Census of Lehigh County farms

<table>
<thead>
<tr>
<th>Item</th>
<th>1940</th>
<th>1930</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of farms</td>
<td>2,074</td>
<td>2,325</td>
</tr>
<tr>
<td>Full owners</td>
<td>1,488</td>
<td>1,731</td>
</tr>
<tr>
<td>Part owners</td>
<td>192</td>
<td>74</td>
</tr>
<tr>
<td>Managers</td>
<td>31</td>
<td>74</td>
</tr>
<tr>
<td>All tenants</td>
<td>363</td>
<td>446</td>
</tr>
<tr>
<td>Value of farms (land and buildings)</td>
<td>$13,709,179</td>
<td>$21,806,201</td>
</tr>
<tr>
<td>All land in farms, acres</td>
<td>152,385</td>
<td>160,314</td>
</tr>
<tr>
<td>Average acreage per farm</td>
<td>73.5</td>
<td>69.0</td>
</tr>
<tr>
<td>Horses and colts</td>
<td>3,381</td>
<td>5,016</td>
</tr>
<tr>
<td>Cattle</td>
<td>9,823</td>
<td>10,611</td>
</tr>
<tr>
<td>Hogs and pigs</td>
<td>9,522</td>
<td>12,841</td>
</tr>
<tr>
<td>Corn for all purposes, acres</td>
<td>18,616</td>
<td>18,315</td>
</tr>
<tr>
<td>Corn for grain, acres</td>
<td>17,640</td>
<td>17,480</td>
</tr>
<tr>
<td></td>
<td>543,785</td>
<td>607,238</td>
</tr>
<tr>
<td>Wheat threshed, acres</td>
<td>20,128</td>
<td>25,542</td>
</tr>
<tr>
<td></td>
<td>400,112</td>
<td>464,416</td>
</tr>
<tr>
<td>Oats threshed, acres</td>
<td>11,031</td>
<td>10,133</td>
</tr>
<tr>
<td></td>
<td>262,398</td>
<td>271,853</td>
</tr>
<tr>
<td>Oats cut and fed unthreshed, acres</td>
<td>419</td>
<td>439</td>
</tr>
<tr>
<td>Barley threshed, acres</td>
<td>2,530</td>
<td>1,276</td>
</tr>
<tr>
<td></td>
<td>77,531</td>
<td>23,860</td>
</tr>
<tr>
<td>Rye threshed, acres</td>
<td>974</td>
<td>2,706</td>
</tr>
<tr>
<td></td>
<td>13,741</td>
<td>42,035</td>
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<tr>
<td>Mixed grains threshed, acres</td>
<td>190</td>
<td>189</td>
</tr>
<tr>
<td></td>
<td>4,673</td>
<td>5,069</td>
</tr>
<tr>
<td>Irish potatoes, acres</td>
<td>12,626</td>
<td>13,560</td>
</tr>
<tr>
<td></td>
<td>1,483,067</td>
<td>1,681,211</td>
</tr>
<tr>
<td>All hay, and sorgums for forage, acres</td>
<td>25,654</td>
<td>24,729</td>
</tr>
<tr>
<td></td>
<td>26,006</td>
<td>33,650</td>
</tr>
</tbody>
</table>

MINERALOGY
By Benjamin L. Miller

Lehigh County has yielded a fairly large variety of minerals, somewhat less than some of the counties of the southeastern portion of the State, but far more than the northern, central and western counties. The variety is due largely to the different types of rock present in the county. These include acid, intermediate, and basic igneous rocks, both deep-seated (plutonic) and shallow (extrusive); sedimentary rocks of the principal types—conglomerate, sandstone, shale and lime-
stone; and metamorphic rocks—gneiss, schist, quartzite, marble, and slate. The glacial deposits that are thinly spread over part of the county yield a great variety of rocks collected by the ice from a wide area to the northeast. These rocks are composed of many minerals.

In general each type of rock serves as the home of particular minerals, as must be the case since rocks are principally classified by their mineral composition. The metamorphosed igneous rocks contain the largest variety and the slightly altered sedimentary ones the fewest.

In Lehigh County the crystalline rocks occupy a comparatively small area in the southern section but they contain several somewhat unusual minerals. The pegmatite dikes that cut through the metamorphic gneisses have yielded several economic minerals, but in quantities too limited to be of commercial importance. The pegmatites have furnished some good mineral specimens. The gneisses themselves are composed of numerous minerals, mainly silicates, but the individual grains are small and the associated minerals are not readily separated. Some minerals have been recognized only under the microscope.

The sedimentary rocks, limestone, sandstone, and shale are composed of a limited number of minerals, mainly oxides and carbonates. The normal minerals are mainly small and the individual grains not readily recognizable with the naked eye. They are cut by veins that may carry other minerals.

The surface alteration and weathering of all the rocks have resulted in several secondary minerals which, in a few cases, possess economic significance, particularly the iron ores and clays.

Most of the geological work in this region has been done by men primarily concerned with the economic mineral products or the stratigraphy and there have been comparatively few strictly mineralogical investigations. While Professor of Chemistry in Muhlenberg College, Dr. Edgar Fahs Smith searched for minerals through Lehigh County and analyzed many of the specimens found. These results he published in 1882, 1883, and 1885. Similar contributions were made by John Eyerman in 1889 and 1911. Owing to the fact that the articles by Dr. Smith and Mr. Eyerman are not readily accessible, nearly all of their descriptions of Lehigh County minerals are quoted in full. Frederick A. Genth collected all the known mineralogical data of the State in his “Preliminary Report on the Mineralogy of Pennsylvania” published in 1875. Samuel G. Gordon in his “Mineralogy of Pennsylvania,” published by The Academy of Natural Sciences of Philadelphia in 1922, brought the information up to date. The latter is a valuable contribution and has been freely used in the preparation of this chapter.

Frederick Prime Jr. reported and described numerous minerals in his investigations of the iron ores of the region. Numerous other geologists have added to our knowledge of the minerals of Lehigh County in minor ways. Many of the articles deal with the minerals found in or near the Friedensville zinc mines of the Saucon Valley.

The list of minerals that follows is believed to be almost complete, according to existing information. Undoubtedly, additions will be made from time to time, especially in the microscopic investigations, and new occurrences will be reported. This chapter is largely a com-
pilation of previously published material, scattered through many volumes, and supplemented by the author's personal observations.

**List of Minerals**

- **Native elements**
  - Copper
  - Graphite
  - Sulphur

- **Sulphides**
  - Chalcocite
  - Galena
  - Greenockite
  - Iron minerals
    - Marcasite
    - Pyrite
    - Molybdenite
    - Sphalerite

- **Halides**
  - Fluorite

- **Oxides**
  - Corundum
  - Iron minerals
    - Anhydrous
      - Hematite
      - Martite
      - Magnetite
      - Ilmenite
    - Hydrous
      - Goethite
      - Limonite
      - Turgite
  - Manganese minerals
    - Psilomelane
    - Pyrohousite
    - Wad
  - Silica minerals
    - Quartz
    - Chalcedony
    - Flint (basanite)
    - Jasper
    - Hyalite
    - Spinel

- **Carbonates**
  - Calcium minerals
    - Calcite
    - Aragonite
    - Dolomite
  - Copper minerals
    - Azurite
    - Malachite
    - Lanthanite
    - Zinc minerals
      - Hydrozincite
      - Smithsonite
  - Feldspar group
    - Orthoclase
    - Plagioclase
  - Garnet group
    - Almandite
    - Andradite
  - Mica group
    - Biotite
    - Muscovite
    - Damourite
    - Sericite
    - Finnite
  - Amphibole group
    - Hornblende
    - Crocidolite
    - (Glauconophane)
  - Pyroxene group
    - Augite
    - Diopside
    - Enstatite
    - Hypersthene
    - Pectolite

- **Silicates**
  - Corundum
  - Anhydrous
    - Demantoid
    - Hypersthene
    - Pectolite
  - Mica group
    - Biotite
    - Muscovite
    - Damourite
    - Sericite
    - Finnite
  - Amphibole group
    - Hornblende
    - Crocidolite
    - (Glauconophane)
  - Pyroxene group
    - Augite
    - Diopside
    - Enstatite
    - Hypersthene
    - Pectolite

- **Other anhydrous silicates**
  - Allanite
  - Calamine
  - Epidote
  - Sillimanite
  - Titanite
  - Tourmaline
  - Zircon

- **Hydrous silicates**
  - Allophane
  - Chloropropyl
  - Halloysite
  - Kaolin
  - Serpentine
  - Stibnite

- **Halides**
  - Fluorite

- **Oxides**
  - Corundum
  - Iron minerals
    - Anhydrous
      - Hematite
      - Martite
      - Magnetite
      - Ilmenite
    - Hydrous
      - Goethite
      - Limonite
      - Turgite
  - Manganese minerals
    - Psilomelane
    - Pyrohousite
    - Wad
  - Silica minerals
    - Quartz
    - Chalcedony
    - Flint (basanite)
    - Jasper
    - Hyalite
    - Spinel

- **Phosphates**
  - Wavellite

- **Uranates**
  - Uraninite

- **Sulphates**
  - Goslarite
  - Melanterite

**Descriptions of Individual Minerals**

In the descriptions of the individual minerals which follow, little is given other than the particular features that characterize the Lehigh County specimens. It has not seemed desirable to describe the ordinary properties which are contained in all textbooks on mineralogy. The crystallographic descriptions are largely omitted since their inclusion would necessitate the reproduction of crystallographic drawings in most instances. Most of the available chemical analyses are included, even though some of them are of doubtful accuracy. It seems unnecessary also to discuss the various problems of nomenclature and chemical formulae.
The minerals that have been mined and utilized are discussed more fully in that portion of the volume dealing with the economic geology. Instead of the full bibliographic reference for each citation or quotation, only the author's name and the year of publication are given. The full title can be found readily by reference to the chapter on Cartography and Bibliography. For one who wishes to obtain all the information available, it will generally be necessary to refer to the individual articles.

**Native Elements**

**Copper (Cu)**

Native copper has been twice reported from the Ironton Mines as follows:

"An interesting occurrence (of native copper) has been noticed by Prof. W. Th. Roepper in the limonite deposits of Ironton, Lehigh County, where it is occasionally met with in minute distorted, probably cubical crystals disseminated through quartz." (Genth, 1875, p. 5.)

"Of more interest to the mineralogist is the occurrence of native copper in this black clay (of the Ironton Mines), which is found in small filiform pieces. Its presence in the metallic state being probably due to the carbonaceous matter in the clay." (Prime, 1878, p. 41.)

**Graphite (C)**

Graphite in thin flakes has been noted at several places in the metamorphosed rocks of Lehigh County. In two different places attempts have been made to open mines for the purpose of obtaining it in commercial quantity. These are described in the chapter on Mineral Resources.

The most numerous occurrences of graphite in the region are in the acid and basic gneisses of South Mountain. About half a mile west of Seidersville, along the Lehigh-Northampton County line, small, thin flakes have been noted in the basic gneiss. Flakes of graphite have been noted in the gneiss along the Little Lehigh west of the Western Salisbury Church. On the crest of South Mountain about three-fourths of a mile east of Emmaus and the same distance east of Vera Cruz, graphite flakes are so numerous that exploratory shafts were dug.

The microscopic examination of some of the gneisses has revealed the presence of tiny flakes indistinguishable to the naked eye.

In the cement rock of the Jacksonburg formation, the carbonaceous matter of these argillaceous limestones has been converted into what is assumed to be graphite along slickensided surfaces. These smooth, brightly polished surfaces are mainly along bedding planes and are abundant in the rock of many quarries. The graphite rubs off readily. Veins of calcite and quartz have developed along these slippage planes and it is common to find fine specimens of veins coated on both walls with a film of graphite.

