COMMONWEALTH OF VIRGINIA

STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

Bulletin 47

Educational Series No. 3

Outline of the Mineral Resources of Virginia

BY

WILLIAM M. McGILL

UNIVERSITY, VIRGINIA

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STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

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LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., June 1, 1936.

To the State Commission on Conservation and Development:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 47 of the Virginia Geological Survey series of reports the manuscript and illustrations on an *Outline of the Mineral Resources of Virginia,* by Mr. William M. McGill, Assistant State Geologist.

This report contains a concise discussion of the most important mineral resources in the State, including coal, construction materials, gold, limestone, dolomite and calcareous marl, manganese, other metallic deposits, and nonmetallic resources. The main features of each kind of mineral deposit are briefly described. The distribution of the chief mineral resources is shown on a series of seven maps.

This report is based on a more detailed report on "Minerals" which was prepared by Mr. McGill for the Virginia State Planning Board and was published by that organization in its report on "Natural Resources." The Virginia State Planning Board, Mr. Charles J. Calrow, Consultant-Director, has generously given permission for the use of this material in the present bulletin.

This report should be of considerable interest and value to property owners in the State, to all who are interested in the development of our mineral resources, and especially to teachers in schools, to whom no summary description of the mineral resources of the State has been generally available.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:

State Commission on Conservation and Development,
Richmond, Virginia, June 8, 1936.

R. A. GILLIAM, *Executive Secretary and Treasurer.*

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By William M. McGill

MINERAL RESOURCES[2]

GENERAL STATEMENT

Virginia has a great variety of rock and mineral resources. More than 140 different minerals have been reported. Some are of great commercial value, whereas others await larger market demands or improved processes of industrial use. Some of the undeveloped mineral deposits may prove to be of commercial value when they have been thoroughly investigated in the field and laboratory and as new uses are developed for them. Still other deposits probably await discovery through detailed field examinations in all parts of the State.

Among the more common rocks and minerals mined and quarried in recent years in Virginia are: Barite, building stone, cement rock, clay, coal, diatomite, dolomite, feldspar, gold, granite, greenstone, gypsum, ilmenite, iron, lead, limestone, manganese, marl, mica, quartz, pyrite, rutile, salt, sand and gravel, sandstone, slate, soapstone, talc, and zinc. New deposits of glass sand, ilmenite and rutile, marble, and phosphate-bearing rocks have been recently discovered or developed.

Information on many of the mineral deposits in Virginia is given in bulletins (Nos. 1-45, inclusive) and maps published by the Virginia Geological Survey. Detailed field surveys and laboratory investigations of particular mineral resources and of the mineral resources in certain areas are being made by the Survey.

OCCURRENCE

Our mineral resources are not found in stock to be ordered as needed. They are distributed unevenly throughout the State, in general according to the kind and structure of the rocks.

The geology of Virginia is varied and complex. Based on the kind of rocks and their structure and on the topography, the State is divided

[1] Revision and condensation of an article entitled "Mineral Resources," in Report of the Virginia State Planning Board, Richmond, vol. 2, Natural Resources, pp. 1-100, December 31, 1935. Used with the permission of Charles J. Calrow, Consultant Director, Virginia State Planning Board, Richmond, Va.

[2] In the preparation of this report the writer has drawn freely upon published reports and bulletins of the Virginia Geological Survey and the United States Geological Survey, the United States Bureau of Mines and upon data prepared by the State Geological Survey. Other references consulted and to which acknowledgment is hereby made are "Mineral Resources of Virginia," by Thomas L. Watson, and the chapter on "Minerals and Their Exploitation," by Roy J. Holden in "Virginia: Economic and Civic." See also "Selected References" at end of this report.

into five distinct geologic and geographic provinces. From east to west they are the Coastal Plain, a dissected plain that slopes gently toward the Atlantic Ocean; the Piedmont Plateau, a gently rolling plateau rising westward from the Fall Zone, along the western margin of the Coastal Plain, to the first continuous mountain ridge; the Blue Ridge, a high continuous, dissected ridge and plateau; the Appalachian Valley, also termed the Valley and Ridge province; and that part of the Appalachian Plateaus in southwestern Virginia. (See Fig. 1.) The east-west width of each province varies, but the geologic limits are fairly well defined. The Appalachian Valley in Virginia consists of a broad valley area on the east, known as the Valley of Virginia, and a series of linear ridges and valleys on the west, known as the Valley Ridges section.

