundary line in both quadrangles belongs within the Piedmont Plateau.

II. Topography.

Appalachian Mountains.— For convenience that portion of the Reading and Durham hills which is under discussion will be called the Boyertown hills. They comprise a rugged country, well dissected by narrow valleys to a depth of four hundred feet above sea-level. The general elevation is about eight hundred feet, with long, level-topped ridges rising two hundred to four hundred feet above this surface.

Piedmont Plateau.— The Piedmont Plateau of the Boyertown and Quakertown quadrangles is irregular in its topography and altitude but has a marked decrease in elevation from northwest to southeast. Some of the country is flat or gently rolling; some of it is traversed by long narrow ridges; a great part of it is occupied by a long ridge, well broken up into hills, many of which rise conspicuously above the general level. This irregularity in topography is an expression of variability in hardness of the underlying rocks and of differential resistance to erosion. The gently rolling country is underlaid by soft shales, the long ridges by more resistant shales, and the marked topographic feature which is locally called "the Ridge" is formed of hard diabase flanked by indurated shale.

"The Ridge" rises to its greatest height of nine hundred feet to the northeast in Haycock mountain on the Doylestown and Easton quadrangles, and extends southwestward with an average width of two miles to the western central part of the Quakertown quadrangle where it divides and curves northwestward and southwestward to the Boyertown quadrangle.

III. Descriptive Geology.

Geology of the Boyertown Hills.

General relations.— The rocks of the Boyertown hills are a series of pre-Cambrian gneisses, mainly of igneous origin, with which are infolded and infaulted Palæozoic quartzites and limestone. The oldest formations, graphitic gneiss and Franklin limestone, are pre-Cambrian sediments, which were invaded by a granite that swallowed up all but remnants of the country rock. The granitic intrusion was closely followed by intrusions of diorite and gabbro, but the order of intrusion has not been established. Nor does the field evidence indicate whether a laccolithic or batholithic origin is to be assigned to the igneous complex. Dykes of diabase cut all the pre-Cambrian rocks of the region.

Graphitic Gneiss.

Distribution.— The graphitic gneiss is not found in any considerable area. The largest occurs just north of Boyertown and two and one half by three and one half miles are its extreme dimensions. Besides this area there are twenty small ones of irregular shape scattered throughout the Boyertown hills.

Lithologic character.— When fresh the rock is bluish gray in color; it is a usually fine grained, closely banded, granular rock whose constituents are quartz and feldspar, small flakes of bronze biotite and graphite and sometimes a pyroxene or amphibole. The rock weathers to rusty, orange-colored, angular fragments which are thickly scattered throughout the soil. With the graphitic gneiss is always associated white pegmatitic material. A dark gabbroitic gneiss is interbedded, in many places, with the graphitic gneiss in such intimate association that it must be mapped with the graphitic gneiss. It may represent injection of the pre-Cambrian sediments by a gabbro magma or may be a basic sedimentary gneiss called Pochuck by the New Jersey geologists.

Franklin Limestone.

Distribution.— Franklin limestone occurs in eight small lenses scattered throughout the country to a point six miles north of Boyertown. Some of the areas are associated with graphitic gneiss and with the iron ore which abounds in this region.

Lithologic character.— The Franklin limestone varies lithologically from a coarse grained, sugary, calcite rock, dusted with magnetite crystals, to a white fibrous type, speckled with green pinite; the white mineral is diopside with interstitial calcite.

Granite.

Distribution.— The granite, which has the most widespread distribution of the pre-Cambrian gneisses, is well exposed throughout the Boyertown hills. Intrustions of gabbro and diorite render the outlines of the granite area very irregular. In some places gabbro has been injected into the granite in bands that are too small to map, producing an injection gneiss composed of alternate light and dark bands. When not injected by gabbro, the granite possesses a secondary gneissic structure due to pressure and may be called a granite gneiss. Its strike follows the northeast and southwest trend of the Boyertown hills.