Graphite is present as a microscopic constituent in most of the commercial slates of the county. Behre (1933, p. 180) describes it occur-
ring in slate as rounded, discoidal, or lenticular specks up to 0.015 mm. in diameter.

**Sulphur (S)**

The only known published description pertaining to native sulphur in Lehigh County is the following:

"Some good sized masses of sulphur were found by me, several years ago at the Ueberroth mine, Friedensville, Lehigh County, probably resulting from the desulphuration of the sphalerite." (Eyrerman, 1889.)

In some of the iron mine dumps composed of clay and considerable pyrite it is not uncommon to note a thin encrustation of fine yellow sulphur crystals. Some sulphur crystals are present in the weathered pyrite of the pyrite prospect shaft on the slope of South Mountain southwest of Wilbur.

**SULPHIDES**

**Chalcocite (CuS)**

No actual occurrence of chalcocite is known in Lehigh County, although it may well be found in association with malachite in Flint Hill in the extreme southeastern corner of the county.

"According to a private communication from Prof. W. Th. Roepper, of Bethlehem, chalcocite, occasionally in small crystals, is frequently met with on the line of junction between the South Mountain rocks and the Triassic sandstone, which latter is often colored green by malachite, resulting from the oxidation of the chalcocite." (Genth, 1875, p. 16.)

**Galena (PbS)**

The writer has not seen nor heard of any specimens of galena being found in Lehigh County, but is convinced that it is occasionally present in small isolated grains in the quartz veins that cut the Shawangunk sandstones and conglomerates of Blue (Kittatinny) Mountain. He has noted it in the railroad cut on the east side of Lehigh Gap and in the same strata farther east. He has seen it in larger amounts in the same formation near Bellefonte, where, in 1915, an unsuccessful attempt was made to mine it. Similar occurrences are reported from the Shawangunk Mountains of southeastern New York.

**Greenockite (CdS)**

The only known occurrence of greenockite in Lehigh County is in the Friedensville zinc mines where it was found by Prof. Roepper. It occurs mainly as yellow, greenish-yellow, or orange-colored earthy (amorphous) encrustations on sphalerite, calamine, or the dolomitic limestones. Roepper also noted it in the residual clay resulting from the decomposition of pyritiferous limestone. He analyzed a specimen of this material and found it to contain 5 percent of cadmium. Genth (1875, p. 19) says "formerly cadmium was separated from the zinc at the Bethlehem works." This statement is questioned.
Marcasite (FeS₂)

Few exact determinations of marcasite have been made in the region, although it is the general belief that it is fairly common in association with pyrite. Some of the massive iron sulphide has the characteristic appearance of marcasite and, furthermore, the readiness with which much of it decomposes when exposed to the atmosphere likewise indicate its presence. This is particularly true of iron pyrite in the Friedensville zinc mines and to a lesser degree in some of the limonite mines.

Pyrite (FeS₂)

Pyrite is a common mineral in Lehigh County. In places it is a rather abundant constituent of the gneisses, being well distributed through the normal gneiss and in the pegmatites cutting the gneiss. It occurs almost everywhere in the Hardyston sandstone and by oxidation makes the limonitic stains that render the stone particularly pleasing in color for residences and public buildings. In the compact quartzite the oxidation has extended inward from the bedding and joint planes less than an inch, but in the more porous beds the pyrite has changed to limonite throughout, even though the layers be six inches or more in thickness.

Pyrite is common in all the limestones, especially in those high in argillaceous and carbonaceous matter. Usually it is in small cubes along bedding planes, but is also present in massive form.

Considerable pyrite was encountered in the lower levels, in several of the limonite mines once worked in the county, both in those deposits contained within the Hardyston quartzite and within the limestones. As suggested in the discussion of the origin of iron ores, this furnishes some evidence for the view that all the iron of the limonite ores was derived from pyrite. The commercial aspects are discussed in the chapter on Mineral Resources.

Pyrite is fairly common in the Jacksonburg cement rock, particularly associated with the graphite occurring along slickensided surfaces.

In the Martinsburg slates one occasionally notes small cubes of pyrite or cavities resulting from their removal. In some of the black "ribbons" of the "hard vein" slate the presence of considerable pyrite (and marcasite?) results in fairly rapid decomposition and disintegration.

Molybdenite (MoS₂)

Molybdenite in thin coatings along joint planes in gneiss has been observed in several places by the writer, but the only occurrence known in Lehigh County where the associated rock is in place is in an abandoned quarry in a dense granite gneiss a short distance south of the Reading Railroad about three-fourths of a mile east of Vera Cruz. When the rocks are broken it is not uncommon to find bright fresh pieces of the mineral. Flakes of molybdenite associated with secondary quartz and epidote were noted in loose masses of basic gneiss on the lower slope of South Mountain south of Farmington. It also occurs in some of the gneisses associated with the hematite iron ore mine just west of Old Zionville.
The outstanding occurrence of sphalerite in Pennsylvania is at Friedensville, where zinc ores were mined over a period of years. This deposit is described in detail in the chapter on Mineral Resources.

Small particles of sphalerite have been reported also from some of the limonite mines in Saucon Valley, particularly from the Greene Mine, slightly less than one mile east of Lanark. On May 20, 1933 the writer found a greenish-yellow sphalerite associated with crystalline dolomite within a grayish-white chaledony lens in an old limestone quarry a short distance southwest of the junction of the Little Lehigh and Jordan creeks, South Allentown. The limestone belongs to the Allentown formation. Other similar discoveries will doubtless be made.

**HALIDES**

**Fluorite** (CaF₂)

Fluorite has been noted by the writer and others in numerous places throughout the State, especially in calcite or dolomite veins in the limestones. Most of it is purple, but the light green variety has also been found.

In recent years both purple and green fluorite have been found in calcite veins in the Ormrod quarries of the Lehigh Portland Cement Co. It is probably this same locality that furnished the specimens analyzed and described by E. F. Smith in the following quotation:

"About one and a half miles southeast of the above locality (Iron ton iron mines) are the limestone quarries of Mr. Kleckner. In them have been discovered veins of beautiful fluorite and fine quartz crystals. The former mineral occurs intimately mixed with the limestone, and presents itself in the most beautiful green, purple and pink colors. Upon several specimens octahedral forms were observed, but not very distinct. It is seldom that entire crystals can be procured, since blasting is invariably necessary to reach them; consequently fragments are the result. Quantitative analyses of the purple and green varieties were made.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Purple variety</th>
<th>Green variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca</td>
<td>50.87 per cent.</td>
<td>50.91 per cent.</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>trace</td>
<td>trace</td>
</tr>
<tr>
<td>Fl</td>
<td>49.20 per cent.</td>
<td>49.00 per cent.</td>
</tr>
</tbody>
</table>

The mean of the specific gravities of five specimens was 3.21; ranging from 3.17-3.24. The shade of purple varied very much in the specimens examined.

Sp. gr. about the same as in case of the purple. South of Emmaus in the Lehigh mountains Mr. Benj. Sadler, Jr., found this mineral in perfect octahedra of deep purple color in a granitic rock. (Smith, 1883, p. 272.)

The rather widespread but sporadic occurrence of small particles of fluorite in both the pre-Cambrian and Paleozoic strata of the State brings up the question of its origin. Although at the present time there seems to be a preference among geologists for the belief in magmatic waters as the source, the writer strongly inclines to the belief that most, if not all, the occurrences of fluorite in limestone known to him within the State have been formed by artesian waters of meteoric origin.
Fluorite is also present in the baked Triassic conglomerates south of Hosensaek in Lower Milford Township.

**OXIDES**

**Corundum** (Al₂O₃)

Edgar F. Smith and N. W. Thomas first reported the discovery of corundum about three-fourths of a mile north of Shimersville in 1882. Following their announcements an attempt was made to mine the material. A trench was dug in the decomposed gneiss and the corundum crystals were picked out by hand. A small shipment is reported to have been made. The writer has picked up small pieces in the vicinity of the trench, now almost obliterated. The indications are that the corundum occurs in a pegmatite dike cutting the gneiss. The descriptions by Smith and Thomas are quoted:

Early in January last, a piece of what was once a large hexagonal prism of corundum terminated by pyramids, was handed us. The specimen we received was an end piece exhibiting a perfect hexagonal form, with pyramidal ending, and on the broken surface of the crystal, the color observed was blue. The weight of this specimen is five pounds. The original complete crystal measured eight inches in length, and the diameter over the secondary axes is about four and one-half inches. On the exterior surface are observable here and there, magnetite crystals and these were the cause of the destruction of the original crystal soon after it had been plowed up. The farmer thinking he had made a valuable discovery and curious to know the appearance of the inside, broke the crystal into several pieces, one of these coming into our possession, after it had been carried about to various parties, for inspection and determination. Only very slight indications of any alteration are apparent on the exterior of the crystal. Soon after getting the above, we received another crystal—a double pyramid—about five and one-half inches long and weighing over five pounds. Since the reception of the preceding, we obtained several cigar boxes full of smaller, well-defined crystals. All of our specimens were found near Shimersville, Lehigh County, Pa., and were thrown out while plowing. The district over which these crystals were scattered, and have been noticed, is rather extensive and is already under lease, and "prospecting" for larger quantities has been commenced. Quite a number of medium sized crystals were sent to the Weissport Emery Works, there tested and declared excellent for technical purposes. We reserve our analyses of the above for a future communication. (Smith and Thomas, 1882.)

This mineral, which we announced (Am. Phil. Soc., March 17, 1882) as occurring near Shimersville, Upper Milford Twp., has since been discovered there in exceedingly fine crystals; color grayish and red. In many the star is very distinct. The specimens are but slightly altered. The brilliant black crystals noticed upon almost all specimens from here have been found to be menaenusite. Dr. Genth (Am. Phil. Soc. Proceedings, Aug. 18, 1882) has published an account of the black spinel found here, which is unquestionably an alteration of the corundum. Very recently several students of this laboratory discovered fine specimens of it. An analysis of the Shimersville corundum gave the following:

|       |       |          |       |   |  
|-------|-------|----------|-------|---|---
| SiO₂  |       | 3.28 per cent. |       |   |   |
| H₂O   |       | 1.37      |       |   |   |
| Al₂O₃ |       | 85.75     |       |   |   |
| Fe₂O₃ |       | 4.26      |       |   |   |
| TiO₂  |       | 2.74      |       |   |   |
| MgO   | trace |           |       |   |   |
| CaO   |       | 1.99      |       |   |   |

Sp. gravity, 3.898 (Smith, 1883.)
Hematite (Fe₂O₃)

Hematite as a red ocherous coloring matter is fairly common throughout the rocks of the county. It has been formed from pyrite and is commonly associated with limonite. Earthy forms of hematite occur about the old iron mines. Doubtless some of the so-called hematite is actually turgite.

The brown hydrous iron ore minerals so extensively worked throughout the county were commonly called "hematite" or "brown hematite." They are actually limonite or mixtures of several hydrous iron minerals.

Hosensack Station and Shimmersville have been cited as localities where hematite has been found.

Martite (Fe₂O₃)

Martite as a pseudomorph after magnetite or pyrite has been recognized in various places but rarely except where it preserves the crystal form of the replaced mineral. The writer has noted it occasionally and "Prof. W. Th. Roepper has observed that it is frequently associated with zircon, allanite, etc., at several of the South Mountain localities near Bethlehem." (Genth, 1875, p. 35.)

Magnetite (Fe₃O₄)

Magnetite is a common accessory mineral in the gneisses of the region, especially the more basic varieties. As the containing rocks decompose, the small magnetite particles are freed and are concentrated by the hillside run-off following rains. The black grains can be readily seen along gullies and in the stream sands.

Magnetite has been found in commercial quantity in several places, as described in the chapter on the Mineral Resources.