The Coastal Plain is underlain chiefly by loosely consolidated beds of clay, greensand, marl, sand and gravel, and diatomite. The rocks of the Piedmont and Blue Ridge provinces are mainly crystalline, including granite, greenstone, soapstone, and slate. They contain barite, clay, emery, feldspar, gold, manganese, mica, pyrite, quartz, rutile and ilmenite, talc and other valuable minerals. The Appalachian Valley region contains enormous reserves of dolomite, limestone, quartzite, sandstone, and shale. It contains also important deposits of barite, cement rock, clay, gypsum, iron, manganese, salt, and zinc, as well as known deposits of marble, glass sand, anthracitic coal, and other resources. The extreme southwestern part of the State, known as the southwestern plateau region, contains the great bituminous coal beds of the State. (See Fig. 1.)

VALUE

The total value of the mineral production of Virginia from 1926 through 1933, a period of 8 years, was $262,508,396.00 or an average of approximately $33,000,000.00 a year. In 1926, the production was valued at $46,136,458.00, and in 1930, it was valued at $34,602,749.00, but owing to unfavorable markets, resulting from the depression, it decreased to $16,927,446.00 in 1932. In 1933, improved economic conditions were reflected in an increased value, the total production for that year being valued at $18,845,740.00. The greatest annual production value was $85,444,569.00 in 1920. The total value of mineral production in Virginia during the last quarter of a century has been more than one billion dollars.

The above figures do not indicate fully the benefits to communities through the bringing in of new capital, the development or establishment of new industries, the employment of local labor, and the increase in taxable values and thus increases in State wealth, through the use of raw mineral materials.

