Geology and Economic Aspects of the More Important High-Calcium Limestone Deposits in Pennsylvania

By F. M. SWAIN

In Cooperation With
The Pennsylvania Railroad

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The Pennsylvania State College
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Geology and Economic Aspects of the More Important High-Calcium Limestone Deposits of Pennsylvania

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INTRODUCTION

The limestone deposits of Pennsylvania form the basis of a large and varied industry, and the production of limestone and of associated dolomite has played an important part in the industrial and cultural development of the State.

The State Geological Survey has published comprehensive data dealing with these resources, besides which the publications of the U. S. Geological Survey and the various geological journals contain numerous references to Pennsylvania limestones. The books by B. L. Miller (8)¹ provide detailed descriptions of limestone quarries throughout the State. The present report discusses, in some detail, the more important high-calcium limestone deposits found in Pennsylvania and includes a review of data to be found in recent publications on the subject. Economically important sources of high-magnesium dolomite rock are present in the State, but discussion of them is reserved until later.

Eastern Pennsylvania contains unlimited supplies of limestone and dolomite for use in road building and other construction work. Western Pennsylvania has lesser amounts of limestone but contains supplies sufficient to satisfy the demand for crushed stone products.

On the other hand, pure limestone for the manufacture of chemical and metallurgical lime and for fluxing stone occurs in only a few places in the State, according to present knowledge.

Exploration in search of additional high-calcium deposits has been carried on for many years by the producing companies, the State

¹See References at end of report.
Geological Survey staff, and others. A large number of outcrops and openings have been sampled, and core drilling has been conducted by the companies, mostly on or adjacent to their own properties. Additional drilling should be done in areas where detailed geological investigation of surface exposures suggests the presence of valuable limestone deposits.

The best known high-calcium deposits in Pennsylvania are those occurring near Bellefonte, in the central part of the State. Steeply dipping strata of Ordovician age have been quarried and mined in this area for many years. Other high-calcium deposits having economic importance lie in Dauphin and Lebanon Counties and in York and Adams Counties. Stone of Cambrian and Ordovician age at these places is quarried and mined for lime and flux.

In west-central Pennsylvania, a limestone of Pennsylvanian age, termed the Vanport limestone from its occurrence at Vanport, Beaver County, is quarried and mined extensively for fluxing stone and other purposes. It is not sufficiently pure, however, to be used for chemical lime manufacture.

Acknowledgments. Appreciation for their assistance in providing data is made to John Curtin, Jr., of the Warner Company, Bayard Magee of the National Gypsum Company, Elwood Gilbert of the New Castle Lime and Stone Company, David K. Shroyer of the H. E. Millard Company, and Messrs. Cook and George of the Thomasville Lime & Stone Company. Valuable suggestions as to the form of presentation in the manuscript were provided by W. M. Myers and F. M. Swartz, and other helpful comments were made by P. D. Krynine and D. R. Mitchell, all of The Pennsylvania State College. R. W. Stone of the Pennsylvania Geological Survey read the manuscript critically.

PRODUCTION OF LIMESTONE AND LIMESTONE PRODUCTS IN PENNSYLVANIA

The relative importance, in industry, of Pennsylvania's limestone deposits is illustrated in Table 1, which gives production figures for 1942. The figures were obtained from the Minerals Yearbook, published by Bureau of Mines, U. S. Department of the Interior.
### TABLE 1

**Production of Limestone and Limestone Products in Pennsylvania in 1942**

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Short tons</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lime</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural</td>
<td>184,663</td>
<td>$1,242,281</td>
</tr>
<tr>
<td>Building</td>
<td>59,918</td>
<td>538,979</td>
</tr>
<tr>
<td>Metallurgical</td>
<td>415,901</td>
<td>2,908,349</td>
</tr>
<tr>
<td>Paper mills</td>
<td>75,277</td>
<td>542,524</td>
</tr>
<tr>
<td>Water purification</td>
<td>23,324</td>
<td>189,952</td>
</tr>
<tr>
<td>Other</td>
<td>271,073</td>
<td>2,286,010</td>
</tr>
<tr>
<td><strong>Sub Total</strong></td>
<td>1,030,156</td>
<td>7,708,095</td>
</tr>
<tr>
<td><strong>Hydrated lime</strong></td>
<td>213,475</td>
<td>1,744,061</td>
</tr>
<tr>
<td><strong>Crushed and broken stone</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riprap</td>
<td>39,970</td>
<td>46,767</td>
</tr>
<tr>
<td>Fluxing stone</td>
<td>10,472,060</td>
<td>10,517,437</td>
</tr>
<tr>
<td>Concrete and road metal</td>
<td>5,944,580</td>
<td>6,415,878</td>
</tr>
<tr>
<td>Railroad ballast</td>
<td>828,230</td>
<td>732,313</td>
</tr>
<tr>
<td>Agricultural stone</td>
<td>680,740</td>
<td>1,671,390</td>
</tr>
<tr>
<td>Other</td>
<td>1,062,320</td>
<td>1,862,832</td>
</tr>
<tr>
<td><strong>Sub total</strong></td>
<td>19,023,500</td>
<td>21,246,667</td>
</tr>
<tr>
<td><strong>Dimension Stone</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>7,660</td>
<td>8,614</td>
</tr>
<tr>
<td>Rubble</td>
<td>8,510</td>
<td>10,402</td>
</tr>
<tr>
<td>Flagging</td>
<td>643</td>
<td>1,055</td>
</tr>
<tr>
<td><strong>Sub total</strong></td>
<td>16,813</td>
<td>20,079</td>
</tr>
<tr>
<td><strong>Portland cement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(shipments from mills, approx.)</td>
<td>6,324,187</td>
<td>46,377,469</td>
</tr>
<tr>
<td><strong>Grand total</strong></td>
<td>26,608,081</td>
<td>877,096,371</td>
</tr>
</tbody>
</table>

As a result of the war there has been capacity production of such materials as fluxing stone, chemical lime, and metallurgical lime. Dimension stone and building lime markets have suffered because
Figure 1. Index map showing the areas of high calcium limestone described in this report.
of the curtailment of domestic construction. The demand for
Portland cement was high in 1942, as a result of the construction
phase of the war program, but it has declined from 1943 to 1945.
The demand throughout the country for crushed and broken stone
of all kinds reached an all time high in 1942, owing to the government
construction program, but has declined since. The production of
crushed limestone for agricultural purposes, road repairs, and railroad
ballast has remained fairly stable.

DISTRIBUTION OF HIGH-CALCIUM PRODUCTS

The geographic distribution of the various high-calcium products
from the principal source areas in Pennsylvania is illustrated in
Figure 2. This market area includes Pennsylvania, eastern Ohio,
West Virginia, Maryland, Delaware, New York, New Jersey, and
the New England states.

Products of the Bellefonte area are shipped principally to the iron
and steel district of western Pennsylvania, to chemical industries in
western New York State, to paper mills in the north-central part of
Pennsylvania, and to paper mills in Maine. The Annville area
supplies chemical plants and steel industries in eastern Pennsylvania,
New Jersey, and New York, and, in addition, lime is shipped to
paper mills in Maine, and fluxing stone and lime to iron and steel
industries in central and western Pennsylvania. From the Thomas-
ville area, lime and flux go to eastern iron and steel industries, and
lime is sold to nearby paper mills in southern Pennsylvania.

Fluxing stone produced in the New Castle and Kittanning areas
of western Pennsylvania is used in the Pittsburgh and Youngstown
iron and steel industries.