Ilmenite (Menaccanite) (FeTiO₃)

Ilmenite is a common constituent of the metamorphic crystalline gneisses of the region, occurring in small grains associated with magnetite. The black sand resulting from the concentration of the heavy minerals from the decomposed gneisses practically always contains ilmenite.

In some of the older literature this mineral is called menaccanite, a term at present obsolete.

Prime describes a specimen found at the Elias Daney mine a short distance northeast of Leiberts Gap as follows:

The foreman at the mine had a single specimen of ilmenite (titaniferous iron ore) which he said had been found in the top clay when working the mine. This was sent to Mr. A. S. McCreath, who analyzed it and reported:

<table>
<thead>
<tr>
<th>Element</th>
<th>wt%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica</td>
<td>8.37</td>
</tr>
<tr>
<td>Lime</td>
<td>0.52</td>
</tr>
<tr>
<td>Magnesia</td>
<td>3.87</td>
</tr>
<tr>
<td>Alumina</td>
<td>2.79</td>
</tr>
<tr>
<td>Titanic acid</td>
<td>32.18</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>trace</td>
</tr>
<tr>
<td>Sulphur</td>
<td>none</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.35</td>
</tr>
<tr>
<td>Iron</td>
<td>38.16</td>
</tr>
</tbody>
</table>

This latter partly as ferrous, partly as ferric oxide. This specimen is evidently extraneous, as but a single one has been found. (Prime, 1878, p. 26.)
Goethite (Fe\textsubscript{2}O\textsubscript{3}·H\textsubscript{2}O)

Goethite has usually not been distinguished from other hydrated iron oxides, but it appears to be present in most of the brown iron ore deposits of the region, particularly in the iron geodes that were abundant in some of the limonite mines.

Limonite (2Fe\textsubscript{2}O\textsubscript{3}·3H\textsubscript{2}O)

Hydrated iron oxides are abundant throughout the county. The term limonite is used to designate those mixtures of ferric iron minerals whose constituents have not been identified. The principal constituents are goethite, lepidocrocite, turgite, hematite, and jarosite. (Galbraith, 1937.) The brown limonite was the principal constituent in the numerous brown iron ore mines once worked but now abandoned. The miners called it brown hematite. Undoubtedly much of what has been loosely called limonite is actually goethite or lepidocrocite. It occurs in many forms. The earthy variety mixed with clay is known as ocher and has been used for paint. The shelly, stalactitic and geode varieties are common. The black varnish-like botryoidal lining of geodes and other cavities reveals a fibrous structure upon fracturing. Although this has been called limonite in the past, it probably is goethite.

Limonite is the chief coloring matter of most of the rocks of the region. The iron was originally derived from pyrite, siderite, and the various ferro-magnesian minerals of the crystalline rocks. Pseudomorphs of limonite after pyrite have been found.

A full description of the limonite ores is given in the chapter on Mineral Resources.

Turgite (2Fe\textsubscript{2}O\textsubscript{3}·H\textsubscript{2}O)

Turgite has been confused with others of the iron oxides. Posnjak and Merwin* make the statement that “the fibrous mineral turgite is variable in composition and considerable evidence is given that it probably represents solid solutions of goethite with hematite together with enclosed and absorbed water.”

Reddish iron oxides are not uncommon in the numerous limonite deposits in Lehigh County. Many of these specimens have been called turgite.

Psilomelane (MnO\textsubscript{2} + impurities)

Most of the limonite ores of the region contain some manganese and in a few places considerable percentages of it. The ocher in some localities contains considerable manganese. Although some of the manganese in the iron ores may be in the form of pyrolusite, it seems that more exists as psilomelane and of the variety known as wad.

Further descriptions are given in the discussion of manganese ore in the chapter on Mineral Resources.

Pyrolusite (MnO\textsubscript{2})

Dendrites of pyrolusite, resembling ferns and frequently so designated, are common in the rocks of the region. Extending in from the cracks in the rocks the dendrites are very conspicuous, especially in some of the limestones.

Nearly all the limonite ores, once so extensively mined in this region, carried some manganese either as pyrolusite or psilomelane. Some of the "mountain ores" were especially high in manganese. A few specimens of stalactitic pyrolusite were found at one of the iron mines southeast of Wilbur.

Dr. Edgar F. Smith contributed the following description:

"At various times miners have reported this mineral as occurring in Lehigh county, but only of late have finely crystallised specimens of it been observed. The crystals are usually seen upon the inside of limonite nodules, frequently covering their entire inner surface. Those in our possession are from the Lehigh mountain south of Allentown, near the village of Mountainville:

\[
\begin{align*}
\text{SiO}_2 & : 9.93 \text{ per cent.} \\
\text{Fe}_2\text{O}_3 & : 4.21 \\
\text{Al}_2\text{O}_3 & : \text{trace} \\
\text{MnO}_2 & : 82.66 \\
\text{Mn}_3\text{O}_4 & : 3.13 \\
\end{align*}
\]

99.93"  

(Smith, 1883, p. 277.)

Wad (\text{MnO}_2 + \text{impurities})

The soft earthy variety of manganese oxide mixed with various impurities and known as wad has the same occurrence and association as psilomelane and pyrolusite.

Genth (1875, pp. 53-54) offers the following:

"It has been observed as a frequent associate of limonite ores. Most of the wad or bog manganese of the limonite region of Northampton, Lehigh, Berks, Montgomery and other counties, contains some cobalt.

"A large deposit of an ocherous cobaltiferous variety occurs, according to Prof. Roepper (priv. com.) near Albertis (Alburtis), Lehigh County, at the mine of the Philadelphia and Reading Coal and Iron Company."

"Some varieties of the Lehigh region contain a considerable admixture of clay, as is shown by the analysis of one by Prof. W. Th. Roepper (priv. com.).

"He found:

\[
\begin{align*}
\text{Clay} & : 43.66 \text{ per cent.} \\
\text{Ferric oxide} & : 19.29 \text{ " "} \\
\text{Manganic oxide} & : 23.54 \text{ " "} \\
\text{Magnesia} & : 0.34 \text{ " "} \\
\text{Phosphoric acid} & : 0.29 \text{ " "} \\
\text{Water} & : 11.04 \text{ " "} \\
\end{align*}
\]

100.26 " "

SILICA MINERALS

Quartz (\text{SiO}_2)

Quartz is the most widely distributed mineral in the world and occurs in many different varieties and under various conditions. It is an essential or an accessory mineral in practically every type of rock within the county.

The light-colored or acid gneisses contain grains of quartz associated with the feldspars and ferro-magnesian minerals; the dark-colored gneisses in places carry a small amount of quartz; all kinds of gneisses are cut by thin quartz veins and by pegmatites in which the
quartz grains may be of considerable size; the Hardyston conglomerates, sandstones and quartzites are composed almost entirely of quartz, both the elastic particles and the cementing matter; all the limestones carry quartz grains and are cut by thin veins in which calcite and dolomite are most abundant but in which quartz is common; the Martinsburg shales contain small quartz grains and in many places have many veins of quartz or quartz and calcite; and the Triassic conglomerates consist of quartz pebbles in a matrix of shale that contains many quartz grains.

Quartz crystals up to four inches in length with well developed crystal faces have been found in cavities in the fractured limestones and loose in the residual soils.

In that part of the Saucon Valley contained in Lehigh County some masses of ferruginous quartzite, probably from the Beekmantown formation, have been found in which each grain has some crystal faces and some individual particles are perfect doubly-terminated crystals. They can readily be seen through a small hand lens.

Genth reports "an interesting variety of fibrous quartz (which had been considered petrified horsehair), with zinc blende and limonite, at the zinc mines at Friedensville, near Bethlehem." (Genth 1875, p. 57) He also states that fetid quartz has been found in the same mines. (p. 59)

Chaledony (SiO₂)

Associated with the abundant yellow jasper in the Hardyston formation which normally crops out along the lower slopes of South Mountain, there are occasional milk-white to light-blue, partially translucent masses of chaledony. In a quarry in Allentown limestone near the junction of the Little Lehigh and Jordan creeks there is a thin layer of chaledony that has been formed by replacement of the limestone.

Flint (basanite, hornstone, chert) (SiO₂)

The dark-colored cryptocrystalline varieties of silica, although described as possessing somewhat different properties, are not here differentiated. Specimens of each type and gradations from one to another can be picked up in the fields or along the streams throughout the areas underlain by limestone. The source of the flint is in the Cambrian and Ordovician dolomitic limestones. In some places it is fairly abundant. All these limestones have a rather high silica content and the silica has, in part, been segregated by underground circulating waters into lenses or nodules of irregular shape. The lenses are commonly more or less parallel to the bedding planes and range in thickness up to several inches. Many specimens show by their physical features that they are replacements of the limestone. Replacements of the fossil algae Cryptozoon proliferum by flint have been found. Occasional irregular masses of flint several feet in diameter cut across the beds. The Beekmantown limestone of the Friedensville zinc mines contains an abundance of flint.

The flint in the soils is the residual, relatively insoluble material left behind when the enclosing dolomitic limestone was removed by solution.
The Indians used the black flint of the region for their arrowheads, many of which have been collected all through the county.

**Jasper (SiO₂)**

Yellow and red jasper are abundant in the Hardyston formation of the southeastern part of the county. The yellow variety is most common. Some of it is uniform in color, but most of it is mixed with clear quartz and much is stained with pyrolusite. The yellow variety grades from a bright golden yellow to a dark brown, and the red from an orange to a brick color or to a deep carnelian red.

The Indians found the jasper very satisfactory for their arrowheads, spear heads and scraping knives. These have been found all over the county and far beyond its borders. Loose pieces of jasper suitable for implements were probably picked up in many places on the lower slopes of South Mountain. In two places excavations of considerable depth were made. Two of the most important sites in the State for digging the material are within the county, one of them on the hill about a quarter of a mile northwest of Vera Cruz and the other about half a mile southeast of Macungie. Another important one is located in Berks County a short distance beyond the borders of Lehigh County. These diggings are described in the chapter devoted to the early history of the county.

The jasper is considered to be a replacement of the Hardyston sandstone inasmuch as petrographic study has revealed some rounded sand grains* although in general no original structures are preserved. Much of the jasper is shattered and cavernous, with the walls of the cavities lined with beautiful small quartz crystals. Some specimens of this drusy variety of jasper have been used in rock gardens and walls because of its beauty.

Jasper has also been noted in a few of the limonite mines in the limestone areas. In such occurrences it has doubtless been formed by replacement of limestone.

**Hyalite (SiO₂·nH₂O)**

F. R. Faux reports the presence of hyalite in the baked Triassic sediments south of Hosensack, Lower Milford Township.

**Spinel (MgAl₂O₄)**

Genth reports spinel from the corundum locality near Shimersville in the following description.

"Disseminated through all the crystals (of corundum) and frequently accumulating on the surface, are minute, very brilliant crystals of a highly titaniferous menaccanite; these are not magnetic. It appears that this corundum has not been altered to a very great extent, only a few specimens of black spinel in irregular masses or rounded, pyramidal forms have been found, besides these only very thin yellowish or greenish, soft coatings, in very minute quantity, which may be a potassium mica. I could not get enough for examination. The spinel has an iron-black color, and is slightly magnetic. Its specific gravity is = 4.056.

---

Mr. George M. Lawrence has made an analysis of it in the Laboratory of the University of Pennsylvania, and found, after deducting 1.47% of silicic acid as follows (a); the calculated composition (b).