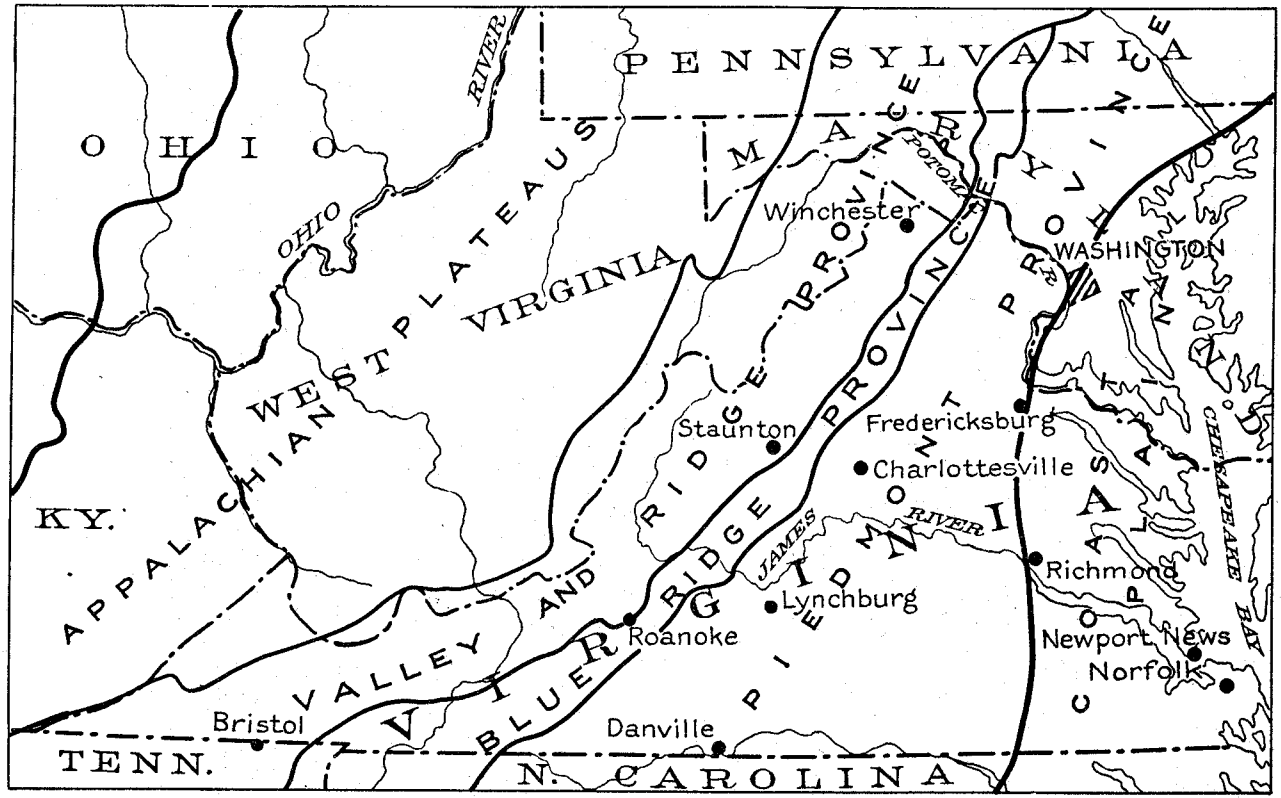


FIGURE 1.—Physiographic divisions of Virginia.

A recent report of the Virginia State Planning Board shows that the chemical and allied industries in Virginia alone use 21 different raw mineral resources in the manufacture of their various products. Of these, 15 are produced in Virginia, 3 are obtained from border states and the remaining 3 are imported.[3]

FUTURE DEVELOPMENTS

The State's mineral resources have had an important part in the creation of available State wealth and doubtless will be of much greater importance to chemical and other mineral-using industries and to the State in the future developments in this age of applied science. The geologic surveying of the State is far from being completed. But a small part of the State's mineral resources has been thoroughly investigated and many of them have been only slightly utilized. Not until all outcrops of rock and mineral deposits of possible commercial importance have been examined and mapped in detail will there be available adequate information on all the mineral resources of the State.

MAPS

The distribution and extent of the geologic formations in Virginia and some of their mineral deposits are shown in different colors on the geologic map of Virginia and the geologic map of the Appalachian Valley of Virginia, issued in 1928 and 1933, respectively, by the Virginia Geological Survey. Particular deposits are shown on separate maps accompanying the various bulletins (1 to 45, inclusive) of the Survey.

An article on mineral resources of Virginia prepared by the writer for the Report of the Virginia State Planning Board[4] on Natural Resources [of Virginia] is accompanied by a set of 7 maps showing the location and distribution, by groups according to kinds and uses, of the various mineral resources described in this report. These maps, with several modifications, are reproduced here by permission of the Consultant-Director of the Virginia State Planning Board. (See Pls. 1, 3, 8, 9, 10, 11, and 14.)

[3] Chemical industries in Virginia: Report of Virginia State Planning Board, Richmond, Industries, Vol. 3-B, map V-24, 1936.

[4] McGill, W. M., Minerals [of Virginia]; *in* Report of Virginia State Planning Board, Richmond, Natural Resources, vol. 2, pp. 1-100, December 31, 1935, maps Nos. IV-1-1, IV-1-2, IV-1-3, IV-1-4, IV-1-5, IV-1-7, IV-1-9.

COAL RESOURCES[5]

GENERAL STATEMENT

The coal deposits of Virginia are the largest and most important mineral assets of the State. The total production has been obtained from three major regions, each of which contains coal of a different geologic age. These regions are the Piedmont or Triassic areas, the Valley fields, and the southwestern plateau region. (See Pls. 1 and 2.)

The first coal mined in the United States was from a thick coal bed along the James River near Richmond, Va., in 1750. Some coal was obtained locally in the Montgomery-Pulaski counties area in the Valley region, before the War between the States. Some of the coal used by the Confederate frigate Merrimac (Virginia), in her fight with the Monitor in Hampton Roads on March 9, 1862, came from the Merrimac mine in the Price Mountain area in Montgomery County.[6] The occurrence of coal in the Valley region has been known for 100 years or more. Deposits in Tazewell County in the southwestern plateau region were discovered in 1873 and a permanent mining camp was established on Laurel Fork in 1881. The town of Pocahontas was established in 1882.

The coal-bearing areas of Virginia are favored by railroad and highway accessibility, normally mild climate, ample water supplies, abundant timber resources, adequate supply of labor, and nearness of ample reserves of varied mineral and raw materials essential to economic development and industrial life.