All producers of high-calcium products also supply crushed and
pulverized stone for agriculture, construction, mine-dusting, and
other purposes. This material is sold at many places throughout
the State, much of it being used locally. High-calcium lime from the
Bellefonte area is shipped occasionally to all parts of the United
States, and to Canada, South and Central America, the Virgin
Islands, and Africa.

Table 2 shows the distribution of Pennsylvania lime according to
### TABLE 2
**Distribution by Uses of Lime Produced in Pennsylvania from 1932-1944**

<table>
<thead>
<tr>
<th></th>
<th>Total lime</th>
<th>Agricultural lime</th>
<th>Building lime</th>
<th>Chem. &amp; met. lime*</th>
<th>Total Hydrate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Short tons</td>
<td>Short tons</td>
<td>% of total</td>
<td>Short tons</td>
<td>% of total</td>
</tr>
<tr>
<td>1932</td>
<td>374,244</td>
<td>127,586</td>
<td>34</td>
<td>62,790</td>
<td>17</td>
</tr>
<tr>
<td>1933</td>
<td>438,795</td>
<td>118,103</td>
<td>27</td>
<td>46,501</td>
<td>11</td>
</tr>
<tr>
<td>1934</td>
<td>434,519</td>
<td>110,151</td>
<td>25</td>
<td>39,822</td>
<td>9</td>
</tr>
<tr>
<td>1935</td>
<td>581,501</td>
<td>137,683</td>
<td>26</td>
<td>38,065</td>
<td>11</td>
</tr>
<tr>
<td>1936</td>
<td>661,464</td>
<td>150,371</td>
<td>23</td>
<td>70,083</td>
<td>12</td>
</tr>
<tr>
<td>1937</td>
<td>692,086</td>
<td>191,045</td>
<td>27</td>
<td>31,900</td>
<td>12</td>
</tr>
<tr>
<td>1938</td>
<td>592,066</td>
<td>169,799</td>
<td>32</td>
<td>61,068</td>
<td>11</td>
</tr>
<tr>
<td>1939</td>
<td>691,460</td>
<td>182,012</td>
<td>26</td>
<td>55,389</td>
<td>13</td>
</tr>
<tr>
<td>1940</td>
<td>833,058</td>
<td>200,556</td>
<td>25</td>
<td>84,583</td>
<td>10</td>
</tr>
<tr>
<td>1941</td>
<td>1,003,009</td>
<td>190,553</td>
<td>19</td>
<td>87,463</td>
<td>10</td>
</tr>
<tr>
<td>1942</td>
<td>1,036,156</td>
<td>184,663</td>
<td>18</td>
<td>59,918</td>
<td>4</td>
</tr>
<tr>
<td>1943</td>
<td>1,021,215</td>
<td>183,309</td>
<td>18</td>
<td>46,488</td>
<td>4</td>
</tr>
<tr>
<td>1944</td>
<td>1,026,292</td>
<td>198,609</td>
<td>19</td>
<td>23,253</td>
<td>2</td>
</tr>
</tbody>
</table>

*Includes dead burned dolomite*
Figure 8. Map showing major distribution of products from the principal high-grade limestone deposits in Pennsylvania. The market areas of such products as railroad ballast, road stone, agricultural limestone, building stone, and pine dust are numerous, mostly local, and are not shown. Other substantially large sources of fixing stone occur in central and eastern Pennsylvania, but are not included on the map. Rather large supplies of limestone and dolomite flux are imported from West Virginia and Ohio. This material goes principally to the Pittsburgh iron and steel district.
its principal uses during the period 1932-1944. The data were obtained from the U. S. Bureau of Mines Minerals Yearbook. During the period from 1932 to 1941, the last pre-war year, there was a gradual and general increase in the use of agricultural and building lime, but a marked increase in the use of lime for chemical and metallurgical purposes.

High-calcium lime made by plants in Pennsylvania is used in the manufacture of steel, paper, glass, rubber, gelatin, calcium carbide, ammonia, paint, linoleum, ethyl alcohol, baking soda, and plastics; for the treatment of water and sewage, neutralization of waste acids, making by-products of coke, and refractory products.

One plant reports the following distribution of its pebble lime production, which amounts to about 75 per cent of the total lime output:

<table>
<thead>
<tr>
<th>Industry</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel mills</td>
<td>29%</td>
</tr>
<tr>
<td>Paper industry</td>
<td>6%</td>
</tr>
<tr>
<td>Rubber industry</td>
<td>9%</td>
</tr>
<tr>
<td>Glass industry</td>
<td>4%</td>
</tr>
<tr>
<td>Chemical industry</td>
<td>10%</td>
</tr>
<tr>
<td>Water purification plants</td>
<td>3%</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>6%</td>
</tr>
</tbody>
</table>

**SPECIFICATIONS**

**Fluxing stone.** Companies located in areas that have large supplies of good fluxing stone generally require a product that has no more than two or three per cent of silica and alumina. In some instances five per cent of these impurities may be tolerated, and in areas not favorably situated with regard to supplies of stone, a still poorer grade of stone has been used. In Pennsylvania it has become the practice among some operators to mix various limestones in order to obtain the desired composition. For example, the Vanport limestone in western Pennsylvania, which contains up to 10 per cent or more of impurities, is mixed with pure dolomite from the Toledo district, Ohio, in order to provide a satisfactory flux. The magnesia content that is permissible in blast-furnace flux varies according to the desires of the operator. Some concerns prefer a flux that is low in magnesia, while others do not object to, or even prefer, a moderately
high magnesia content. This subject is discussed at length by Bowles (1).

Lime. For almost all purposes the limestone used in the manufacture of high-calcium products must contain 97 to 98 per cent of calcium carbonate. In Pennsylvania, such deposits are at a premium as most of the limestones of the State contain substantial amounts of silica and alumina, as well as more or less magnesium carbonate. Formerly, agricultural lime was prepared from these less pure deposits, but in recent years it has become customary for most farmers to buy lime rather than to burn it themselves.

The high-calcium lime produced at Bellefonte, Annville, and Thomasville, in Pennsylvania, is suited to almost all desired uses. In making finishing plasters, it is deficient in plasticity and other physical properties so that it has not found widespread use in this field.

Specifications have been established for high-calcium lime products with reference to the uses for which they are to be employed. Various publications of the U. S. Bureau of Standards relating to this subject are listed on page 9:

REGIONAL GEOLOGY OF PENNSYLVANIA LIMESTONES

The limestone deposits of Pennsylvania range in age from pre-Cambrian to Permian and occur mainly in two physiographic-geologic areas: the structurally complex region of southeastern and central Pennsylvania and the structurally less complex region of western Pennsylvania. In a general way the boundary between these two regions lies along the Allegheny Mountain Front.

The limestones of southeastern and central Pennsylvania are mostly Lower and Middle Paleozoic in age. The deposits of this region are widely distributed and total many thousands of feet in thickness, but they are extremely variable in their calcium-magnesium content and in the amount of sand, clay, and iron impurities that they contain. Although there are numerous occurrences of limestone beds five to ten feet thick that are pure and are suitable for chemical lime, the prevailing steep dips deter their exploitation on a large scale. Thicker deposits of pure stone that permit large-scale quarrying or underground mining are known in only a few places.
Publications of the U. S. Bureau of Standards
Relating to Limestone

CIRCULARS

96 Recommended Specifications for Quicklime and Hydrated Lime for use in the Cooking of Rags for the Manufacture of Paper.
106 Lime-Specifications and Definitions.
118 Recommended Specifications for Limestone, Quicklime, and Hydrated Lime for Use in Glass Manufacture.
144 Recommended Specifications for Limestone and Quicklime for Use in the Manufacture of Sulphite Pulp.
150 Recommended Specification for Quicklime and Hydrated Lime for Use in the Manufacture of Sand-lime Brick.
152 Recommended Specifications for Ceramic Whiting.
153 Recommended Specification for Quicklime and Hydrated Lime for the Manufacture of Silica Brick.
189 Recommended Specification for Quicklime and Hydrated Lime for Use in Absorption of Carbon Dioxide.
201 United States Government Master Specifications for Quicklime for Structural Purposes.
207 Recommended Specification for Limestone, Quicklime, Lime Powder and Hydrated Lime for Use in the Manufacture of Sugar.
251 Recommended Specification for Quicklime and Hydrated Lime for Use in the Manufacture of Sugar.
337 Manufacture of Lime.
372 Recommended Specifications for Quicklime and Hydrated Lime for Use in Soap-making.
373 Recommended Specifications for Quicklime for Use in Distillation of Ammonia Liquors.