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<tr>
<th></th>
<th>a</th>
<th></th>
<th>b</th>
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</thead>
<tbody>
<tr>
<td>$\text{Al}_2\text{O}_3$</td>
<td>56.42</td>
<td></td>
<td>25.40</td>
</tr>
<tr>
<td>$\text{Fe}_2\text{O}_3$</td>
<td>13.17</td>
<td></td>
<td>48.51</td>
</tr>
<tr>
<td>$\text{FeO}$</td>
<td>22.93</td>
<td></td>
<td>26.09</td>
</tr>
<tr>
<td>$\text{MgO}$</td>
<td>4.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{TiO}_2$</td>
<td>2.62</td>
<td></td>
<td>100.00</td>
</tr>
<tr>
<td></td>
<td>106.00</td>
<td></td>
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</table>

"The titanic acid is present evidently as a mechanical admixture of menaccanite $\text{FeTiO}_3$; deducting this and 24.16% of corundum, the composition of the pure spinel is given under (b). I do not consider the $\text{FeFe}_2\text{O}_4$ a mechanical admixture of magnetite, as it cannot be dissolved out by hydrochloric acid." (Genth, 1882.)

**CARBONATES**

**Calcite (CaCO₃)**

Calcite is an abundant mineral throughout Lehigh County. Its most abundant occurrence is in the Cambro-Ordovician limestones where it is the principal constituent mineral. It is present also as a vein mineral, commonly in association with quartz, in the limestones and shales. Some beds of limestone are composed of practically pure calcium carbonate, but most contain varying amounts of other minerals, particularly dolomite.

Calcite (and quartz) vein matter is strikingly shown in the Jacksonburg cement rock in many quarries. The contrast of the black cement rock and the white mineral veins produces an attractive effect. These calcite veins are normally finely crystalline but here and there cleavage rhombs up to an inch or more in diameter can be found.

Occasional small cavities in the limestones contain calcite crystals, varying from the acute scalenohedral form (dogtooth spar) to the flattened form (nail-head spar). Some of the crystals are transparent although most are tinted a light yellow and are only translucent. The mineral collector rarely finds any specimens of museum value.

Although there are no large caves in the county there are solution cavities in many places in the limestones where calcite stalactites have been found. A small cave in the Ziegenfuss quarry in the southwest part of Allentown at one time yielded some beautiful specimens of calcite and aragonite.

Genth reports stalactitic calcite in the form of "hollow quills at Catasauqua." (Genth, 1875, p. 154.) The exact locality is unknown to the writer.

**Aragonite (CaCO₃)**

Clusters of tiny, acicular and tree-like crystals of aragonite are occasionally noted in the cavities in the limestones. F. R. Faux reports beautiful arborescent forms found in a cave in the Ziegenfuss quarry in the southwest part of Allentown. These are very fragile but make very attractive specimens. Many stalactites in open caverns are composed of aragonite.
Genth describes aragonite from Friedensville as follows:

“A highly interesting zinciferous variety of aragonite, in crystals of three-fourths to one inch in length, forming radiating groups of a white and yellowish-white color, has been observed at the Friedensville Zinc Mines, by Prof. W. Theo. Roepper, who kindly furnished me with his analysis.

“It contains

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Carbonate of lime</td>
<td>94.29</td>
</tr>
<tr>
<td>Carbonate of zinc</td>
<td>4.73</td>
</tr>
<tr>
<td>Insoluble</td>
<td>0.53</td>
</tr>
</tbody>
</table>

99.46

“Most of the aragonite from Friedensville contains carbonate of zinc.”

(Dolomite (CaMgCO₃))

Dolomitic limestones are widespread throughout the limestone belts of the county. In small cavities in these limestones it is not unusual to find small saddle-shaped crystals of dolomite. Some fine specimens are to be found in the rock waste beside the open pit of the Ueberroth zinc mine, Friedensville.

The magnesium carbonate in the magnesian limestones ranges up to approximately 45 percent. With the exception of the Jacksonsburg limestones used in manufacture of portland cement and occasional beds within the Beekmantown formation, it is unusual for any limestone from Lehigh County to show less than 5 percent MgCO₃, thus indicating the widespread occurrence of dolomite.

(Azurite (Cu₃(OH)₂(CO₃)₂) and Malachite (Cu₂(OH)₂CO₃))

Azurite and malachite are included in the minerals of Lehigh County although no actual occurrence is known to the writer. On the north slope of Flint Hill, a part of which comprises the extreme southeastern corner of the county, some prospecting for copper ore was carried on about 30 years ago. Malachite coatings of limestone pebbles in the Triassic limestone conglomerate were fairly abundant. Some of the limestone pebbles had been removed by solution, leaving cavities whose sides were covered by a thin film of malachite. Inasmuch as the same rock formation extends into Lehigh County it is probable that careful search may show that malachite occurs in this county as well. Azurite commonly is associated with malachite so that it may also be present.

(Lanthanite (La₃Ce₅)(CO₃)₃·8H₂O)

Probably the rarest mineral thus far reported in the county is lanthanite. Only a single specimen has come to light even though extended search has been made for more material.

In 1853 Dr. W. W. Dickenson, the superintendent of the then active zinc mine at Friedensville, observed a pinkish piece of rock thrown out of an exploratory shaft. It was about the size of a man’s fist and found about 6 feet from the surface embedded in “ochery soil,” evidently largely residual clay resulting from the solution of the limestones. It was close to a calamine vein and was first believed to have originated from either the dolomitic limestones or the zinc ores. Further investigations seemed to indicate that it was probably derived
from a mass of allanite that had come from the crystalline gneisses that lie only a short distance to the north and had been transported as hillside wash. The first published description by Blake contains the following:

"The specimen was about three inches in diameter and attracted my attention by its delicate pink color and peculiar structure, being an aggregation of thin plates and scales of a pearly luster, forming a light reticulated mass which was found to be highly crystalline on examination by a glass, and the crystals were apparently rectangular in form. . . .

"The isolated plates or crystals appear transparent, and nearly colorless, but when the mineral is seen in mass it has a beautiful pink or rose color, and is not unlike that of peach blossoms." (Blake, 1853.)

Blake published a further description in 1858 (see bibliography), J. L. Smith discussed it in 1854, and Genth in 1857 and 1875. Genth gives additional data with analysis as follows:

"The original specimen . . . consisted of an aggregate of small orthorhombic crystals in thin four-sided plates or minute tables, with beveled edges and a micaceous cleavage; it shows pearly lustre, and a delicate pinkish, grayish-white color. H = 2.5-3; sp.gr. = 2.505-2.666." (Genth, 1875.)

<table>
<thead>
<tr>
<th></th>
<th>Smith</th>
<th>Genth</th>
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<tbody>
<tr>
<td>Lanthana (and Didymia)</td>
<td>54.90</td>
<td>55.03</td>
</tr>
<tr>
<td>Carbonic acid</td>
<td>22.58</td>
<td>21.95</td>
</tr>
<tr>
<td>Water</td>
<td>24.09</td>
<td>24.21</td>
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<tr>
<td></td>
<td>101.57</td>
<td>101.19</td>
</tr>
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</table>

Eyerman tells of his unsuccessful search for other specimens in 1882. He says:

"I have . . . always attributed this rare carbonate to the allanite locality, at Weber's, Lower Saucon, Northampton County, six miles from Easton, and notwithstanding the fact that my frequent exploratory work here has failed to disclose another allanite pocket, I still contend that this locality, and not Friedensville, was the source of the lanthanite." (Eyerman, 1911.)

**Siderite (FeCO₃)**

Siderite is common in many of the brown iron ore mines of the region, especially in the lower levels. It is light yellowish-gray to light brown and is usually in the dense amorphous form. Small crystals occur in some places.

Siderite ores were especially abundant in some of the Ironton mines, in Barber's mine south of Alburtis, and in some of the mines in the Saucon Valley. These are described in the chapter on iron ores.

**Hydrozincite (Zn₅(OH)₆(CO₃)₂)**

Almost the only account of hydrozincite is the brief statement by Genth (1875) who says that "fine specimens have been found at Friedensville, Lehigh County, consisting of mammillated incrustations or porcelain-like and earthy masses."

**Smithsonite (ZnCO₃)**

Smithsonite is not one of the important zinc minerals in the Friedensville zinc ore deposits although specimens were noted from time to time.

"It is found in small, but brilliant, white or grayish-white scalenohedra and in granular and globular masses at Friedensville, Lehigh County." (Genth, 1875, p. 161.)
The feldspars form a large and essential part of the gneisses and pegmatites of the county. In the pegmatites the crystals range up to an inch or more in size. They are also present in the Hardyston sandstones and in microscopic size in the limestones and other sedimentary rocks. Microscopic studies have shown the presence of orthoclase, microcline, microperthite (albite-orthoclase), albite, oligoclase, labradorite, and anorthite. More investigations will doubtless reveal the presence of still other members of the feldspar group than these mentioned. Orthoclase is most common in the gneisses of the region.

Garnet Group

Garnet is present as a rock-forming mineral in many of the metamorphic pre-Cambrian rocks of the South Mountain region. It is especially prominent in the Moravian Heights gneiss and readily visible to the naked eye. Microscopic examination reveals garnets in other types of rocks, even in the limestones and slates. Almandite is the most common garnet but andradite and grossularite have been noted. Very few specimens of museum grade have been found.

The only special studies on the local garnets were made by Edgar F. Smith. His descriptions are quoted.

Almandite \((\text{FeAl}_2\text{(SiO}_4\text{)}_2)\)

At Mohr's magnetite mine in Upper Milford Twp., one-quarter mile from Shimersville, were found rather fine dark-red colored, imperfect dodecahedral crystals of this mineral. They occur in quartz and a granular limestone. The sp.gr. of well-selected material was 4.03, and an analysis of the same gave:

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<tr>
<td>(\text{SiO}_2)</td>
<td>35.02 per cent.</td>
<td></td>
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<tr>
<td>(\text{Al}_2\text{O}_3)</td>
<td>19.18</td>
<td></td>
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<tr>
<td>(\text{Fe}_2\text{O}_3)</td>
<td>4.92</td>
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<tr>
<td>(\text{FeO})</td>
<td>29.47</td>
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<tr>
<td>(\text{MnO})</td>
<td>4.80</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(\text{CaO})</td>
<td>2.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(\text{MgO})</td>
<td>3.70</td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>100.37</strong></td>
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</table>

Directly south of the above locality upon the land of Mr. Yeakel, quite a large bed of garnet in very minute dark-red crystals has been discovered. It occurs with magnetite. (Smith, 1883.)

Andradite \((\text{Ca}_3\text{Fe}_2\text{(SiO}_4\text{)}_2)\)

Near Hosensack Station in Lower Milford Twp., on the Perkiomen R. R., exists a second variety of garnet, found by Mr. E. F. Krauss, '84, in perfect dodecahedral forms of olive color—occasionally the red variety is observed—in a matrix of feldspathic rock. Specular iron ore often accompanies the garnet. The rocks in this region, lying in the most chaotic condition, appear filled with garnets, mostly in well-defined moderately translucent forms. An analysis of the yellow variety gave:

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<tbody>
<tr>
<td>(\text{SiO}_2)</td>
<td>35.25 per cent.</td>
<td></td>
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<tr>
<td>(\text{Fe}_2\text{O}_3)</td>
<td>32.17</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(\text{FeO})</td>
<td>.92</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\text{CaO})</td>
<td>30.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\text{MgO})</td>
<td>trace</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>99.14</strong></td>
<td></td>
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</tbody>
</table>

The specific gravity determined in two specimens was 5.05-5.27. (Smith, 1883.)
Garnet is present in some of the Triassic sediments of Lower Milford Township where baking has taken place by the intrusions of diabase. An occurrence of this kind is on the hill south of Hosensack. The garnet fills cavities formed by the solution of fragments of limestone. Some of the lumps are almost two inches in diameter.