All of the Virginia areas are adjacent to excellent rail transportation facilities which afford favorable and direct connections with many of the large cities and industrial centers of the northern, middle western and southern sections of the United States. The Virginian, the Chesapeake and Ohio, and the Norfolk and Western railways, distinctly "coal-carrying" railroads, serve the coal-bearing regions of Virginia. These railroads also provide direct connection with the growing export port of Hampton Roads, Va., while the Southern Railway affords connection with the export port of Charleston, S. C.

RESOURCES AND PRODUCTION

Statistics compiled as a result of detailed field studies made by the Federal and State geological surveys give Virginia a total estimated original tonnage of 32,201,000,000 tons of coal of all ranks. (See Table 1.) About 22,000,000,000 tons is considered recoverable and of this

[5] See "Selected References" at end of this report.
[6] Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 3, 1925.

TABLE 1.—*Estimated tonnages of coal in Virginia areas*

COUNTY	Thickness Coal-bearing Formations (feet)	Known Workable Beds[a]	Estimated Original Tonnage[b]	Recoverable Tonnage[c]	Virginia Geological Survey Bulletins[d]
Piedmont Areas (Triassic).					
Amelia, Chesterfield, Goochland, Henrico, and Powhatan	2,000–2,500	2–5 (?)	1,000,000,000[e]	.....	Roberts, J. K., Bulletin 29, 1928
Valley Fields (Mississippian).					
Montgomery, Pulaski, Wythe, Bland, Smyth, Roanoke, Botetourt, Augusta, and Rockingham.	600–1,800	2–4 (?)	1,000,000,000	.....	Campbell, M. R., Bulletin 25, 1925
Southwestern Plateau Region (Pennsylvanian).					
Tazewell	2,800	15	2,406,576,000	1,600,000,000	Harnsberger, T. K., Bulletin 19, 1919
Dickenson	2,800	13	6,899,906,000	4,900,000,000	Giles, A. W, Bulletin 21, 1921
Russell	3,000	7	1,009,600,000	706,000,000	Wentworth, C. K., Bulletin 22, 1922
Buchanan	3,700	15	12,032,700,000	8,400,000,000	Hinds, Henry, Bulletin 18, 1918
Lee	5,650	20	1,952,589,450	1,365,000,000	Giles, A. W., Bulletin 26, 1925
Wise and Scott	5,570	26	5,900,000,000	4,400,000,000	Eby, J. B., and others, Bulletin 24, 1923
Total, Southwestern Plateau region			30,201,371,450	21,371,000,000	
Total for State			32,201,371,450		

[a] Beds 30 inches or more thick.
[b] Beds 14 inches or more thick.
[c] Based on 70 per cent of total estimated tonnage.
[d] See also Watson, T. L., *in* Mineral Resources of Virginia, pp. 336-384, 1907, and Holden, R. J., *in* Virginia: Economic and Civic, pp. 83-90, 1933.
[e] Holden, R. J., *op. cit.*, p. 84.

COAL BEARING AREAS OF VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

BULLETIN 47, PLATE -1

PREPARED BY VIRGINIA GEOLOGICAL SURVEY
REPRINTED FROM REPORT ON NATURAL RESOURCES
OF VIRGINIA STATE PLANNING BOARD

LEGEND

SOUTHWESTERN VIRGINIA REGION (PENNSYLVANIAN MEASURES) BITUMINOUS
1550 SQUARE MILES 30,000,000,000 TONS
SEE VIRGINIA GEOLOGICAL SURVEY BULLETINS 12, 18, 19, 21, 22, 24, & 28

VALLEY FIELDS (MISSISSIPPIAN MEASURES) ANTHRACITE-SEMI-BITUMINOUS
100 SQUARE MILES 1,000,000,000 TONS
SEE VIRGINIA GEOLOGICAL SURVEY BULLETIN 25

PIEDMONT AREAS (TRIASSIC MEASURES) BITUMINOUS
150 SQUARE MILES 1,000,000,000 TONS
SEE VIRGINIA GEOLOGICAL SURVEY BULLETIN 29

1550 SQUARE MILES
30,000,000,000 TONS
BITUMINOUS
PENNSYLVANIAN AGE

100 SQUARE MILES
1,000,000,000 TONS
ANTHRACITE-SEMI-BITUMINOUS
MISSISSIPPIAN AGE

150 SQUARE MILES
1,000,000,000 TONS
BITUMINOUS
TRIASSIC AGE

KENTUCKY

TENNESSEE

NORTH CAROLINA

WEST VIRGINIA

MARYLAND

DELAWARE

amount about 900,000,000 tons is classed as anthracite and semianthracite, about 400,000,000 tons as semibituminous, and the balance as bituminous.[7] In 1929 the production of coal in Virginia amounted to 12,748,306 tons and in 1933 to 8,178,642 tons. About 495,158 tons of coke was produced in 1929, and only about 70,493 tons in 1933. Practically all of this production was obtained from the southwestern Virginia region. According to statistics published by the United States Bureau of Mines, Virginia to the end of 1932 had produced 296,050,284 tons of coal.