Lithologic character.— An abundant and widely distributed variety of granite is a dense, fine to medium grained, pink and green mottled rock. The constituents are quartz, feldspar, biotite, chlorite, and epidote in vein filling, and magnetite. The feldspar is either orthoclase and microperthite or microcline. A less important type is a hornblende granite with accessory oligoclase.

Diorite.

Distribution and field relations.— Diorite is exposed in more than a dozen areas of variable size and shape, occurring as far south in the Boyertown hills as Hill Church and Barto. Its appearance, weathering, and lithologic character are purely igneous. In the field the diorite is separated from the granite by the content of plagioclase which has been verified by microscopic study.

Gabbro.

Distribution.— Gabbro in the Boyertown hills occurs in irregular and dyke like areas. Its extent is subordinate to that of the diorite.

Lithologic character.— The typical rock is a dark greenish black, medium to fine grained, olivine free, augite gabbro. It is frequently quartz bearing. The augite has undergone alteration to hornblende in many cases and much of the gabbro may be called a hornblende gneiss. The feldspar which is of the composition of labradorite is usually saussuritized.

Palæozoic Rocks.

Partially bordering the pre-Cambrian rocks of the Boyertown hills and also occurring within the hills themselves, are areas of Cambrian quartzite and limestone. The contacts of the Palæozoic sediments with the gneisses are unconformable or faulted.

Diabase.

Distribution.— Diabase dykes intrusive in the pre-Cambrian gneisses occur throughout the Boyertown hills. All the exposures are narrow and interrupted. The widest of these dykes occurs one quarter of a mile southeast of Rittenhouse Gap. Though interrupted in outcrop, diabase dykes may be traced several miles along the strike which, in the northwestern part of the hills is northeast and southwest. Northwest of Boyertown the strike is in the opposite direction, northwest and southeast, but it turns to the prevailing northeast-southwest strike just north of Boyertown. Rock exposures in ledges are few and the existence of the diabase is indicated by a trail of bowlders across the country underlaid by the rock.

Lithologic character.— Most of the pre-Cambrian diabase is fine grained. In the field several distinct types appear. The most abundant is a medium to fine grained, almost black diabase, heavily augitic, with sparkling laths of feldspar and pyrite visible. A mottled dark and light green diabase is also common. In this variety the augite is chloritized to a large extent and the feldspar is dulled by alteration; pyrite is also abundant. The result of more complete chloritization is a dense dark green rock which occurs only in a few local outcrops near Barto.

The freshest type of diabase shows in thin section, feldspar, augite, some biotite and pyrite. The texture is ophitic. Plagioclase, which is chiefly labradorite, occurs in thin laths and the interstices are filled by augite. The augite is clouded and much broken up by alteration to chlorite. Some secondary biotite is present and abundant pyrite. In many cases the feldspar is saussuritized and its character obscured but the ophitic arrangement is still visible. The alteration of feldspar and augite may be carried so far that the thin section shows only chlorite, quartz and zoisite. This stage represents the extreme phase of alteration in the pre-Cambrian diabase. Pyrite is an accessory constituent which is characteristic of the pre-Cambrian diabase.

There is a limited occurrence near Gap Hill, of a purplish gray, aphanitic dyke rock. A study of the thin section reveals a trachytic arrangement of

orthoclase twinned according to the Carlsbad law and a little chlorite and magnetite in minute specks. The rock is a trachytic rather than a diabasic dyke rock. It also contains pyrite.

Age.— A pre-Cambrian age has been ascribed to the diabase described above for the following reasons. The diabase occurs in pre-Cambrian materials and does not penetrate Cambrian or younger rocks. The diabase has undergone considerable alteration and contains abundant pyrite which is absent from Triassic diabase.

Triassic Rocks of the Piedmont Plateau.