TECHNICAL PAPERS

16 The Manufacture of Lime.
908 Cement-Lime Mortars.

RESEARCH PAPER

1232 Particle Size and Plasticity of Lime.
In western Pennsylvania the limestones of the surface exposures are Mississippian, Pennsylvanian, and Permian in age. The rocks in this part of the State are principally shales and sandstones with relatively thin limestone beds forming a less important part of the sequence. Most of the limestone beds here are shaly and sandy, but one formation, the Vanport limestone of Pennsylvanian age, is moderately pure and has become an important source of fluxing stone for the blast furnaces in western Pennsylvania, eastern Ohio, and the West Virginia panhandle. The Vanport bed is 10 to 20 feet thick where it is quarried and mined. Its extensive use for flux results from its uniform, though not exceptionally high-grade composition, its flat-lying structural attitude, and its proximity to the tri-state iron and steel industry. A deposit such as the Vanport limestone occurring in the highly folded region of central and southeastern Pennsylvania probably would never have become important as a source of fluxing stone.

IMPORTANT LIMESTONE DEPOSITS

The principal high-calcium limestone deposit in Pennsylvania, both as regards its extent and its uniformity in quality, is that located in a northeast-southwest trending belt through Bellefonte, mostly in Centre County. The stone is Middle Ordovician (Black River) in age, and has been named the Valentine limestone. Quarries and underground operations around Bellefonte are worked for chemical lime, flux, and other products.

In a band running east-west across central Dauphin and Lebanon Counties is the so-called Annville limestone of Middle Ordovician (Stones River) age. Although apparently not as uniformly high grade as the stone at Bellefonte, the Annville limestone nevertheless comprises a large reserve of good quality material. It has been used principally to enrich the Portland cement mix in the Lehigh Valley cement district, and for chemical and metallurgical lime and blast furnace flux.

A limestone sequence of Lower Cambrian age, and belonging to the Kinzers formation, is of good quality around York and Wrightsville, York County. It has been quarried rather extensively for lime and flux.
Figure 3. Chart showing stratigraphic sections of the limestone deposits discussed in this report. The sections are arranged according to their approximate geographic location, as indicated by the outline map of the State. Data for the compilation of the sections were obtained from the various references cited.
Near the hamlet of Bittinger in eastern Adams County limestone probably belonging in the Kinzers formation contains bands of high-calcium stone that have been quarried for lime and flux.

In western Pennsylvania, particularly around New Castle, Lawrence County and Kittanning, Armstrong County, the Vanport limestone of Pennsylvanian age has been used very extensively for blast furnace flux and less extensively for agricultural lime. Quarries and mines in the Vanport limestone in Lawrence and Armstrong Counties produce a large proportion of the fluxing stone in the State. Although other deposits of stone suitable for flux are known and in several places are being worked for this purpose in central and eastern Pennsylvania, the proximity of the Vanport limestone to the blast furnaces and steel mills of the Pittsburgh and Youngstown districts has made it the most important source of fluxing material.

_The Valentine Limestone_

_Centre and Clinton Counties, Pennsylvania_

The high-calcium limestones of central Pennsylvania recently have been studied in detail by Kay (4, 5, 6), who has revised the stratigraphic nomenclature from that previously used. The work of Kay is economically important in that it clarifies our ideas of the stratigraphic relationships of the high-calcium beds, and provides assistance in prospecting for additional stone. Similar studies on the other important limestone deposits are needed.

Known locally as the "Bellefonte ledge," the Valentine member of the Curtin limestone formation (6) is quarried and mined by four companies in Nittany Valley, Centre County. The stratigraphic sequence and nomenclature of the Valentine limestone and associated rocks, in descending order is as follows (Kay 1943 1944).

<table>
<thead>
<tr>
<th>Ordovician system (upper middle part)</th>
<th>Thickness at type locality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mohawkian series</td>
<td>(feet)</td>
</tr>
<tr>
<td>Trenton group</td>
<td></td>
</tr>
<tr>
<td>Salona limestone formation: dark limestone and interbedded dark shale; metabentonite layers.</td>
<td>175</td>
</tr>
<tr>
<td>Nealmont limestone formation</td>
<td></td>
</tr>
<tr>
<td>Rodman member: dark, impure limestone with nodular chert in lower part.</td>
<td>30</td>
</tr>
</tbody>
</table>
Ordovician system (upper middle part).

Mohawkian series
Trenton group
Nealmont limestone formation (continued)
 Centre Hall member: interbedded shaly and thick-bedded limestone; fossiliferous, with *Maclurites logani* Salter........ 44
 Oak Hall member: thick-bedded limestone with metabentonite seams........................................... 60
 —regional unconformity—

Black River group
Curtin limestone formation
 Valentine member ("Bellefonte ledge"): thick-bedded to laminated, mostly very pure limestone; *Tetradium cellulosum* in lower part in the Bell mine; only the upper 70 feet, as a maximum, is used for chemical lime......... 90
 Valley View member: impure, shaly, thick-bedded limestone; bentonite layers; *Tetradium cellulosum* in upper part 52

Benner limestone formation
 Stover member: mostly dense, thick-bedded limestone, sparingly fossiliferous........................................ 91
 Snyder member: dense, lithographic limestone, and limestone-pebble conglomerate beds; *Tetradium cellulosum*, *T. fibratum*, and *T. prisomostylus columnaris*........... 98

The Valentine limestone forms an outcropping band along the southeastern flank of Bald Eagle Mountain, and along parts of both flanks of Nittany Mountain and its branches in Centre and Clinton Counties (see accompanying sketch map). It disappears in Clinton County between Salona and Antes Gap, probably as a result of being removed by erosion before the deposition of overlying strata. Southwestward from Salona it is present through Jacksonville and Bellefonte at least as far as a quarry four miles southwest of Bellefonte (4). Somewhere between this quarry and Union Furnace near Tyrone, Blair County, it again disappears.

In the other belts of outcrop to the southeast, it is absent east of Loganton in Sugar Valley, Clinton County, but appears between Loganton and Tylersville. It is present at Pleasant Gap, but at Lemont and around the nose of Nittany Mountain at Oak Hall, it is absent.