**Mica Group**

Mica is a common rock-forming mineral in both the highly metamorphosed pre-Cambrian crystalline rocks of the region and the slightly metamorphosed sedimentary strata. In the gneiss hills, in many places, the soil formed by the decomposition of the gneiss contains abundant mica flakes. The different varieties noted are described below.

**Muscovite** \((\text{H}_2\text{KAl}_6\text{Si}_4\text{O}_{10})\)

Muscovite in small crystals is a fairly common rock constituent of the Byram and Moravian Heights gneisses. In the pegmatites that cut these rocks, cleavage pieces from 3 to 4 inches in diameter have been found. An attempt was once made to work some of these pegmatites about 1½ miles southwest of Seidersville but without success.

In the sedimentary rocks two varieties of muscovite have been noted, damourite (?) and sericite.

**Sericite.**—The Cambrian and Ordovician limestones of the county are mainly fairly high in silica and aluminous matter which represents mud that was washed into the Paleozoic sea when these limestones were forming. In the various movements that have taken place in the earth’s crust since their deposition this argillaceous material has been metamorphosed to sericite. It forms glistening surfaces along the bedding planes and in many places is a conspicuous characteristic of these rocks. Also the mica which produces the fine cleavage in the slates of the county, is mainly sericite.

**Damourite.**—The Second Geological Survey of Pennsylvania referred to the mica occurring in the Paleozoic limestones of the State, formed from the muddy sediments mixed with the calcareous oozes, as damourite. The writer prefers to call this material sericite.

**Pinite.**—At the base of the Hardyston formation in many places in the county, but especially along the north side of the mountain between Bethlehem and Allentown, there is a light green amorphous, clay-like deposit up to a foot in thickness. This has been called serpentine (See note under this mineral). As a result of microscopic examination and chemical analysis, E. T. Wherry determined it to be pinite, a variety of muscovite. In a few places it has been colored red by the precipitation of red iron oxides from circulating waters.

Pinite is believed to be the metamorphosed ancient soil formed from the underlying gneiss and not removed before the deposition of the Hardyston sandstone.

**Biotite** \((\text{H}_2\text{K}(\text{Mg,Fe})_3\text{Al}(\text{SiO}_3)_2)\)

Biotite in small flakes is abundant as one of the constituents of some of the basic gneisses of the county; larger are pieces in some pegmatites.
AMPHIBOLE GROUP

Hornblende (Ca,Mg,Fe,Al, and Na silicate)

Hornblende constitutes a very important part of nearly all the gneisses and pegmatites of Lehigh County. It is rarely absent even in the lighter-colored gneisses and may constitute practically all the rock in the darker, more basic varieties. In several of the pegmatites some of the individual hornblende crystals may be over an inch in diameter. Specimens with crystal faces are rare.

Crocidolite (NaFe(SiO₃)₂)

Shortly after coming to this region in 1907, E. T. Wherry discovered a light blue mineral in several places in the gneisses between Center Valley and Vera Cruz. In places the blue color was so prominent, especially when the rocks were wet, that it could be noted in the rock along the roadside when driving by. Specimens were collected and the mineral roughly determined as an amphibole.

In 1913 Miss E. F. Bliss described the mineral as occurring in several places in Berks and Lehigh counties and identified it as glaucoephane. In 1922 Wherry made a further mineralogical examination and concluded that it was crocidolite, not glaucoephane. Both of these papers contain analyses and optical data. No one of the specimens described came from Lehigh County. Wherry states that this mineral is known to occur in about 50 localities.

The last paragraph of Wherry's paper is quoted.

It is interesting to consider the mode of occurrence of the material: it is found as impregnations and coatings in gneissoid rocks of pre-Cambrian age, in diabase of Triassic age, and in sediments of the latter age intruded by the diabase. The gneisses thus impregnated are usually greatly shattered; the crocidolite not only fills the resulting crevices, but also replaces the original minerals of the gneiss. Replacement of hornblende was described by Mrs. Knopf (E. F. Bliss), and it may be added that the rocks, which usually contain considerable primary quartz where unaltered, are practically free from this mineral in extensively crocidolitized zones. Some of the silica has been redeposited, with the crocidolite, in the form of secondary quartz. The same phenomenon is noticeable in the replacement of these gneisses by sericite which is of frequent occurrence in the region, namely that the primary quartz is replaced more rapidly than the feldspar. This points to the deposition of the crocidolite, like the sericite, from hydrothermal solutions. The shattering of the crocidolitized gneisses is, in the experience of the senior writer, almost always connected with faulting of late Triassic date, and since the same mineral occurs in the late Triassic diabase and the sediments it has metamorphosed, the suggestion is here made that the hydrothermal solutions which deposited the crocidolite in the various occurrences came alike from the Triassic diabase magma. (Wherry, 1922.)

Actinolite and Asbestos (Ca(Mg,Fe)₉(SiO₃)₄)

Genth (1875, p. 69) says that "the so-called 'mountain leather' of a brownish color is found upon the limestone in the zinc mines at Friedensville."

F. R. Faux reports the presence of acicular actinolite crystals and actinolite asbestos in the baked Triassic conglomerate south of Hosensack.

PYROXENE GROUP

Augite (CaMg(SiO₃)₂) with Al and Fe

Augite is an important constituent of the gneisses of the district.
Diopside (Sahlite or Salite) (CaMg(SiO₃)₂)

Diopside has been recognized in some of the gneisses near Alburtis. It is fairly common in the pre-Cambrian metamorphic rocks.

Enstatite (MgSiO₃)

The microscopic examination of some of the gneisses of the region has shown the presence of enstatite.

Hypersthene ((Fe,Mg)SiO₃)

Hypersthene occurs as an important mineral constituent of some of the gneisses of the region and has been recognized by microscopic investigations.

Pectolite (HNaCa₂(SiO₃)₂)

Dr. Edgar F. Smith has studied pectolite from this region as follows:

This mineral occurs in Lehigh County, Pa., upon limestone and intimately associated with stilbite. Its exact locality is Hosensack Station, on the Perkiomen Railroad. It usually consists of compact masses of acicular crystals, of a grayish color. When reduced to powder the material is woolly and adheres to the pestle. The specific gravity is 2.6. Several analyses were made by Mr. E. B. Knerr and myself, with the following result:

\[
\begin{array}{c|c}
\text{SiO}_2 & 55.17 \text{ per cent.} \\
\text{Fe}_2\text{O}_3 & 30.00 \\
\text{CaO} & .80 \\
\text{K}_2\text{O} & .37 \\
\text{Na}_2\text{O} & 9.02 \\
\text{H}_2\text{O} & 4.63 \\
\hline
\text{Total} & 99.99 \\
\end{array}
\]

From what information we have obtained, it would seem that this is the first time that pectolite has been observed in the State. (Smith, 1885, p. 412.)

OTHER ANHYDROUS SILICATES

Allanite (complex Ca₆Fe₂Al₃Ce silicate)

Allanite has been found in several places in the gneisses of South Mountain. So far as known it has not been reported from Lehigh County but must be present as it is present in the Northampton County gneisses nearby. It was first reported from Bethlehem by Genth in 1855 who published an analysis. Later a mass about 100 pounds in weight was found on the mountain south of the Lehigh University buildings. Since that time allanite has been noted in several localities in the vicinity of Bethlehem and Redington. It occurs in grains readily visible to the naked eye. Generally it is overlooked because of its resemblance to hornblende.

The analysis given by Genth (1875) represents the average of two analyses made by Peter Keyser. It is as follows:

\[
\begin{array}{c|c|c}
\text{SiO}_2 & 33.31 & \text{CaO} & 11.28 \\
\text{Al}_2\text{O}_3 & 14.34 & \text{MgO} & 1.23 \\
\text{Fe}_2\text{O}_3 & 10.83 & \text{Na}_2\text{O} & .941 \\
\text{FeO} & 7.29 & \text{K}_2\text{O} & 1.33 \\
\text{Ce}_2\text{O}_3 & 13.42 & \text{H}_2\text{O} & 3.01 \\
(Di, La)_2\text{O}_3 & 2.70 & & \\
\hline
\text{Total} & 99.06 & \text{Sp.gr.} & 3.491 \\
\end{array}
\]
Calamine (H₂Zn₃SiO₈)

Calamine is the most important ore mineral in the Friedensville zinc ores so far as mining operations have been carried on. It has been formed from sphalerite, which probably everywhere in that section underlies the calamine.

It is found in attractive small crystals or groups of crystals and in the massive form.

Eyerman (1889, p. 29) gives the following analysis of a specimen from the Ueberroth mine:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>24.32</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>2.12</td>
</tr>
<tr>
<td>H₂O</td>
<td>7.86</td>
</tr>
<tr>
<td>ZnO</td>
<td>65.05</td>
</tr>
</tbody>
</table>

Further data will be found in the chapter on Mineral Resources.

Epidote (complex Ca₃Al₃Fe₃ silicate)

Epidote is a very common mineral in the light and dark-colored pre-Cambrian gneisses of Lehigh County. It has been formed from feldspars and hornblende. In some places, specimens of gneiss can be obtained in which approximately half the rock is epidote. It is common also in the pegmatites. Bands or streaks of almost pure epidote occur. Slickensided surfaces are commonly coated with a thin layer of epidote. In almost all cases the mineral is so fine-grained as to appear to the naked eye to be a homogeneous amorphous mass with a dull pistachio-green color, but small brilliant crystals, readily visible, have been observed, mainly along fault planes.

Sillimanite (Al₂SiO₅)

Wherry (1918) has reported abundant sillimanite in quartz-mica schists of Lehigh County. It "occurs in long slender prisms, mostly curved or bent slightly and in sub-parallel arrangement." In one locality, one mile west of Seidersville, it constitutes 35.1 percent of the rock. It is found mainly in the Moravian Heights formation. The sillimanite rock near Seidersville was quarried at one time in the belief that it was soapstone.

Titanite (CaTiSiO₅)

Dr. Edgar F. Smith described a find of titanite within the county:

This mineral, rather rare in Pennsylvania, we have also found in Lehigh County, Lower Milford Township, about two miles distant from Hosensack Station. It occurs in the same region in which we observed an olive-colored garnet, previously described in this Journal, Vol. 5, No. 4. The titanite crystals are well defined, but not more than half an inch in length. They are associated with green pyroxene crystals. Their color is a dark brown. Specific gravity 3.45. The analysis of the above made by Mr. Knerr and myself gave:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>34.87 per cent.</td>
</tr>
<tr>
<td>TiO₂</td>
<td>43.41</td>
</tr>
<tr>
<td>CaO</td>
<td>21.75</td>
</tr>
</tbody>
</table>

100.03

(Smith, 1885, p. 412.)
Tourmaline (complex Al,Mg,Fe,etc. silicate)

Tourmaline has been found in quartz or pegmatite veins cutting the gneisses of Lehigh County. Some of the pegmatites contain black crystals over half an inch long. Dr. Edgar F. Smith’s description of Lehigh County occurrences is quoted.

Mr. Benj. Saddler, Jr., of this laboratory, while searching for corundum at Shimersville, picked up a piece of feldspathic rock, often found here, in which were imbedded three or four large and quite perfect, black crystals of tourmaline. Want of time prevents giving an analysis of the same.

Dr. Henry K. Hartzell, of Allentown, also presented us with a hornblendic rock in which were beautiful brown tourmaline crystals, found near what is known as the Bethlehem Iron Co.’s mine on the Lehigh Mt., and not more than 1 1/4 miles northwest of Shimersville. A qualitative examination for identification is all that was made.