General relations.— The rocks of the Piedmont Plateau which lie southeast of the Boyertown hills are sediments and diabasic intrusions of Triassic age. The sediments were derived from crystalline rocks and were deposited in local lakes and estuaries. Erosion has removed a large part of these sediments and this remnant has been preserved in a long narrow basin produced by faulting and down-warping. Into these sediments were intruded diabase sheets of Triassic age. In the area of the Quakertown quadrangle the diabase is intrusive in the Brunswick conglomerate and shale which is the upper member of the Triassic sediments.

Brunswick Conglomerate.

Distribution.— The Brunswick conglomerate outcrops in irregular areas in the northern part of the quadrangle in the region adjoining the Boyertown hills.

Lithologic character.— It is a coarse grained variegated, reddish purple conglomerate with quartz and limestone pebbles which weather out of the matrix producing a cellular rock. Associated with the conglomerate is a vitreous red quartzite.

Brunswick Shale.

Distribution.— The Brunswick shale which adjoins the conglomerate to the southeast covers, in this region, a widespread area. Its dip is gently northwest in accord with the prevailing dip of the Triassic rocks.

Lithologic character.— The shale is uniformly soft with a few harder sandstone beds. The formation is red in color and breaks up readily into small fragments which are scattered throughout a red clay soil.

Triassic Diabase.

Distribution.— In the area of the Quakertown quadrangle the diabase is in the form of large intrusive sheets and dykes of great extent. The main mass of diabase forms Haycock Mountain in the Doylestown-Easton quadrangles, and extends southwestward into the Quakertown quadrangle with a width of two and one half miles. Near Rock Hill it narrows to one and one half miles but near the western central part of the quadrangle the diabase widens to three miles and divides north and south. Both branches divide again; the northeastern sub-branch sends out three narrow dykes, one of which spreads out into a wide area near the northern central part of the quadrangle and is united by a dyke with the Haycock Mountain end of the mass. The northwestern sub-branch narrows to a hundred feet where it passes into the area of the Boyertown quadrangle. The southern branch narrows to one half mile near Perkiomen Creek where it divides, and its northern sub-branch enters the Boyertown quadrangle; the southern sub-branch extends southward along Perkiomen Creek to a mile from the southern border of the Quakertown quadrangle and turns westward to pass into the area of the Boyertown quadrangle. The diabase gives rise to rough hilly country, thickly covered with large bowlders and for the most part heavily wooded. The prominent topographic feature which it produces is locally known as the "Ridge." There is a large quarry in diabase situated at Rock Hill where the rock is removed for road metal. The farmers break up bowlders by hand and shape the rough stones into paving blocks.

Field relations.— The diabase sheet, which is about 1000 feet thick, cuts the Brunswick formation at various horizons but does not pass below into the middle member of the Triassic sediments. Two excellent contacts of diabase and shale occur in cuts of the Perkiomen branch of the Philadelphia and Reading Railroad, one three quarters of a mile south of Salford, the other just south of Ziegler Station. At both exposures the contacts are nearly vertical and the shale dips 15° to the northwest along a strike discordant to the diabase. Similar relations obtain in the contact south of Rock Hill along the Bethlehem branch of the Philadelphia and Reading Railroad. South of Green Lane in a cutting made for a railroad siding, there is a dyke of diabase three hundred feet wide with vertical contacts with the enclosing shale.

Lithologic character.— The diabase of the greater part of the "Ridge" is light colored, coarse grained, crystalline rock with a distinctly ophitic texture. Its constituents are grayish feldspar and sparkling green augite

in almost equal amount. Magnetite and a little biotite and quartz are rarely present. Augite crystals conspicuously mottle the rock in some places. This coarse grained, light colored type is characteristic of the greater part of the Quakertown quadrangle. Another variety which occurs in many places is a medium grained, dark grayish black in color, with ophitic texture. Its constituents are the same as those of the coarse grained type. The diabase near the border of the sheet and of the smaller dykes is very fine in grain. It possesses a bluish gray to greenish black ground mass in which sparkle laths of dark green feldspar. This marked gradation from coarse to fine grain which radiates outward from the centre of the sheet indicates the intrusive character of the diabase and the marked chilling effect of the country rock.