The Valentine limestone attains a maximum known thickness of 90 feet at Bellefonte in the Warner Company's Bell mine. Other thicknesses are shown in the following table:
SKETCH MAP OF HIGH-CALCIUM LIMESTONE AREA IN CENTRE AND CLINTON COUNTIES, PENNSYLVANIA

Figure 4. Sketch map of high-calcium limestone area in Centre and Clinton Counties, Pennsylvania (data after Butts, 1930 and Kay, 1943, 1944). The outcrop of the Middle Ordovician Valentine high-calcium limestone is shown by solid lines where its presence is fairly certainly known, and by dashed lines where it is poorly exposed but presumably present. The mines of the Warner Company and the National Gypsum Company are indicated on the map.
TABLE 3
THICKNESS OF VALENTINE LIMESTONE AT VARIOUS PLACES, IN FEET

<table>
<thead>
<tr>
<th></th>
<th>Upper Valentine</th>
<th>Lower Valentine</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Martin Miller quarry (old) 4 miles SW of Bellefonte</td>
<td>62</td>
<td>15</td>
<td>77</td>
</tr>
<tr>
<td>2. Whiterock quarry (old) near Jacksonville</td>
<td></td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>3. Quarry at Salona, Clinton county</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Whiterock quarry, Pleasant Gap</td>
<td>30</td>
<td>15</td>
<td>45</td>
</tr>
<tr>
<td>5. West of Tylersville</td>
<td></td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>6. Spring Bank, Brushy Valley</td>
<td></td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>7. Bell mine, Bellefonte</td>
<td>65</td>
<td>25</td>
<td>90</td>
</tr>
<tr>
<td>8. Chemical Lime, mine No. 1, Coleville</td>
<td>55</td>
<td>22</td>
<td>77</td>
</tr>
</tbody>
</table>

In at least two places near Bellefonte, the Valentine limestone is sharply reduced in thickness owing to channelling of its upper surface. The channels are filled with the overlying Nealmont limestone (5). Regional erosion along the strike accounts for the disappearance of the high-calcium stone between Salona and Antes Gap, and between Bellefonte and Tyrone. Presumably, also, erosion is responsible for the southeastward disappearance of the bed. Its extent beneath thousands of feet of younger rocks to the northwest is unknown.

The high-calcium stone occurs along the flanks of several elongate, northeast-southwest trending anticlinal uplifts. On the northwest flank of the Nittany Valley, the dips range from $45^\circ$ to $90^\circ$ northwest. In the Bell mine of the Warner Company the dip steepens with increased depth. On the southeast flank of the Nittany Valley, as exposed at Pleasant Gap, the dips are much less, ranging from $20^\circ$ to $30^\circ$ in a southeast direction. Data elsewhere are lacking.

The band through Bellefonte is offset by at least one major dip-fault a short distance northeast of the borough where the horizontal displacement has amounted to about one-fourth mile. Smaller faults occur at other places along the belt of outcrop, but for the most part faulting has not been an important hindrance in the mining operations.

Composition. The upper parts of the Valentine limestone (see Table 3), average 97 to 98 per cent CaCO$_3$, with about one per cent
MgCO₃ and one per cent or more of insolubles. The lower part of the member is slightly less pure, having up to five per cent of MgCO₃ and insolubles. The lower stone is satisfactory for flux and agricultural limestone but for chemical lime the upper part must be used.

Reserves. On the basis of published information, generalized reserve figures for several townships in Centre County can be calculated. The data are incomplete so that the figures should be considered as estimates. In the case of the westerly band of stone in Benner township, that which contains the operations of the Warner Company and the National Gypsum Company, an estimated 14 million tons of stone has been removed. The reserve figure given for this band includes the stone estimated to have been taken out. Twenty per cent has been subtracted from all the estimations to take care of local thinning of the high-calcium unit and local impure stone. The economically recoverable reserves will be reduced still further, depending upon the amount of stone left as hanging wall and foot wall and pillars in the process of mining.

**TABLE 4**

**Estimated Reserves of Valentine Limestone in Centre Co., Pa.**

<table>
<thead>
<tr>
<th>Township</th>
<th>Average thickness (feet)</th>
<th>Area of outcrop (sq. mi.)</th>
<th>Reserves to depth of 500 ft. (millions of tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benner, west band</td>
<td>80</td>
<td>0.08</td>
<td>50</td>
</tr>
<tr>
<td>Benner, east band</td>
<td>50</td>
<td>0.13</td>
<td>10.4</td>
</tr>
<tr>
<td>Spring, west band</td>
<td>80</td>
<td>0.07</td>
<td>56</td>
</tr>
<tr>
<td>Spring, east band</td>
<td>50</td>
<td>0.038</td>
<td>30.8</td>
</tr>
<tr>
<td>Marion</td>
<td>60</td>
<td>0.12</td>
<td>96</td>
</tr>
<tr>
<td>Walker</td>
<td>30</td>
<td>0.05</td>
<td>40</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>283.2</td>
</tr>
</tbody>
</table>

Present Operations. There are numerous old quarries along the belt of outcrop of the Valentine limestone, but only two are operating at present: the Martin Miller quarry west of Jacksonville and the Whiterock quarries at Pleasant Gap. A large quarry at Salona in Clinton County, producing mainly crushed stone, has a 10-foot layer of the Valentine limestone.
The Martin Miller quarry produces fluxing stone that is used in open-hearth furnaces and goes mainly to the Johnstown area. The Whiterock Quarries produce open-hearth stone for the Pittsburgh district and agricultural limestone that is shipped all over the State.

The largest operations in the Valentine limestone are the deep mines and plants of the Warner Company and the National Gypsum Company located respectively at the west edge of Bellefonte and three miles west of Bellefonte. The production of these companies, totaling nearly 500,000 tons in 1944, consists of chemical quicklime and hydrated lime, agricultural stone, stone for glass manufacture, mine dusting, and other uses.

The Annville Limestone
Dauphin and Lebanon Counties, Pennsylvania

Beginning near Swatara, in south-central Dauphin County, and trending east-northeast as far as Womelsdorf, Berks County, is a discontinuous band of high-calcium limestone of Ordovician age. It has been quarried for many years as the "Annville" limestone, named from the town of Annville, eastern Lebanon County. The stone has been used principally in Portland cement manufacture and for lime and fluxing stone. It is up to 400 feet thick in places, but only 50 to 150 feet of it is sufficiently pure to be used for chemical lime.

As shown on the accompanying sketch map (figure 5), the Annville limestone and associated shaly limestones are bordered on the north by the Middle and Upper Ordovician Martinsburg shale, and on the south by the Lower Ordovician Beekmantown limestone and dolomite. The Annville is stratigraphically older and underlies the Martinsburg shale, but its exact age relationships are uncertain. Stose and Jonas (13) present evidence that suggests a Stones River (lower Middle Ordovician) age for the Annville limestone.

The regional relationships, according to these authors, are as follows: southwest of Harrisburg, the Martinsburg shale rests upon the Chambersburg limestone (Middle Ordovician); the Chambersburg rests upon the Stones River limestone (Lower Middle Ordovician); and the Stones River in turn rests upon the Beekmantown limestone (Lower Ordovician). From Harrisburg to Hummelstown, the Martinsburg is in contact with Beekmantown limestones, presumably
as a result of thrusting of the limestones onto the Martinsburg. From Hummelstown northeastward through Hershey, Swatara, and Lebanon, nearly to Womelsdorf, the Martinsburg shale rests upon dark, argillaceous, thin-bedded limestones 50 to 100 feet thick, termed the Leesport limestone ("cement rock") by Stose and Jonas (13). This unit is believed to be the equivalent of the Jacksonburg "cement rock" occurring in Lehigh, Northampton, and Berks Counties. Beneath the Leesport in the Hummelstown-Womelsdorf belt there occurs a variable thickness of mostly limestone and marble, the Annville limestone. Beneath the Annville are limestones and dolomites bearing Beekmantown (Lower Ordovician) fossils. A Stones River gastropod, Maclurea magna, has been identified from the Annville at Womelsdorf.