On the mountain, two miles south of Allentown, occurs a vein consisting of a brownish-black mineral, which in appearance reminds one greatly of allanite, but the incomplete analysis given below would indicate otherwise, and probably mark it as another occurrence of tourmaline. Its surface in many places is covered by a reddish colored mineral as yet unexamined. The dip of the vein is about 66°. The analysis as far as made is:

- Loss upon ignition: 2.19 per cent.
- SiO₂: 39.41
- Al₂O₃: 19.46
- Fe₂O₃: 8.44
- FeO: 7.00
- CaO: 3.49
- MgO: 2.14
- B₂O₃: 9.00
- Alkalies: undetermined

(Smith, 1883, pp. 275-276.)

B. F. Buie has found rounded grains of yellow, brown, black, and green tourmalines fairly abundant in the insoluble residues of the Allentown limestones.

Zircon (ZrSiO₄)

Zircon has been observed in many of the pegmatites of the pre-Cambrian gneisses and in petrographic investigations as one of the accessory rock-forming minerals. On account of the small-sized grains it is only occasionally noted. One of the best places known to the writer is in the isolated gneiss hill along Little Creek west of Western Salisbury church. Careful search would doubtless add numerous new localities. Allen Heyl has found abundant zircon crystals on the south slope of South Mountain north of Vera Cruz. Some specimens are doubly terminated.

It has been found as one of the insoluble minerals of the limestones of the region and recognized in some of the alluvial sands.

The best description of the mineral in the county is that published by Edgar F. Smith many years ago.

On the farm of Jacob Stine, Esq., Upper Milford Twp., about two miles south of Macungie, are found large quartz fragments distributed over the ground surface. When these are broken, minute crystals are observed here and there in them. Close examination showed these to be perfect forms of zircon—the prism with pyramid being quite distinct; the color of these microscopic crystals varied from a cinnamon to very dark brown. In some of the quartz fragments minute leaflets of graphite and pyrite crystals were seen accompanying the zircon. Enough qualitative tests were made to
identify the latter as such. Almost every piece of quartz examined con-
tained one or more crystals of it. Their removal from the matrix was
tedious and difficult. Scarcity of material prevented a quantitative exami-
nation. (Smith, 1883, p. 273.)

HYDROUS SILICATES

Allophane (Al₂SO₄·5H₂O)

The mineral identified as allophane was commonly observed in the
limonite mines when they were operating. Likewise Genth (1875, p.
107) reports that “at the Friedensville zinc mines, near Bethlehem,
it is found in white botryoidal and stalactitic masses.”

Edgar F. Smith had opportunity to study the minerals of Lehigh
County during those years of iron mining activity and published the
following description:

About seven miles from Allentown, near the village of Ballistsville, are
numerous iron mines (Ironton mines), in which from time to time have
been found white, mammillary and stalactitic incrustations upon the ore.
In one of these mines a pocket was recently discovered, the inner side of
which was completely covered with this coating. The latter has a mother-
of-pearl-like appearance, and may be readily detached from the ore by
means of a knife. Upon subjecting a portion of this material to a qualita-
tive examination, the presence of water, alumina and silica was revealed.
By strong hydrochloric acid, complete decomposition ensued. A quantita-
tive examination yielded the following results:

<p>| | | |</p>
<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O</td>
<td>40.86</td>
<td></td>
</tr>
<tr>
<td>SiO₂</td>
<td>21.39</td>
<td></td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>35.20</td>
<td></td>
</tr>
<tr>
<td>CaCO₃ and MgCO₃</td>
<td>1.96</td>
<td></td>
</tr>
<tr>
<td></td>
<td>99.41</td>
<td></td>
</tr>
</tbody>
</table>

Prof. Prime, in his report on the Geology of Lehigh Co. (DD, p. 43),
mentions the occurrence of this mineral in some of the iron mines, but
gives no analytical data. (Smith, 1883.)

Chloropal ((Fe,Al)₂Si₃O₈·5H₂O)

In 1932 while a shallow well was being dug on the lower slope of
South Mountain a short distance north of Friedensville on the prop-
erty of Alex. Males, a peculiar light green clayey substance was en-
countered with physical properties somewhat similar to paraffin.
The writer visited the locality, examined the material, and noted the
occurrence. The material occurred about 15 feet from the surface
mainly in the form of veins up to 2 inches in width cutting through
the hillside wash of decomposed Byram gneiss. Some of the decom-
posed matter may have been in situ. The green substance in a few
places also was disseminated through the residual sand and clay.
After some study the mineral was determined to be chloropal.

Edgar F. Smith made a rather elaborate study of similar material
in 1883. Since the mineral is an unusual one his entire description
is quoted.

A little west of the preceding locality (Lehigh Mountain, near Mountain-
ville) are rather extensive iron mines. Over the entire mountain-top holes
are observed (dug, evidently in search of ore), and about these in the debris
several students of this laboratory detected pieces of a yellowish-green
colored mineral, so soft as to be readily impressed by the finger-nail. Before
the blow-pipe the material, although infusible, gradually assumed a black
color and became magnetic; gave strong iron reaction and the silica skeleton. In a closed tube it yielded much water. Since the finding of the above specimens frequent visits have been made to this locality. On a recent trip, while examining some of the larger and deeper excavations, large pieces of the above mineral were noticed about six feet below the surface and overlying the iron deposit. The mineral varies somewhat in color from an olive to greenish-yellow. A number of analyses of the material brought in from time to time by various parties have been made, the results agreeing quite well and pointing to the mineral chloropal. The sp.gr. was found to be 2.033.

### Analyses

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<tr>
<th></th>
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<th>3</th>
<th>4</th>
<th>5</th>
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<tr>
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<td>20.79</td>
<td>20.45</td>
<td>19.09</td>
</tr>
<tr>
<td>SiO₂</td>
<td>40.20</td>
<td>40.51</td>
<td>42.81</td>
<td>41.16</td>
<td>41.41</td>
<td>42.79</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>39.52</td>
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<td>38.18</td>
<td>30.79</td>
<td>35.25</td>
<td>39.19</td>
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<tr>
<td>FeO</td>
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<td>—</td>
<td>—</td>
<td>0.21</td>
<td>—</td>
<td>—</td>
</tr>
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<td>P₂O₅</td>
<td>trace</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>MgO</td>
<td>trace</td>
<td>—</td>
<td>—</td>
<td>1.54</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>2.05</td>
<td>3.04</td>
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<tr>
<td>H₂O</td>
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<td>19.31</td>
<td>19.31</td>
<td>17.71</td>
<td>19.36</td>
</tr>
<tr>
<td>SiO₂</td>
<td>42.37</td>
<td>41.35</td>
<td>41.33</td>
<td>43.54</td>
<td>43.60</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>39.37</td>
<td>39.09</td>
<td>38.97</td>
<td>39.52</td>
<td>37.50</td>
</tr>
<tr>
<td>FeO</td>
<td>trace</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>trace</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>MgO</td>
<td>trace</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>99.13</th>
<th>99.14</th>
<th>99.54</th>
<th>100.25</th>
<th>101.07</th>
</tr>
</thead>
</table>


The mineral decomposes completely with hydrochloric acid. In all cases the specimens under examination were carefully freed of any adhering ferric oxide, and tested for ferrous oxide, phosphoric acid, calcium and magnesium oxides, and the alkalies. No trace of crystallisation is present. The mineral is earthy in appearance, smooth to the touch, and may be polished by friction.

Some specimens, almost white in color, have been found; one of these gave the following quantitative results:

- H₂O .......................... 17.65 per cent.
- SiO₂ .......................... 44.52
- Fe₂O₃ .......................... 11.04
- Al₂O₃ .......................... 25.95
- MgO .......................... trace
- K₂O .......................... 0.94

100.10

**Halloysite (H₂Al₂Si₂O₁₀+H₂O)**

It is probable that the investigations of clays made during the past few years may lead to new determinations of some of the argillaceous minerals found in this region. The discussion given here of halloysite and kaolin, and perhaps chloropal, are therefore regarded as merely tentative and the statements quoted are of the character of historical material.
Genth (1875, p. 122) says that "a mineral resembling halloysite is found in compact porcelain-like masses at the zinc mines at Friedensville."

Gordon (1922, p. 127) considers the clay called "sauconite" as a variety of halloysite, but here it is discussed as a variety of kaolin, following Genth.

\[ \text{Kaolin (H}_4\text{Al}_2\text{Si}_4\text{O}_{10}) \]

Kaolin as used here is a general designation of the clay minerals. In the decomposition of feldspar in the gneisses and pegmatites much kaolin has been formed. In the change to kaolin the gneiss crumbles and most of the resulting products are removed by erosion. However, in places along the hillsides, the rotten rock, consisting mainly of kaolin and quartz, is not removed and may be ten to twenty feet deep.

The kaolin is commonly stained by iron oxide. In no place in Lehigh County has it been found practicable to separate the kaolin commercially.

Prof. Roepper, the man who first recognized the zinc minerals at Friedensville, studied a variety of clay found there. The following discussion by Genth presents Roepper's ideas.

I have to mention, however, several peculiar clays, which have been found in this State.

The first occurs at the Ueberroth Zinc Mine near Friedensville, Lehigh county, where it has been discovered by Prof. W. Th. Roepper, who named it "Sauconite," and kindly furnished me with the following description and analyses. It has also been analyzed by John M. Blake (Dana's Mineralogy 1868, 49).

Apparently amorphous, fracture conchoidal; streak brown and shining; colors buff, ochre-yellow, brown, dark gray and white; translucent on thin edges; translucency increased by wetting. When thrown into water emits a crackling sound. $H = 1.5$; sp.gr. = 2.66-2.70.

The following varieties have been analyzed by Roepper: a. pale yellowish-white; b. ochre-yellow (after having been dried during one hour at 105°C.); c. Blake analyzed a pale-yellow variety:

<table>
<thead>
<tr>
<th></th>
<th>a.</th>
<th>b.</th>
<th>c.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicic acid</td>
<td>48.94</td>
<td>46.45</td>
<td>41.36</td>
</tr>
<tr>
<td>Alumina</td>
<td>10.66</td>
<td>7.41</td>
<td>8.04</td>
</tr>
<tr>
<td>Ferric oxide</td>
<td>3.85</td>
<td>14.28</td>
<td>9.53</td>
</tr>
<tr>
<td>Zinc oxide</td>
<td>26.95</td>
<td>22.86</td>
<td>32.24</td>
</tr>
<tr>
<td>Magnesia</td>
<td>0.97</td>
<td></td>
<td>1.02</td>
</tr>
<tr>
<td>Lime</td>
<td>2.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potash</td>
<td></td>
<td></td>
<td>trace</td>
</tr>
<tr>
<td>Water</td>
<td>7.06</td>
<td>6.73</td>
<td>7.76</td>
</tr>
<tr>
<td></td>
<td>99.88</td>
<td>98.69</td>
<td>99.97</td>
</tr>
</tbody>
</table>

Like all similar minerals, the composition is somewhat variable, owing in part to accidental admixtures, and a replacement of one isomorphous substance by another.

Allowing in the first analysis for a mechanical admixture of 3.45 per cent. of silicic acid (quartz), the oxygen ratio of zinc-oxide and lime (RO), to alumina and ferric oxide (R₂O₃), to silicic acid and water are $1:1:4:1$, corresponding with the formula: $3(RO)_3SiO_3 + R₂O₃ + 3SiO₂ + 3H₂O$.

I believe the sauconite to have as good a claim to be a distinct mineral species, as nine-tenths of the amorphous species, acknowledged as good. (Genth, 1875, pp. 120-121.)

The clays of the county are further described in the chapter on the Mineral Resources.
Serpentine \((\text{H}_2\text{Mg}_2\text{Si}_3\text{O}_9)\)

Locally some altered igneous rocks in the region may properly be classed as serpentine. The occurrence of this mineral within this county may well be ignored.

A greenish mineral found at the base of the Hardyston formation and determined to be pinite has been mistaken for serpentine. Genth evidently had this in mind when he says:

Outside of the serpentine range, common serpentine has been observed in peculiar varieties which deserve fuller investigation: in Potsdam sandstone, a short distance north of Bethlehem etc. (Genth, 1875, p. 113.)