The estimated tonnage of coal in the different areas and counties, [illegible] data on the thickness and number of coal beds, is given in Table [illegible]. Analyses of coals from the various seams in the different fields are given in Bulletins 9, 12, 18, 19, 21, 22, 24, 25, 26, and 29 of the Virginia Geological Survey.

PIEDMONT AREAS

OCCURRENCE

In the Piedmont region of Virginia are two coal areas of Triassic age, namely: The Richmond basin, along the eastern margin of the Piedmont province a short distance southwest of Richmond, and the Farmville area, north of the town of that name. The Richmond basin occupies parts of Chesterfield, Henrico, Goochland, Powhatan, and Amelia counties and has an area of about 150 square miles. The Farmville area includes parts of Prince Edward, Cumberland and Buckingham counties and covers an area of about 40 square miles. Thin seams of coal, not of commercial importance, are known in one or two other local areas underlain by Triassic rocks in the eastern Piedmont region.[8]

In both areas the coal occurs in the Manassas sandstone or overlying Bull Run shales of Triassic age, and the areas are thus often called the Triassic coal-bearing areas.

CHARACTER OF THE COAL

The coal in the Triassic areas is of bituminous rank and though variable is of good quality. The principal impurities are pyrite and shale or slate. Five workable coal beds are reported in the Richmond coal basin, separated by beds of sandstone and shale. The upper beds are the thickest and the topmost one is said to have a maximum thickness of from 30 to 40 feet on the east side of the basin.

[7] Thom, W. T., jr., Petroleum and coal, Princeton, Princeton University Press, p. 199, 1929, after Campbell, M. R.

[8] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, pp. 94-116, 1928.

Natural coke also occurs in the Richmond basin. It is porous, not unlike synthetic coke in appearance, and does not weather as readily as the coal. The coke has a reported thickness of from 2 to 4½ feet.

Analyses of both the coal and the coke are given by Roberts.[9]

PRODUCTION

The first coal mined in the United States came from the Richmond basin. Old records show that the first period of continuous mining was somewhere between 1770 and 1780. A second period of activity began about 1842 and continued until 1877. About 1890 mining was resumed and some production was maintained, locally at least, until 1923. No active mining is in progress in this area at this time. The total production of coal from the basin from 1822, the first year for which any records are available, through 1923, has been estimated at 5,697,620 tons.[10] It has been estimated that possibly more than 1,000,000,000 tons of coal occur in the Richmond basin.[11]

No extensive commercial development has been attempted in the Farmville area although some slight production of coal, mainly for local consumption, has been obtained from it.

FUTURE OUTLOOK

The proximity of the Richmond basin to Richmond and the existing favorable railway and water transportation facilities have at times aroused considerable interest in attempted commercial development of the area. Although this area has no commercial importance at this time and could scarcely be expected to compete with the large developed mines in the southwestern plateau region, it may prove to be an important reserve for future commercial development.

VALLEY FIELDS

OCCURRENCE

On the west side of the Great Valley in Virginia outcrops of coal have long been known at several different localities. It is reported that some of these were explored as early as 1833 with unsuccessful attempts made to develop coal mines in this part of the State shortly after the War between the States. Results of detailed studies of these areas by geologists of the United States and the Virginia geological surveys have resulted in the determination of several separate fields. The deposits occur in the Price formation of Mississippian age, mainly

[9] Op. cit., pp. 108-111, 114.
[10] Roberts, J. K., op. cit., p. 106.
[11] Holden, R. J., Minerals and their exploitation, *in* Virginia: Economic and Civic, p. 84, Richmond, Whittet and Shepperson, 1933.