Throughout its belt of outcrop, the Annville limestone is closely folded. Lesley (7) gives many examples of the complexity of structure as exhibited in quarries. In many instances the folds are overturned to the north so that the true stratigraphic relationships are reversed, and the Martinsburg shale or Leesport limestone forms the footwall in quarries. Either as a result of pre-Martinsburg erosion or of thrust-faulting, the Martinsburg shale in some places, as between Lebanon and Avon, Lebanon County, rests directly upon the Beekmantown limestone. At least two eroded, canoe-shaped, overturned synclines occur along the strike of the Annville limestone, and the beds are offset by faulting in several places.

Information as to thickness of the Annville limestone is incomplete, owing in part to lack of study and in part to its intensely folded condition, which makes accurate thickness interpretation difficult. B. L. Miller (8) reports that it is a little less than 400 feet thick in the belt between North Lebanon and Palmyra. The actual thickness of pure stone suitable for chemical lime is much less; it varies from about 50 feet in places east of Annville to about 150 feet in the Millard quarries west of Annville.

Composition. The Annville limestone according to B. L. Miller (8) averages about 95 per cent CaCO$_3$ throughout its belt of outcrop, but in part it becomes purer. In the quarries of H. E. Millard west of Annville, the stone is reported to average 97 to 98 per cent CaCO$_3$, with about one per cent insolubles and about 0.75 per cent MgCO$_3$.

Reserves. On the basis of present knowledge it is not possible
GEOLeGIC MAP OF HIGH-CAULCULMI LIMESTONE AREA IN DAPPHIN AND LEBANON COUNTIES, PENNA.


STRATIGRAPHIC DIVISION: 1. Martinsburg Shale, including isolated areas of Leopold limestone in Hanover and North Amwell townships, not indicated separately: 2. Leopold limestone and North Amwell limestone, shown by a stippled pattern, and as yet not mapped separately; in general, the Amwell limestone occupies the southern part of the belt of outcrop; 3. Bearmstown limestone and dolomite; 4. Conococheague limestone; 5. Tomstown limestone; 6. Ch.,

Hardyton quartzite; gri, granodiorite; TR, Triassic red shale and sandstone, intruded by diabase in many places.

Solid double lines, trending mostly north-south, indicate normal faults; the questionable northern extension of the fault in Jackson Township is indicated by dashed lines. Dashed double lines trending mostly east-west at the northern margin of the Triassic outcrop, indicates a belt of high-angle faulting. Arrows in the outcrop belt of the Leopold and Amwell limestones indicate direction of dip; in most instances the rock layers of this belt are overturned, but details of the structure have not been completely worked out. The locations of the various companies producing lime, fluxing stone, and crushed stone are shown.
to make detailed reserve estimates of the Annville limestone. From all indications, however, it appears that a very large supply of good quality stone is present between Swatara and Womelsdorf.

In a belt two and one-half miles long from the Annville quarries of H. E. Millard west to Palmyra, the reserves of stone to a depth of 100 feet, that are owned by this company, may be estimated at about 15,000,000 tons. Based on an average production of about 750,000 tons per year, a reserve sufficient to last 18 to 20 years is indicated. This is but a small fraction of the stone that might be available throughout the belt of outcrop, by quarrying methods, to a depth of 100 feet, and if underground methods were to be used extensively, the supply would be greatly increased. Two of the companies operating in the area are at present working the stone underground.

Present operations. The Annville limestone has been extracted for many years for shipment to the eastern Pennsylvania cement plants, where it is used to enrich the cement mix with calcium carbonate. In early days the stone was quarried for agricultural lime and flux for the iron furnaces to the south and east (7). Recently it has been used for chemical lime, agricultural limestone, flux, and other products.

In 1945, three companies operated in the Annville stone: H. E. Millard, The Annville Stone Company, and The Calcite Quarry Corporation. H. E. Millard has quarries 2½ miles west of Annville, at the west edge of Swatara, and at Millardsville, on the Berks County line. The products of the company include chemical quick-lime, blast-furnace flux, cement limestone, agricultural limestone, and crushed stone for construction purposes. The products go mainly to the eastern steel mills, to chemical plants in the metropolitan district of New York and New Jersey, and to the cement plants of eastern Pennsylvania. Some shipments of the stone and lime are made to the west into Harrisburg and Pittsburgh and northeast to paper mills in Maine. Agricultural stone and crushed stone are sold at numerous points in Pennsylvania. Annual production amounts to about 750,000 tons per year, including about 200,000 tons of quicklime.

The Calcite Quarry Corporation mines the Annville limestone, by the room and pillar method, halfway between Lebanon and
Mycerstown. Crushed stone for cement plants, flux, agricultural and construction purposes are produced.

The Annville Limestone Company, located one mile northeast of Hershey, mines the limestone by the shrinkage stope method. The products are similar to those of the Calcite Quarry Corporation.

Numerous old quarries occur in the Annville limestone (7). Most of the production from these operations was for cement limestone, flux, and crushed stone. Rapid encroachment of water into the quarries caused the abandonment of most of them after a short period of operation. The H. E. Millard company has gone to considerable expense to control the water in its Annville quarries.

The Kinzers Limestone, York County, Pennsylvania

The Kinzers limestone, of Lower Cambrian age, and occurring in a belt beginning at Wrightsville on Susquehanna River and trending west through York to Spring Grove, in York County, has been quarried extensively for lime, fluxing stone, and Portland cement. The present operations for chemical lime and flux are located at Thomasville and at West York.

The Kinzers formation, in this area (14) consists of three members: a lower member of dark shale and earthy limestone 100-150 feet thick; a middle member of thick-bedded pure limestone and marble, grading into dolomite 100-150 feet thick; and an upper member of earthy, siliceous, thin-bedded limestone 125-180 feet thick.

The middle member contains the high-calcium beds, but their distribution is somewhat erratic and subject to rapid lateral changes. This lateral variation in composition is a result of partial dolomitization along and adjacent to joint planes in the originally pure limestone. As a consequence, the individual quarrying operations are limited in extent.

Various thickness measurements of the pure Kinzers limestone, as it is exposed in quarries along the belts of outcrop, are (14):

<table>
<thead>
<tr>
<th>Location</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite thickness in quarries north of Wrightsville</td>
<td>80</td>
</tr>
<tr>
<td>Thomasville Stone &amp; Lime Company quarry, Thomasville</td>
<td>60</td>
</tr>
<tr>
<td>Willis Creek Valley, northwest of York</td>
<td>139</td>
</tr>
<tr>
<td>York Valley Lime &amp; Stone Co. quarry, 6 miles southeast of York</td>
<td>110</td>
</tr>
<tr>
<td>National Gypsum &amp; Lime Company quarry, west of York</td>
<td>50-70</td>
</tr>
</tbody>
</table>
The Kinzers formation is underlain by the Vintage dolomite and overlain by the Ledger dolomite, all of Lower Cambrian age. The Kinzers is abundantly fossiliferous and contains the Lower Cambrian fauna of the Olenellus zone. Except in York County, the formation is shaly and siliceous and generally unfit as a source of high-calcium limestone.

The structural attitude of the high-calcium beds in York County is extremely complex; the rocks are highly folded and faulted and are discontinuous along the strike so that quarrying of the stone presents many problems. The faulting in the limestone belt apparently is mostly of the normal type, although great thrust-fault zones lie a short distance to the south.

**Composition.** The Kinzers limestone in this area is characteristically low in silica, but the magnesium content is variable. The best grade of stone averages about 98 to 99 per cent CaCO₃, with one to two per cent MgCO₃. Other stone occurring in large amounts has up to five per cent or more of MgCO₃. The best stone is used for chemical lime, while the less pure type is used for flux and crushed stone.