The feldspar is chiefly doubly twinned plagioclase and is acid labradorite with the equal maximum extinction angles from 25° to 30° and of the composition ab50 an50. It occurs in prismatic individuals without terminal faces and occupies about 45% of the rock. There is a scanty amount of quartz and orthoclase in a microperthite intergrowth. Augite which occupies 50% of the rock, is green to brown to yellow in color, slightly frayed and chloritized. It contains inclusions of feldspar which was the first mineral to crystallize and was followed by crystallization of augite in prisms and as interstitial material. Apatite which is a prominent constituent occurs in long slender needles. Magnetite and a scanty amount of bronze biotite are also present. The prominence of the ophitic texture shows that the rock is a true diabase and not a gabbro. In the finer grained varieties the proportion of augite to feldspar is larger but the constituents are the same. Olivine is noticeably absent in the diabase of the Haycock Mountain sheet.

Alteration of the Shale.— The shale adjacent to the diabase has undergone considerable alteration. It has been indurated, its color has been changed from the prevailing red to a bluish black or grayish green. There results a crystalline aphanitic rock which is not separable from fine grained diabase without much care. Useful criteria for separation of the two rocks are faint sparkle of feldspar and a slightly green color present in diabase but lacking in the shale, lack of conchoidal fracture and spheroidal weathering in the shale. The metamorphosed shale is exposed for as much as three sixteenths of a mile in proximity of the diabase contact. Railroad cuttings south of Salford station afford good opportunity for studying the gradation from altered to unaltered shale. Ten feet north of the diabase contact the shale is dense greenish gray and crystalline. Ninety feet north of the green shale is exposed a hard blue shale simulating a fine grained diabase. A half mile further north the shale has become deep purple and softer and

in another of a mile has passed into the red and unaltered rock characteristic of the Brunswick formation. At the above locality there is developed in the shale a feature common to the indurated shale of the region; this feature is the presence of round shot like nodules of chlorite pseudomorphs after cordierite. Such a rock has been called a spilosite.[1] After weathering, these nodules give the rock a spotted aspect. Study of the indurated shale in thin section shows a fine grained hornfelds composed chiefly of quartz with scanty feldspar. Sometimes the rock is speckled with fine grains of epidote. Minute magnetite granules are abundant. There are present nodules of cordierite which appear in ordinary light as dark knots in a light quartz ground mass. In many of them the cordierite has been largely replaced by pinite and chlorite.

IV. Conclusion.

In addition to the difference in grain between the diabase of the Haycock sheet and that of the Boyertown hills, which is caused by the greater size of the former intrusion, the Haycock diabase possesses certain characteristics by which it is distinguished from the diabase of the Boyertown region. The most prominent characteristic is freshness of the constituents of the diabase of the Haycock sheet; the diabase of the Boyertown hills, on the other hand, has undergone marked alteration; saussuritization of the feldspar and chloritization of the augite has produced a clouding of the rock, has obscured the ophitic texture, and has changed the color. Pyrite is absent in the diabase of the Haycock sheet but is abundant in the diabase of the Boyertown hills. Stratigraphic relations point to a difference in age between the two kinds of diabase under discussion. The field relations readily prove the Triassic age of the Haycock diabase sheet, which has invaded Upper Triassic sediments in the Quakertown Quadrangle. The diabase of the Boyertown hills nowhere penetrates to a horizon younger than the pre-Cambrian. It cannot be traced either into the Palæozoic or into Triassic sediments. Therefore the alteration which is prevalent in the diabase of the Boyertown hills may be explained by their pre-Cambrian age and by the consequent fact that they have undergone greater metamorphism than the diabase of Triassic age.

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[1] J. Volney Lewis, Annual Report of Geological Survey of New Jersey. 1907, p. 138.

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