Stilbite \((\text{Ca}_2\text{Na}_2\text{Al}_2\text{Si}_5\text{O}_{18} \cdot 6\text{H}_2\text{O})\)

The only known occurrence of stilbite in the county is that described by Edgar F. Smith. It is quoted.

This mineral was first found in Lehigh county, by Mr. E. F. Kraus, upon a limestone in the orchard of Mr. Jacob Schell, near Hosensack station. The specimens are in the form of large globular radiating concretions. Sp. gravity, 2.21.

Analysis

\[
\begin{align*}
\text{SiO}_2 & \quad 55.31 \text{ per cent.} \\
\text{Al}_2\text{O}_3 & \quad 14.88 \\
\text{Na}_2\text{O} & \quad 1.66 \\
\text{H}_2\text{O} & \quad 18.47 \\
\text{Totals} & \quad 99.32
\end{align*}
\]

(Smith, 1883, p. 277.)

Eyerman (1889, p. 32) points out that an error by the printer resulted in the omission in the above analysis of CaO..., 9.00 per cent.

PHOSPHATES

Wavellite \((\text{Al}_5(\text{OH,F})_3(\text{PO}_4)_2 \cdot 5\text{H}_2\text{O})\)

Analyses of the limonite ores of the region show the presence of phosphorus. In most cases the phosphorus mineral present is not apparent. In a few instances, however, beautiful patches of radiating white wavellite crystals can be discovered along cracks or joints if the ore or associated ferruginous rocks are broken. All the occurrences known to the writer are in those ore mines in the belt of the Hardyston formation. Some fine specimens were collected by the writer at the pyrite prospect shafts on the slope of the mountain southeast of Wilbur.

The complete descriptions by Smith of the Macungie location are quoted.

The specimens of Wavellite are from the neighborhood of Macungie, Lehigh Co., Pa. They present radiating nodules on limonite; their color is white. These crystals were considered to be calamine, and on this account we experienced some difficulty in ascertaining the locality. Indeed, we were obliged to show qualitative proof of the absence of zinc to the parties interested, before being made acquainted with the history of the specimens. Our analyses were made of some of the well-defined crystals. The method of analysis pursued, was that described by Dr. F. A. Genth, in Am. Journal of Science, etc., II Vol. 23, p. 423.
MINERALOGY

Analysis

$\begin{align*}
\text{Al}_2\text{O}_3 & \quad 36.66 \text{ per cent.} \\
\text{P}_2\text{O}_5 & \quad 34.14 \\
\text{H}_2\text{O} & \quad 28.32 \\
\text{Fl} & \quad \text{trace} \\
\text{Limonite} & \quad 0.60 \\
\hline
& \quad 99.72
\end{align*}$

Chemical Laboratory of Muhlenberg College, Allentown, Pa., March 3, 1882. (Smith and Thomas, 1882, p. 231.)

Not more than a quarter of a mile from the above locality (two miles south of Macungie, Upper Milford Township) and upon the same farm, were found the beautiful crystals of wavellite described by Dr. N. W. Thomas and the writer, Proceedings of American Philosophical Society, March 17, 1882. The first specimens of this mineral were noticed as occurring on limonite; since the publication of the preliminary notice we have obtained, through the liberality of Mr. Stine, a number of specimens lying upon or disseminated through a jasper-like rock which overlies the iron bed. The adjacent land is covered with rock of this character. Mixed with the iron is much pyrolusite. At present the shaft, in which the most beautiful wavellite was found, is filled with debris. From the quantity of the mineral found at first, and the many points at which it was observed prior to the caving-in of the surface, we may reasonably expect to yet obtain handsome specimens. It usually occurs in beautiful, colorless, radiating nodules on the limonite or jasper-rock.

Accompanying the wavellite and frequently upon the same specimen were observed nodular, light clay-like forms; sometimes, too, very dark nodules. Some of these revealed no definite radiating structure, while in others this was quite prominent; yet all trace of the white needles of wavellite had completely disappeared. In several instances these nodules were larger than a pigeon's egg. To learn their composition, specimens of both light and dark varieties were analysed. Light variety: sp.gr. 2.5.

$\begin{align*}
\text{H}_2\text{O} & \quad 19.37 \text{ per cent.} \\
\text{SiO}_2 & \quad 32.42 \\
\text{Al}_2\text{O}_3 & \quad 23.19 \\
\text{Fe}_2\text{O}_3 & \quad 3.82 \\
\text{P}_2\text{O}_5 & \quad 19.19 \\
\text{CaO} & \quad 1.00 \\
\text{MgO} & \quad 0.47 \\
\hline
& \quad 99.46
\end{align*}$

Dark variety, sp.gr. 2.40. Analysis:

$\begin{align*}
\text{H}_2\text{O} & \quad 26.29 \text{ per cent.} \\
\text{SiO}_2 & \quad 6.52 \\
\text{Al}_2\text{O}_3 & \quad 29.37 \\
\text{Fe}_2\text{O}_3 & \quad 15.61 \\
\text{P}_2\text{O}_5 & \quad 22.52 \\
\hline
& \quad 100.31
\end{align*}$

(Smith, 1883, pp. 273-274.)

URANATES

Uraninite

Dr. Edgar T. Wherry has recognized small grains of uraninite at the Vera Cruz molybdenite locality described on a previous page.

SULPHATES

Goslarite ($\text{ZnSO}_4\cdot\text{H}_2\text{O}$)

Hydrous sulphate of zinc or white vitriol has the mineralogical name goslarite. It is found as a result of the oxydation of zineblende in incrusta-
Wherever pyrite is exposed to oxidizing conditions, melanterite is apt to be found. It has been noted at the pyrite prospect between Mountainville and Emmaus and about some of the limonite mines where pyrite occurs. It has been especially noticeable at the old mine north of Breinigsville.

**GEOLOGIC HISTORY**

*By Benjamin L. Miller*

More than a billion years of history is recorded in the rocks of Lehigh County and it is the duty of the geologists to decipher these records. The task is a tremendous one and is at present only in the preliminary stage. Many of the main events are dimly understood, especially those concerned with great upheavals or revolutions, but there are great gaps in our knowledge. The untangling of happenings in the dim past is made difficult and in some instances impossible by the destruction of much of the record. One may liken the work of the geologist to that of the historian who endeavors to write a consecutive history of mankind from a badly mutilated volume. If he can find in some other library another copy of the same book, perchance the missing portions of one volume will be found in the other one. By gradually extending his researches to other libraries where imperfect copies are preserved, eventually the gaps may be lessened and the story pieced together. Geologists work in a similar manner. Gaps in the recorded history existing in one locality may be filled in by data secured in another region.

Nature has been engaged alternately in construction and destruction; records have been written in the rocks and later in large part erased by the natural agents of weathering, erosion and metamorphism. Some records are transcribed in a language that is unintelligible except by the slow process of trial and error. An interpretation that seems reasonable at one period may be relegated to the discard when additional facts are obtained. Scientists have been accused of inconsistency when, without being conscious of any “loss of face,” they throw aside their earlier explanations and advance new ones. Lesley expressed the idea in the following sentence: "Geologists should be consistent; but what can poor geologists do when Nature is the mother of inconsistency." Little progress can be made unless interpretations (hypotheses and theories) are formulated to explain the facts accumulated. These are then tested by all the additional information that can be secured. Thus, the explanation may be strengthened, modified or thrown aside for a newer and better interpretation. Only in this manner have our natural sciences advanced.

The methods used by the geologist are those that have developed during the past century. By studying the natural processes of destruction and construction, and observing their effects and results, keys for deciphering the events recorded in the rocks and in the structural and physiographic features have been obtained. In the story of

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past events in this region, only the barest outline can be presented at this time. Gaps will be filled by future workers.

The events of each era and period have been described somewhat in the descriptions of the different formations. It remains therefore to piece together the records. Due to the fact that the pre-Cambrian events are so different from those of later times it is fitting that Dr. Fraser tell the geologic story of that distant time.

Pre-Cambrian History
By Donald M. Fraser

With the assumption that the Franklin limestone is the oldest formation in the district, the earliest recorded event in Lehigh County would be the deposition of a series of carbonate rocks. Little else is known regarding this earliest time. Following the accumulation of the limestone, or possibly more or less contemporaneously with it, clastic sediments containing carbonaceous material were deposited. The present quartz-graphite member of the Franklin formation is the remnant of this depositional period which surely resulted in a fairly extensive sedimentary formation at the time of its accumulation.

With the changing conditions of deposition the sediments from which the present Moravian Heights formation has been derived were laid down. These were quartzose sediments but were more argillaceous than the clastic material associated with the Franklin formation. Again, on the basis of the present distribution of small areas of the Moravian Heights throughout tens of square miles, it is assumed that the original sediments were of considerable extent. They may well have covered several hundred square miles.

The next formation is the Pochuck gneiss. This basic rock, in the past, has been considered as of possible partial sedimentary origin and in part to have been derived from the metamorphism of a gabbro or diorite-gabbro type of igneous material. The present writer regards the Pochuck to be entirely of igneous origin. It may have been formed by the metamorphism of a gabbroic type of rock but it could also have been derived from the metamorphism of a series of andesite and basalt lava flows. Whichever may prove to be the correct interpretation, the next event in the district following the accumulation of the Franklin and Moravian Heights sedimentary formations was igneous activity. Either the present Pochuck gneiss material was introduced by intrusions of a basic magma or by the extravasation of lavas.

The earliest of these three formations has been tentatively assigned to Archean time and the later two to the Huronian. They are all of patchy occurrence and with the exception of the Pochuck have very small areal extent.

Later Proterozoic time probably saw extensive erosion and igneous invasion of an acid type of magma. The group of rocks known as the Byram gneiss ranges from what is considered to be typical Byram (a quartz-microcline microperthite rock) to quartz monzonite types. Associated with these are numerous pegmatites. The entire series has been mapped as Byram because more detailed study and mapping than that possible on the scale of the map used here, will be necessary.
to delineate the various facies. In the sequence of pre-Cambrian events, therefore, we are able to state only that during later Proterozoic time extensive granitic intrusion prevailed in the area under discussion. That this intrusion was in part deep-seated is evidenced by the highly irregular and injected and contorted nature of the contact between the Byram and Poehuck. It follows, therefore, that after the granitic invasion there was very extensive erosion before the surface upon which the Cambrian rocks were deposited could have been exposed. Proterozoic magmatic activity continued into early Paleozoic time or repeated invasions of magmatic material may be suggested with the later activity continuing into at least Lower Paleozoic time. The evidence for this is the occurrence of quartz-feldspar dikes in the Hardyston sandstone near its contact with the pre-Cambrian granite material. With the dying stages of magmatic action existent into Lower Paleozoic time, at least some of the quartz veins found in the Cambrian and Ordovician rocks may well be of magmatic origin.

Cambro-Ordovician History

The Paleozoic history of this section recorded in the rocks begins with the deposition of the Hardyston sandstone in the Lower Cambrian period. There is, however, a big gap between these deposits and the underlying crystalline rocks of the pre-Cambrian.

The Hardyston sandstones, wherever contacts have been observed, rest unconformably upon greatly metamorphosed gneisses. An examination of these basal rocks shows that they attained their present character of coarse-grained and banded crystalline rocks while deeply buried beneath enormous loads of other rocks. The Byram gneiss, which is the most common type of rock on which the Hardyston rests, was originally a granite and it is now generally recognized that granites are igneous rocks that cooled at considerable depth beneath the surface. The gneissic banding, which the Byram shows, is believed to have been developed as the result of subsequent excessive compression and resultant heating such as can also take place only at great depth. These features must have been acquired long before the Hardyston strata were laid down since these deposits show positively that they have never been subjected to such metamorphic agencies. The conclusion, therefore, seems certain that a long period of erosion, during which a great thickness of pre-Cambrian rocks was removed, preceded the opening of Cambrian deposition. One can only guess at the depth of surface rocks carried away but it appeals to the writer that the amount was upwards of a thousand feet and probably several thousand feet. It is pure conjecture as to where the eroded material was transported and deposited as no evidence bearing on this problem is now known. Here, therefore, is one of the great gaps in our history of past events in the region.