**Reserves.** No detailed reserve estimates of the Kinzers high-calcium limestone in York County can be made on the basis of present knowledge. The companies operating at Thomasville have diamond-drilled much of their properties and have fairly accurate knowledge of the good stone present, but in other places data are lacking. No information is available as to the reserves of the third large concern, the National Gypsum Company, which operates a quarry and mine at West York.

The Thomasville Stone & Lime Company (courtesy of Mr. Cook, plant superintendent) estimates that on its property at Thomasville, there is a reserve of about 3,000,000 tons of stone averaging less than 2 per cent MgCO₃. At the present rate of production, this supply will be sufficient to last about 10 years. Their reserve estimate is based upon reliable geological investigation.

As this property comprises only a small part of the area of outcrop of the high-calcium limestone (see geological map, Stose and Stose, 1944) it is probable that a substantial reserve of good stone occurs in the area between Susquehanna River and Spring Grove. Core drilling is necessary to determine these reserves adequately. At the
present time, the land that is underlain by the limestone is excellent farmland and is thickly settled, so that much of it is not available for limestone quarrying. With favorable economic conditions, underground mining of the stone might prove to be profitable in the future.

**Present operations.** The purer parts of the Kinzers limestone make an excellent chemical lime, and three of the companies now operating here produce this material. In addition, the stone is crushed or pulverized for flux, glass plant stone, and agricultural limestone.

Although numerous old quarries occur in the belt from Wrightsville through York to Thomasville, most of them are no longer active. The Thomasville Lime & Stone Company and the J. E. Baker Company, both located at Thomasville, produce the various commodities listed above. The National Gypsum Company at West York produces lime and pulverized stone of various kinds. Various products that are reported for this company include quicklime and hydrated lime, agricultural stone, mine dust, and a precipitated, very fine-grained lime carbonate for tooth powder and other purposes. The Medusa Portland Cement Company has a plant at West York, where several types of cement are made.

The products are shipped mainly to steel mills, chemical plants and paper mills in eastern Pennsylvania and West Virginia, but substantial amounts of agricultural limestone and lime are used locally.

*High-calcium Limestone of the Kinzers Formation near Bittinger, Adams County, Pennsylvania*

In the lowlands around Bittinger, southeastern Adams County, a formation of lower Cambrian age contains a sequence of high-calcium limestone. For many years the stone has been quarried for lime and flux. It occurs in isolated patches as a result of intense folding and faulting followed by erosion.

The high-calcium deposits are restricted to four areas: (1) a narrow curving belt beginning about ½ mile southeast of Bittinger, running through that village, thence curving northeast and north about 1½ miles; (2) a narrow northwest-southeast trending band about ½
SKETCH MAP OF HIGH-CALCIUM LIMESTONE AREA IN YORK AND ADAMS COUNTIES, PENNA.
mile long, lying 1 mile northwest of Bittinger; (3) a narrow sinuous
belt about 1.4 miles long, lying 1.1 miles west of Bittinger; (4) a
north-south trending, pod-shaped area 0.6 miles long running through
the village of Centennial.

Except in the Bittinger band, the limestone is overlapped on the
west by Triassic red beds. The high-calcium beds are underlain and
overlain by impure dolomite, and, in part, pass laterally into pure
dolomite. Exposures are poor because of a widespread soil cover.
The total thickness of the impure dolomite and overlying high-
calcium beds is estimated at 2000 feet (11).

The age relationships of the high-calcium stone and associated
rocks have not been worked out in detail, but the data suggest a
Kinzers age. In York County, the Kinzers formation comprises a
lower argillaceous limestone and shale member, a middle pure but
partly dolomitized limestone member, and an upper sandy limestone
member, which attain 500 feet in thickness. The brachiopod *Nisusia
festinata* Billings is present in the middle and upper members
but has not been reported in the lower member in the York area.
The same species has been found in an impure banded layer just
below the high-calcium limestone in the Steacy and Wilton quarry
at Bittinger. A dark shale, below, contains *Olenellus* and *Salterella*,
typical Kinzers fossils. Stose (11) states that in his opinion the
limestone at Bittinger is the same as the high-calcium beds in the
York Valley, although he refers the former to the Ledger formation
and the latter, in a later publication, to the Kinzers formation.
Until more evidence is gathered, the high-grade stone at Bittinger
may be tentatively considered as Kinzers in age.

Detailed measurements of the high-calcium beds are not available,
but in the Steacy & Wilton quarry at Bittinger, 300 feet of limestone
are exposed. Judging from the width of outcrop as mapped (U. S.
Geol. Surv. Folio 225) and with a dip of 70° northwest, the total
thickness of the stone present in the Steacy & Wilton quarry is
396 feet. Just northeast of the preceding, at the Bethlehem Mines
Company quarry, the high-calcium beds are calculated to be 407 feet
thick. In the Shriver quarry, located one mile north of Bittinger,
the thickness of pure stone is calculated at 457 feet, although as
mapped, the contacts are uncertain.

**Composition.** Information as to the composition of the limestone
in the Bittinger area is incomplete, but it is said to be 99.5 per cent CaCO₃ in parts of the Steacy & Wilton quarry at Bittinger. The impurities appear to be mostly MgCO₃, with very little silica, alumina, and iron oxide.

**Reserves.** It is not possible to estimate the reserves of limestone that may be present in this area on the basis of information at hand. Judging from the areal outcrop of the stone, it appears that moderately large supplies remain to be worked, but careful exploration by diamond-drilling would be necessary to obtain reserve data.

**Economic aspects.** No companies were operating around Bittinger late in 1945. Formerly the Steacy & Wilton Company and the Bethlehem Mines Corporation worked large quarries near Bittinger, and several other smaller concerns were once active. The stone has been used to make chemical lime and flux as well as for construction and agricultural stone. The lime was used in wall plasters and in paper manufacture. The fluxing stone was shipped to steel mills in eastern Pennsylvania and Maryland.

**Vanport Limestone**

The Vanport limestone occurs in the Allegheny group of Pennsylvanian age. It underlies the Lower Kittanning coal and is underlain by the Clarion and Brookville coals, although shale and sandstone beds intervene between the limestone and coals. The Vanport is rather widely distributed over several counties of west-central Pennsylvania and continues westward into Ohio.

For the most part the limestone exposures are in the stream valleys. Around New Castle and Kittanning the flat-lying beds have been stripped and mined for many years as a source of flux and Portland cement.

The geologists of the last century referred to the Vanport as the “Ferriferous limestone,” because on its upper surface a band of carbonate iron ore is developed. The ore was dug by early settlers and smelted in small furnaces throughout this part of the State. In thickness the ore varies from a few inches to a foot or more. It is no longer of commercial value.

**Character.** The Vanport limestone, as typically developed, occurs in two principal lithologic units: an upper, gray, relatively pure
FIGURE 7. Isopach map of Vanport limestone showing the variations in its thickness in west-central Pennsylvania (data mostly from publications of the Pennsylvania Geological Survey and the U.S. Geological Survey). As in the case of all such maps attempting to show thickness variations, the lines are not completely accurate owing to incomplete data. Because of the scale of the map, no attempt has been made to interrupt the thickness lines where they cross stream valleys that are cut below the level of the Vanport bed.

To the east the Vanport seems to disappear by passing into shale or sandstone. Similar disappearance probably takes place in a southerly direction, as the Vanport has not been reported to occur in wells in Westmoreland and Allegheny Counties. Relatively recent erosion has removed the Vanport to the north, so that its original thickness in the area is unknown. The limestone is reported to occur on hilltops in northern Elk and southern McKean Counties, but accurate data are not available on these occurrences.