A block of semianthracite coal from Montgomery County, Virginia. From Geological Survey Bulletin 25, by M. R. Campbell.

A block of semianthracite coal from Montgomery County, Virginia. From Geological Survey Bulletin 25, by M. R. Campbell.

in the counties of Montgomery, Pulaski, Wythe, Bland, Smyth, Roanoke and Botetourt. The Valley fields produce the only hard coal (anthracite group) that can compete successfully with the anthracite coal of Pennsylvania. Much importance attaches to these fields, with an encouraging outlook for their future.

M. R. Campbell[12] has subdivided the fields on the basis of their importance, as follows: (1) The fields of Montgomery and Pulaski counties; (2) the fields of Wythe County; (3) the fields of Bland and Smyth counties; (4) the fields of Roanoke and Botetourt counties; (5) the fields of Augusta and Rockingham counties; and (6) scattered fields of little or no economic importance.

Montgomery County.—There are two distinct fields in Montgomery County, the Brush Mountain field in the northern part and the Price Mountain field in the south. There is only one coal bed, the Merrimac or "Big Seam," of generally workable thickness (5 to 9 feet) in the Brush Mountain field.

Pulaski County.—There are two fields in the Pulaski area, the Little Walker Mountain field, which is a southwestward continuation of the Brush Mountain field of Montgomery County, and the Pulaski field, extending eastward through the town of Pulaski.

Wythe County.—Two distinct coal fields occur in Wythe County, the Max Meadows field, occupying a detached synclinal basin about 6 miles long, near Max Meadows, and the Reed Creek field, comprising a narrow zone of coal-bearing rocks along the south slope of Little Walker and Brush mountains, nearly across the county. In the Max Meadows field three coal beds, generally occurring near the middle of the Price formation, have been found. Two are of generally workable dimensions and the third may be.

Bland and Smyth counties.—A narrow belt of coal-bearing rocks extends from Point Pleasant, 6 miles east of Bland in Bland County, southwestward for a distance of more than 30 miles to the vicinity of Saltville in Smyth County. Because of the general thinness of the beds and the high ash content of the coal, it is not thought that these fields are particularly promising, certainly not for many years to come.

Roanoke and Botetourt counties.—In Roanoke and Botetourt counties occurs a northeastward extension of the Brush Mountain field of Montgomery County, which has been termed the North Mountain field. This field is not active at present but has attracted considerable interest because of its nearness to James River and the possibility of transporting its coal to Richmond by this water route.

[12] Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 322, 1925.

Other Valley fields.—Small deposits whose development has been unsuccessfully attempted are known to occur locally along the northwest slope of Narrow Back Mountain from the vicinity of Stokesville in Augusta County to Rawley Springs in Rockingham County. None of these are now thought to be of commercial importance.

CHARACTER OF THE COAL

The coal of the Valley fields (See Pl. 2) of Virginia has been generally regarded as anthracite, but in order to differentiate it in the trade from the anthracite of Pennsylvania, it has been designated as "Virginia hard coal or anthracite mined in Virginia" by the U. S. Geological Survey and is considered as semianthracite or anthracite, depending upon the meaning of these terms. The Valley coal burns first with a characteristic yellow flame and then with a bluish flame.

SOUTHWESTERN PLATEAU REGION

OCCURRENCE OF COAL

The southwestern plateau coal-bearing region, comprising several designated fields, is located west of the Appalachian Valley in the extreme southwestern part of the State. Occupying the northeastern part of the Cumberland plateau and the southeastern part of the Kanawha plateau, this area comprises about 1,850 square miles of bituminous coal-bearing lands in Tazewell, Russell, Scott, Buchanan, Wise, Dickenson and Lee counties. The results of detailed surveys, including mapping, by the Virginia and United States geological surveys show that about 80 per cent or 1,500 square miles of this area is productive. The southwestern plateau fields are the largest and most productive in the State and give Virginia an important rank among the coal producing states.

At present the greater part of the production is being obtained from Wise County, but the other counties contain large reserves of coal. The estimated original tonnage of minable coal, in beds 14 inches or more thick, the estimated tonnage of recoverable coal, the approximate thickness of the coal-bearing formations, and the known number of minable beds in the counties embraced in the southwestern plateau region as determined by detailed studies made by the Virginia Geological Survey in cooperation with the United States Geological Survey, are given in Table 1.