The earliest recorded event in the Paleozoic history of the district is the depression of the entire region as well as extensive areas both to the northeast and southwest. The entire Appalachian region, which had presumably long been an area of erosion, gradually sank beneath the waters of a great southeasterly advancing inland sea.

Beginning with Hardyston time and continuing throughout the entire Paleozoic era, all geologists believe there was a large continental
land mass, to which the name "Appalachia" has been applied, from 100 to 300 miles or even more in width, that paralleled the present Atlantic shore line. At times the northwest margin of this land perhaps lay only a short distance to the southeast of what now constitutes Lehigh County. At other times, the shore may have been several scores of miles away.

The inland sea covered all of the present Appalachian province. It varied from time to time in size and shape owing to movements or warpings of the earth's crust. In this sea, which appears to have always been comparatively shallow, practically all the materials now constituting the sedimentary rocks of Lehigh County were accumulated on a gradually sinking bottom.

When the depression of the area occurred, there was probably a fairly deep cover of soil and rotten rock over the land. The waves of the advancing Cambrian sea seem to have removed most of this surficial cover inasmuch as the Hardyston in most places rests on fresh unchanged gneisses. Locally, however, a thin band of a peculiar rock is found at the contact, which is believed to be an old soil. It has now been altered to a dense, fine-grained, light green rock that has been called pinite. It is never more than a few feet thick and can seldom be recognized over any extensive area. It is developed in several localities in Lehigh County. It is questionable as to whether this material should be included in the Byram or in the Hardyston. Inclusions of angular vein quartz fragments link it with the former, and occasional rounded pebbles suggest the latter reference.

The lowest strata of the Hardyston are conglomeratic in several places but not everywhere; occasional pebbles are more than an inch in diameter. These coarser sediments constitute a basal conglomerate that was formed either near the mouths of streams or where shore currents were reasonably strong. They probably formed near the shore as the advancing sea transgressed. They also indicate that the land mass from whence the pebbles were derived was fairly high and thus furnished stream gradients sufficiently steep to transport the pebbles. Probably owing to the southeasterly retreat of the shore line by the sinking of Appalachia, coarse pebbles were carried into this region for only a short time. Most of the deposits of Hardyston time were sands, generally fairly fine. Crystalline rocks from Appalachia were breaking up without the complete decomposition of the feldspars, and numerous grains of fresh orthoclase were deposited with the quartz grains and kaolin. The arkosic character is a prominent feature of the Hardyston sandstones.

A progressive change in the sediments from sands to shales and calcareous oozes took place and we pass from the Hardyston to the Tomstown sediments. The Tomstown and also the overlying Allen-town formations contain occasional fine sandstone lenses, indicating that unusual conditions, probably freshets or floods, once in a great while brought some sands into the region. Generally, however, only the finest land-derived material came in. This indicates the lowering of Appalachia to the extent that the streams entering the sea carried only the finest material in suspension and these only at certain times. They brought calcareous matter in solution and this was precipitated on the ocean bottom either by purely chemical processes or by the
agency of minute organisms, particularly bacteria. Probably both methods were operative. The rocks themselves present no evidence as to the method by which the calcareous matter was taken out of solution.

During Allentown time, less sand and mud entered the sea although shaly layers and a few fine sandstone lenses indicate that occasionally terrigenous matter came into the sea from Appalachia. The life of the Allentown seas was not varied, so far as local evidence indicates. The only abundant fossils are the calcareous algae, *Cryptozoa*, which are fairly abundant. In places they withdrew from the sea water and built into their structures sufficient calcareous matter to form deposits several feet in thickness.

Occasionally during both Tomstown and Allentown time the sea was so shallow that at low water, perhaps low tide, the fine muds were exposed to the drying action of the sun and developed mud cracks as they contracted in drying. These are preserved in many localities. Ripple marks and oolites also indicate shallow water.

When the deposits of the Tomstown and Allentown formations were accumulating, the oozes contained much magnesia, and these limestones are prevailingly dolomitie. In part the magnesia may be secondary but it is regarded as largely original.

In the succeeding interval of time, when the Beekmantown limestones were formed, the calcareous oozes at times contained very small quantities of MgCO₃ and we therefore have in this formation the alternations of high- and low-magnesian strata.

Throughout Tomstown and Allentown time the seas had been generally clear of land-derived sediment except at occasional brief periods. The Beekmantown sea was even clearer and mud seldom came into it. This probably means that Appalachia was so low as to yield to the sluggish streams a minimum amount of mud in suspension and practically none of it was carried into this region. An alternative interpretation is that the nearest land mass was more distant.

Shell-fish were more abundant during the Beekmantown but, as indicated by the rarity of fossils, relatively sparse in this section, especially as compared with some other regions in the Appalachians.

Following the formation of the Beekmantown there was a short break in deposition, as shown by an unconformity between the Jacksonburg and the Beekmantown. Deposition was resumed and the seas became increasingly muddy and the MgCO₃ decreased. The interval represented by the deposition of the lower member of the Jacksonburg formation was a time when high-calcium oozes accumulated. It was followed by the deposition of much terrigenous mud which was mixed with the calcareous oozes. These constitute the upper member of the Jacksonburg. These argillaceous low-magnesian limestones are the most valuable deposits of the county, as they have furnished the material for the extensive portland cement industry of this region.

Fossils are much more abundant in the Jacksonburg than in any of the other sediments of the region, thus indicating more favorable conditions for life and growth. The animals seem to have been mainly near-shore forms and their skeletons were broken by wave action to such an extent that the fossils are mainly fragments. Crinoids were abundant but only the disarticulated plates are preserved.
Increasing muddiness of the seas and the practical disappearance of calcareous precipitates resulted in the deposition of the argillaceous Martinsburg strata. Carbonaceous matter is abundant in these dark gray or black sediments. Its source is problematical but may have been marine plants. Graptolites may have contributed part of the carbonaceous content. Frequent changes in the character of the sediments has resulted in the production of the light and dark layers that are called ribbons by the slate operators. These are most prominent in the basal member of the Martinsburg.

The sandy member represents a period during which considerable sand entered the sea in this section. Likewise, more calcareous matter was precipitated and these sandstones, when fresh, effervesce freely when hydrochloric acid is applied.

For about 200 million years, from early Cambrian to Upper Ordovician, deposition had been going on almost continuously in this region, and sediments had accumulated to a thickness of 7,500 to 10,000 feet. The continent of Appalachia and the inland sea underwent modification many times but there were few breaks in the process of deposition. A minor one occurred at the close of the Beekmantown and another one at the close of the Jacksonburg.

Taconic Disturbance

After Martinsburg deposition there was a marked disturbance in this region, so great that it has sometimes been called the Taconic Revolution. It is named from the Taconic Mountains of western Massachusetts where it was first studied. How much of the complex folding and faulting of this region is due to this period of compression and uplift and how much was produced by later movements of the Appalachian Revolution is still a matter of argument and discussion. The writer holds the belief that a large part, perhaps the major portion of the rock folding of this region, was produced at the close of the Ordovician. He is inclined to the belief that the slaty cleavage of the Martinsburg was chiefly produced at this time. The pressure seems to have come from the southeast.

A period of erosion followed the disturbance but the amount of material then removed can not be determined with any accuracy.

Silurian and Later Paleozoic History

After a marked erosion period, during which time all of the Northampton County area was above water, the region again sank beneath the waters of the vast inland sea. The deposits then made constitute the Tuscarora conglomerates and sandstones that form the northern boundary of the county. The basal conglomerate layer exposed in Lehigh Gap rests conformably upon the eroded edges of the Martinsburg slates. There is a difference of thirteen degrees between the bedding planes of the two formations.

The coarse pebbles of the Tuscarora, many more than an inch in diameter, furnish evidence of strong currents and probably steep slopes of the land mass to the southeast that furnished the material.

Later sedimentary Paleozoic history is not preserved in Lehigh County, although it is probable that some and perhaps all of the later Silurian, Devonian, Mississippian and Pennsylvanian formations exposed in the regions to the northwest in neighboring counties may have once extended into this county. If so, they have been entirely removed by subsequent erosion.

Appalachian Revolution

The Paleozoic era in the Appalachian region ended by one of the most profound periods of uplift, folding and faulting that has ever taken place. Thousands of feet of rocks were folded by compressive forces coming from the southeast as though they were mere sheets of paper. These movements, added to those that deformed the earlier strata at the close of the Ordovician, made the complex and baffling structures so characteristic of Lehigh County.

Triassic History

The next recorded event is in the southern part of the county. A slowly subsiding basin twenty to thirty miles in width extending in a northeast-southwest direction entirely across the southeastern part of Pennsylvania. Into this basin thousands of feet of sediments were deposited. The deposits are mainly shales, shaly sandstones and soft sandstones with a prevailing red color. In that portion of the Brunswick represented in Lehigh County coarse conglomerates are more common and indicate the occurrence of torrential streams. Some of the pebbles are limestones that seem in part to have come from distant points. The conglomerates have been attributed by some to the deposits formed at the mouths of streams.

Toward the close of Triassic sedimentation there were intrusions and surface outflows of basic igneous matter that now form our traprock hills. This is the last time that igneous action has taken place in Pennsylvania.

Glacial History

In the Pleistocene period this region was invaded by a lobe of the great ice sheet that originated in eastern Canada. Although the erosional and depositional work of the ice profoundly modified much of the New York and New England regions, this section reveals few evidences of its work. It passed through the valley, probably covering practically all the area between Kittatinny (Blue) Mountain and South Mountain, with a slight advance into the Saucon Valley. The ice in this advance seems to have been thin so that the amount of erosion was trivial. Deposition throughout most of the county was of little consequence except in some depressions, such as old stream valleys and solution holes in the limestones.

Whether the deposits formed during the greatest advance of the ice should be considered as belonging to the Illinoian Ice Sheet as claimed by Leverett or the preliminary advance of the Wisconsin Ice Sheet as advocated by Williams is a problem that has long been in question and is discussed elsewhere. The terminal moraine between Wescosville and Traxlerstown represents the greatest advance of ice of the Illinoian or the early stage of the Wisconsin.
Physiographic History

The physiographic record has been discussed in the chapter on Physiography, so only a brief summary is given here.

The existing topography is the result of erosion and minor deposition with alternate peneplanations and uplifts that have been at work in this region ever since the Appalachian Revolution. Decomposition, rain wash and streams have been the tools with which Nature has carved the existing hills and valleys.

Presumably, the period of Schooley peneplanation in Tertiary time saw the entire area reduced to a featureless low-lying region with all elevations due to earlier earth movements destroyed. From this surface the present differences in elevation have been developed, following an uplift that revived the agents of erosion. Those areas with the most resistant rocks, such as the siliceous sandstones of Kittatinny (Blue) Mountain, have suffered least and now stand highest, whereas the softer and more soluble rocks, such as the limestones, constitute our valleys.

If this region maintains its present elevation with reference to sea level, the destructive processes of erosion will continue to modify the topography. The tendency will be to reduce the existing differences and produce even more subdued scenery, with the ultimate reduction to another base level plain. Under present conditions this may result in from one to three million years. From what we know of the earth's instability, one may well question whether before that time there may not be interruptions or modifications in the erosive process caused by deformations of the crust.
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