Some of the thickness variation within the area of present distribution of the Vanport may be due to partial removal before deposition of the overlying sediments, as in places around Templeton and east of Kittanning. In calculating thicknesses, an attempt has been made to exclude the iron ore at the top of the Vanport, but the figures include both the upper gray stone, and the lower, blue, less pure beds.
portion, and a lower, blue, less pure portion. At the type locality, Vanport central Beaver County, however, these divisions are less easily recognized. Miller (8) gives the following section at Vanport.

<table>
<thead>
<tr>
<th>Upper unit</th>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
</table>
| 9. Blue limestone | 4'0" | 4'0"
| 8. Shale | 0'4" | 4'4"
| 7. Light gray to blue limestone | 8'0" | 12'4"
| 6. Shale | 0'6" | 12'10"
| 5. Limestone | 0'8" | 18'4"

<table>
<thead>
<tr>
<th>Lower unit</th>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
</table>
| 4. Shale | 2'2" | 15'0"
| 3. Hard ferruginous limestone | 1'0" | 16'6"
| 2. Shale | 0'6" | 17'0"
| 1. Fossiliferous limestone | 2'0" | 19'0"

The boundary between the upper and lower units in this section is not certain, but may fall between beds 4 and 5. Another section a short distance west of Vanport, given by Miller (8), is as follows:

<table>
<thead>
<tr>
<th>Upper unit</th>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
</table>
| 3. Gnarly or knotty, gray limestone breaking on weathering into beds about 1½ inches thick... | 3'6" | 3'6"
| 2. Shaly layer, containing some limestone, deeply stained by ferruginous matter | 0'6-12" | 4'0"

<table>
<thead>
<tr>
<th>Lower unit</th>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
</table>
| 1. Gnarly blue to light dove-colored limestone, which breaks on weathering into thin beds ½ to 1½ inches thick | 7'0" | 11'0"

Northward from Vanport the formation takes on its more typical development as in the quarry of the Clydesdale Brick Co., Ellwood City (8).

<table>
<thead>
<tr>
<th>Upper unit</th>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
</table>
| 3. Gray limestone, massively bedded, but breaking into thin layers on weathering | 6'7" | 6'7"
| 2. Hard massive bed, called the “Bull layer” | 1'0" | 7-8"

<table>
<thead>
<tr>
<th>Lower unit</th>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
</table>
| 1. Blue limestone, breaking into thin beds on weathering, top somewhat shaly | 15'0" | 22-23"
In southern and central Lawrence County, around New Castle, Bessemer, and Wampum, the Vanport limestone is well known and widely exploited. A section in the Pittsburgh Crucible Steel Co. quarry at Bessemer, according to Miller (8), is as follows:

<table>
<thead>
<tr>
<th>Upper unit</th>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Gray limestone containing some iron carbonate</td>
<td>0'11''</td>
<td>0'11''</td>
</tr>
<tr>
<td>5. Massive gray limestone which breaks into three beds when shot; shows stylolitic structure</td>
<td>4'1''</td>
<td>5'0''</td>
</tr>
<tr>
<td>4. Massive gray limestone, more crystalline than above.</td>
<td>3'0''</td>
<td>8'0''</td>
</tr>
<tr>
<td>3. Massive gray limestone</td>
<td>4'7''</td>
<td>12'7''</td>
</tr>
<tr>
<td>2. Gray limestone, somewhat gnarly with numerous laminations in upper 2 feet</td>
<td>5'0''</td>
<td>17'7''</td>
</tr>
<tr>
<td>1. Blue to almost black limestone</td>
<td>5'4''</td>
<td>22'11''</td>
</tr>
</tbody>
</table>

The stylolitic structure in bed No. 5 is commonly developed in the Vanport limestone throughout its area of outcrop. Stylolites, or solution-sutures, are wavy seams found generally in massive limestone beds. They run roughly parallel to the bedding planes and are thought to be the result of differential solution, by percolating ground waters, acting along planes of easy solubility, and taking place very slowly throughout long periods of geologic time. The amount of stone removed by the process is thought to be about equivalent to the relief of the stylolite columns, which generally varies from less than an inch to several inches. Thus the stylolite-forming process may be responsible for the loss of considerable amounts of pure stone when considered from an acreage viewpoint.

Eastward from the Lawrence County occurrences the Vanport limestone has been quarried and mined extensively at Annandale in northern Butler County and at Worthington and along Allegheny River above Kittanning in Armstrong County. A typical section described by Miller as found in a mine of the Pittsburgh Limestone Company, about 1½ miles southwest of Worthington, is as follows:

<table>
<thead>
<tr>
<th>Upper unit</th>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Gnarly limestone, either massive or divided into 4-6 layers by thin partings of black shale; large crinoid stems abundant; thin shale parting at base.</td>
<td>1'6''</td>
<td>1'6''</td>
</tr>
</tbody>
</table>
**Upper Unit (continued)**

<table>
<thead>
<tr>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1'6''</td>
<td>3'0''</td>
</tr>
</tbody>
</table>

5. Limestone as above; thin shale parting at base

4. Limestone, thin-bedded, with different layers separated by very thin shale partings; commonly called the “shelly bed”

<table>
<thead>
<tr>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2'0''</td>
<td>5'0''</td>
</tr>
</tbody>
</table>

3. Shale parting

<table>
<thead>
<tr>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0'3''</td>
<td>5'3''</td>
</tr>
</tbody>
</table>

2. Limestone, gray, massive when fresh, but breaking into thin, rough-surfaced layers on weathering. It has local thin shale partings. This is the principal bed of stone and is of the best grade.

<table>
<thead>
<tr>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>8'9''</td>
<td>14'0''</td>
</tr>
</tbody>
</table>

**Lower Unit**

<table>
<thead>
<tr>
<th>Bed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>4'3''</td>
<td>18'3''</td>
</tr>
</tbody>
</table>

1. Blue to black limestone with some fossils. Breaks into more or less rectangular blocks when shot.

Examination of these sections of the Vanport reveals at once that the formation is variable in lithologic character and minor subdivisions, but the details of Vanport stratigraphy have not been worked out. Published palontological information on the Vanport is scarce, and a careful study of its lithology and fossil remains should prove valuable from an economic standpoint.

At many places the Vanport is sharply reduced in thickness, possibly as a result of channelling before the deposition of overlying sediments. On the east and south the limestone disappears, probably by passing into shale, although the details of this disappearance have not been worked out fully. The original extent of the limestone to the north is not known because it has been removed by erosion in that area. Westward into Ohio the Vanport is widely distributed and is an important quarry rock.

**Composition.** The upper or gray part of the Vanport limestone, except the weathered and ferruginous uppermost layers, contains about 90 to 95 per cent CaCO₃. The principal impurities are silica, alumina, and iron oxide. Magnesium carbonate content is usually low. The lower or blue part of the Vanport contains a somewhat higher percentage of silica and alumina, and iron and phosphorous oxides are present in varying amounts. The CaCO₃ content in this lower part ranges between about 88 and 92 per cent.

**Reserves.** The Vanport limestone occurs in practically unlimited amount in the several counties of west-central Pennsylvania, but
owing to its variability in thickness, it is not everywhere suited to exploitation. In most instances, because of the steep surface slopes and thick overburden, it is necessary for large operations to be carried on underground. At present a thickness of 15 feet is about the minimum at which mining may be undertaken. The isopach map (Figure 7) illustrates the known variations and thicknesses of the Vanport. Areas where this stone is 15 feet or more in thickness are: southern and southwestern Lawrence County, northwestern Beaver County, southwestern Clarion County, northern and south-central Butler County, south-central Venango County, southwestern Armstrong County, and a narrow belt in southeastern Mercer County. As shown by well logs, the Vanport is nearly 30 feet thick in southwestern Indiana County, but it is too deeply buried here to be exploited under present economic conditions.