The topography of the southwestern Virginia coal-bearing region is rugged to mountainous. Flat lands, even of small extent, are rare. Altitudes range from 3,700 feet and more above sea-level along the

northeastern and central parts of the area to about 1,000 feet and less in places along the Kentucky boundary. The area is drained mainly by tributaries to Ohio River.

The principal commercial fields of the southwestern Virginia region are (1) the Pocahontas or Flat Top field, (2) the Clinch Valley field, (3) the Big Stone Gap field, and (4) the Southwestern Virginia field.

COAL MEASURES

Throughout most of the region the coal-bearing formations are exposed on the surface and the surface features have been carved out of them. The rocks as a rule dip gently to the northwest, about 50 to 75 feet per mile, so that, from east to west, successively higher coal beds come in at the top of hills with the lower beds disappearing beneath the surface. This results in the exposure of a large number of coal beds over small areas. As a result of folding and faulting along the southeastern boundary of the coal-bearing region steeper dips prevail in that part of the region.

The coal-bearing formations of southwestern Virginia belong to the lowest part of the Pennsylvanian system. They consist essentially of beds of sandstone, shale, coal and thin clays. The series has been divided into five formations, which in ascending order are the Lee, Norton, Gladeville, Wise and Harlan. They have a thickness of about 4,500 to 5,800 or more feet.

COAL SEAMS

Lee formation.—The best known coal beds of the Lee formation are the Pocahontas (particularly Nos. 3 and 5), the War Creek, the Horsepen (Middle and Upper), and the Seaboard. The famous Pocahontas No. 3 is the main bed from which production is obtained in the Pocahontas or Flat Top field in Tazewell County. Coal beds of the Lee formation crop out mainly in Tazewell and the eastern parts of Buchanan and Russell counties.

Norton formation.—The Norton contains at least 7 workable coal beds in Russell and Buchanan counties, 4 or 5 in Tazewell County, and 10 or more in Dickenson County, in each of which counties it is mined. Among the more important or better known coals are the Jawbone, the Raven (Red Ash), the Kennedy (Widow Kennedy), the Lower Banner, the Upper Banner, the Splash Dam and the Norton.

Gladeville sandstone.—The Gladeville sandstone, which lies between the Norton and Wise formations, is a coarse-grained, thick-bedded, cross-bedded, generally white sandstone. It does not contain any workable beds of coal but is an important horizon marker throughout the

southwestern Virginia region, and has a thickness of from 75 to 150 feet.

Wise formation.—The Wise formation, which lies above the Gladeville sandstone, contains at least 20 beds of workable coal in Lee and Wise counties. Coals are mined in Dickenson, Lee, and Wise counties. Among the best beds are the Dorchester ("Glamorgan"), Blair, Imboden (Edwards), Taggart, Taggart Marker, Low Splint, Pardee and High Splint.

Harlan sandstone.—The top member of the coal-bearing formations is the Harlan sandstone. It is mainly a sandstone but contains throughout the greater part of its thickness alternating beds of sandstone and clay. It is reported to carry coal at two horizons and to have a maximum thickness of 825 feet.

MINING CONDITIONS

In general favorable mining conditions prevail throughout most of the southwestern plateau region. As the coal beds are generally only gently inclined and most of them lie above the levels of the main streams most of the mines are drift mines, although a few slope mines occur locally. The prevailing gentle dip of the coal beds is favorable to electric haulage. Gas is not very troublesome. Abundant supplies of mine timbers are readily available and water for power plants and camps can be obtained with little trouble during most of the year.

The larger mining companies keep abreast of the time in mining operations and in mining equipment. The mines are in large part electrically equipped. Cutting machines of the latest type are used to mine the coal and electric motors are used to haul it to the tipples. Most of the tipples are of modern construction and are equipped with shaker screens to make three sizes of coal—lump, egg, and slack.

CONSTRUCTION MATERIALS[13]

GENERAL STATEMENT

Abundant reserves of stone suitable for building and construction work, as well as for decorative purposes, occur throughout the Piedmont, Blue Ridge, and Appalachian Valley provinces of Virginia. Among these are granite, greenstone and gneiss, sandstone and quartzite, limestone and marble, slate and soapstone, micaceous schist, and diabase. Occurrences of sand, gravel, and calcareous marl adapted to cement manufacture, and clay for brick-making are readily accessible in the Coastal Plain province. In addition most of the counties in the Great Valley and southwestern Virginia regions contain reserves of clay, shale and limestone of probable potential value for making light-weight concrete aggregate. (See Pls. 3, 9, and 14.)