Present operations. The Vanport limestone is used for fluxing stone, railroad ballast, highway stone, agricultural limestone, Portland cement manufacture, and mine dusting. The principal product of the existing plants is fluxing stone, with the finer sizes and rejects being used for other purposes.

The companies now operating in the Vanport limestone are: the Pittsburgh Limestone Company with plants at Hillsville, near New Castle, at Annandale, Butler County, and at Worthington and Kaylor, Armstrong County; the Carbon Limestone Company at Hillsville; the Bessemer Lime & Cement Company at Bessemer, west of New Castle; and the Medusa Portland Cement Company at Wampum, south of New Castle.

During the war the operators supplying fluxing stone have been producing at capacity. In recent years, however, blast furnaces in this area have been buying increasing amounts of dolomite from Toledo, Ohio. The pure dolomite is mixed with the Vanport limestone in order to improve the quality of the flux. If this trend continues during postwar years the production of Vanport limestone may become appreciably restricted.

At various times in the past, other companies have stripped or mined the Vanport limestone in Lawrence, Beaver, Butler, Armstrong, and Mercer Counties. Some of these companies are now operating elsewhere but have retained properties underlain by Vanport limestone, which may someday be reopened.
Other Deposits of Fairly High-Grade Stone in Pennsylvania

Fluxing stone is obtained at several other places in Pennsylvania, but for the most part the deposits contain from 5 to 10 per cent or more of silica and alumina impurities. Their use for fluxing stone is largely dependent upon their favorable situation with respect to market areas and transportation facilities. Among the more important operations are those of the Bethlehem Mines Corporation at Naginey, Mifflin County; at West Conshohocken, Montgomery County; at Steelton, Dauphin County; and at Bethlehem, Northampton County. The Everett-Saxton Company has produced a large amount of flux from their quarries near Everett, Bedford County. Other areas that have furnished large supplies of fluxing stone are at Williamson, Franklin County, and at Williamson and Blairfour, Blair County. All of these deposits are of Cambro-Ordovician age.

The Stones River limestone at Williamson, which has been quarried by the J. E. Baker Company and other concerns, is of relatively good quality. It is reported by Stose (10) to compare favorably in composition with similar stone quarried in the vicinity of Martinsburg, West Virginia. Careful study of the Stones River formation in this area might reveal deposits suited to the manufacture of chemical lime.

The Helderberg limestones of Devonian age are of fairly good quality in several places, as at Canoe Creek Station, Blair County; one-half mile east of McCoysville, Juniata County; near Hughesville, Lycoming County; at Maitland Gap, Mifflin County; and two miles southwest of Mifflinburg, Union County. In most instances, however, the thickness of the pure stone is not sufficient to warrant large-scale operations.

SUMMARY

Pennsylvania contains unlimited supplies of limestone suitable for roadstone, ballast, agricultural limestone, Portland cement and other products, but at only a few places are the deposits known to be of sufficient thickness and quality to be of large commercial importance as sources of chemical lime and flux.

The most important source of fluxing stone is the Vanport limestone
occurring in west-central Pennsylvania. The flat-lying structural attitude of this formation and the ease with which it may be stripped or mined, together with its proximity to large blast furnaces have resulted in its extensive exploitation. It is somewhat deficient in quality and its future production may become restricted by the importation of purer stone from other regions.

Fluxing stone is obtained at numerous places in central and southeastern Pennsylvania. Most of that produced in central Pennsylvania moves westward to the Pittsburgh district, while that in southeastern Pennsylvania moves eastward. The best quality flux is obtained around Bellefonte, Centre County; in the Annville-Lebanon area, Lebanon County; and at Thomasville, York County. Other important sources of flux are at Naginey, Mifflin County; Steelton, Dauphin County; Bethlehem, Northampton County; and West Conshohocken, Montgomery County.

There are several other deposits of limestone of fair quality in central and southeastern Pennsylvania. Because the present operations have large reserves and because sources in other states are strong competitors, it is doubtful whether other only moderately good deposits will be opened on a large scale for fluxing stone. Exceptions to this may occur in cases where a firmly-established company opens a property already held for that purpose, or where a large construction stone operation markets fluxing stone as an additional product.

The principal sources in Pennsylvania of stone for chemical lime are the Valentine limestone in the vicinity of Bellefonte, Centre County; the Annville limestone in Dauphin and Lebanon Counties; and the Kinzers limestone in York and Adams Counties. The stone at these places makes excellent lime for chemical and metallurgical use.

The Valentine limestone is of Middle Ordovician (Black River) age. Recent work by Kay has shown that this limestone is limited in its area of outcrop to Centre and Clinton Counties. Westward it extends for an unknown distance beneath great thicknesses of younger sediments where exploitation of it is not feasible. Similar deposits at this horizon in other parts of central and eastern Pennsylvania apparently are lacking. The Valentine limestone has been mined and quarried for many years as a source of lime, fluxing stone and other products, and large reserves of good stone appear to be present,
both in the vicinity of present operations and in areas as yet not worked on a large scale.

The Annville limestone forms a narrow belt through central Dauphin and Lebanon Counties, extending a short distance into Berks County. It is thought to be Stones River (lower Middle Ordovician) in age, but detailed paleontologic information is lacking, and complex structural conditions make interpretation of the stratigraphic relationships difficult. The Annville is an important source of high-calcium limestone and while accurate reserve data are not available, it is probable that the supply is large. Other Stones River limestones are of good quality at Williamson, Franklin County, and near Martinsburg, West Virginia. The detailed geology of the Annville limestone occurrences is in need of investigation, and in addition, the whole belt of the Stones River formation in south-central Pennsylvania should be searched for high-calcium limestone.

The Kinzers formation in York County, and rock that presumably is of the same age in eastern Adams County, contain valuable high-calcium stone. The Kinzers is of Lower Cambrian age and, other than in the above localities, apparently does not contain important reserves of high-calcium limestone. The geology of the York and Adams occurrences is extremely complex and accurate reserve estimates can be obtained only by core-drilling, owing to poor exposures of the stone.

The principal competitors to the Pennsylvania producers of chemical lime are located in West Virginia, around Martinsburg; in Tennessee, at Knoxville; and in Missouri, at Ste. Genevieve and other nearby localities. At Ste. Genevieve, the Spergen limestone of Mississippian age is of exceptionally uniform high quality, averaging over 98 per cent CaCO₃. The lime produced from this stone has found many markets in the East, where it competes actively with Pennsylvania lime.
REFERENCES


PUBLICATIONS OF THE MINERAL INDUSTRIES
EXPERIMENT STATION

Research results of the Experiment Station are disseminated through the following publications: (1) Bulletins which present the proceedings of technical conferences and the detailed results of the experimental studies of a problem which may be more comprehensive than a single project. (2) Information Circulars which present in nontechnical language the results of studies which are given in greater detail in other publications, and statistical data or pertinent information gathered from other sources. (3) Technical Papers consisting of bound copies of papers published in scientific journals (reprints), of progress reports, and of results of experimental studies which represent isolated phases of research and which will be summated later in bulletin form.

A few of the publications are listed below. These may be obtained from the Director of the Mineral Industries Experiment Station, The Pennsylvania State College, State College, Pennsylvania, at the price quoted.

BULLETINS


TECHNICAL PAPERS


CIRCULARS