In addition to the production of "dimension stone" for general building or structural purposes, considerable quantities of "sized or finished" stone are used for monumental, ornamental and accessory work and in the construction of sidewalks. Increasingly large quantities of crushed and broken stone are used annually in the manufacture of concrete and cement, for road metal, railway ballast and for various other construction uses not always thought of in the general consideration of building work. Of the total of 2,399,640 short tons of stone (including granite, basalt, marble, limestone, sandstone, soapstone and miscellaneous stone) valued at $2,704,009 sold or produced in Virginia in 1932, 2,082,710 short tons with a value of $1,849,944 was used for concrete, road metal and railway ballast.

GRANITE

DISTRIBUTION AND CHARACTER

Granite is a coarse-grained igneous rock composed essentially of quartz, feldspar, and mica. In Virginia granites of variable texture, mineral composition and color occur throughout the Piedmont province and in the eastern part of the Blue Ridge province. The schistose or banded types, more properly designated granite-gneiss, were derived in part from the massive types by metamorphism.

The main developed areas, from which the greater part of the State's production has been obtained, are in a general north-south direction along the eastern boundary of the Piedmont region. Here quarries were opened many years ago in areas where little overburden covered the granite and thus little stripping was necessary.

[13] See "Selected References" at end of this report; also sections on "Limestone, Dolomite, and Calcareous Marl" and "Nonmetallic Resources."

As the stone from the early quarries has proved satisfactory for building, monumental and other purposes, there has been as yet but minor production of stone from other known areas. Many of the undeveloped areas are favorably located with regard to railroad and other transportation facilities and it is to be hoped that improved economic conditions and a more detailed investigation of some of these undeveloped areas will lead to their development and the creation of a market for stone from them.

PRINCIPAL AREAS AND USES OF STONE

The principal developed areas from which stone of established merit for monumental and building purposes has been produced are the Petersburg, the Richmond, and the Fredericksburg areas. Granite from quarries in these areas has been widely used outside the State. Monumental stone from a quarry in the Petersburg area has been shipped as far west as Denver, Colorado, and according to Watson,[14] granite from the Richmond area was used in the construction of the State, War, and Navy Building in Washington. Other stone from the same area has been shipped to various places in Pennsylvania and Maryland for building and monumental use. The Cook quarry, about 2 miles west of Petersburg was operated as early as 1837, although extensive quarrying was not begun until 1887. The Netherwood quarry, about 2 miles southwest of Richmond, said to have been worked in 1845, is one of the largest and oldest in the Richmond area. The Hawkins quarry, between James River and the Southern Railway is also reported to be one of the first opened in the Richmond area. In the Fredericksburg area, the Hazel Run quarry, on Hazel Run about 1 mile west of Fredericksburg, was operated in 1879, for stone used in the Presbyterian Memorial Chapel in Fredericksburg.

Granite from the Petersburg area, which includes the northeast corner of Dinwiddie County and the adjoining part of Chesterfield County, is reported to be of excellent quality. It is used for monumental, general building and various forms of street work.

More than 25 quarries have been opened and worked in the Richmond area, which includes the parts of Chesterfield and Henrico counties in the immediate vicinity of Richmond. Most of the quarries are located in the granite bluffs along James River. Some have been worked to a depth of 200 feet, and one, the Western quarry, is reported to have employed, when active, between 500 and 800 men. According to Watson[15] two types of granite occur in the Richmond area: A fine-

[14] Watson, T. L., Mineral Resources of Virginia, p. 23, Virginia-Jamestown Exposition Commission, Lynchburg, Va., J. P. Bell Co., 1907.
[15] Watson, T. L., Granites of the southeast Atlantic States: U. S. Geol. Survey Bull. 426, p. 93, 1910.

CONSTRUCTION MATERIALS IN VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

BULLETIN 47, PLATE-3

PREPARED BY VIRGINIA GEOLOGICAL SURVEY
REPRINTED FROM REPORT ON NATURAL RESOURCES
OF VIRGINIA STATE PLANNING BOARD

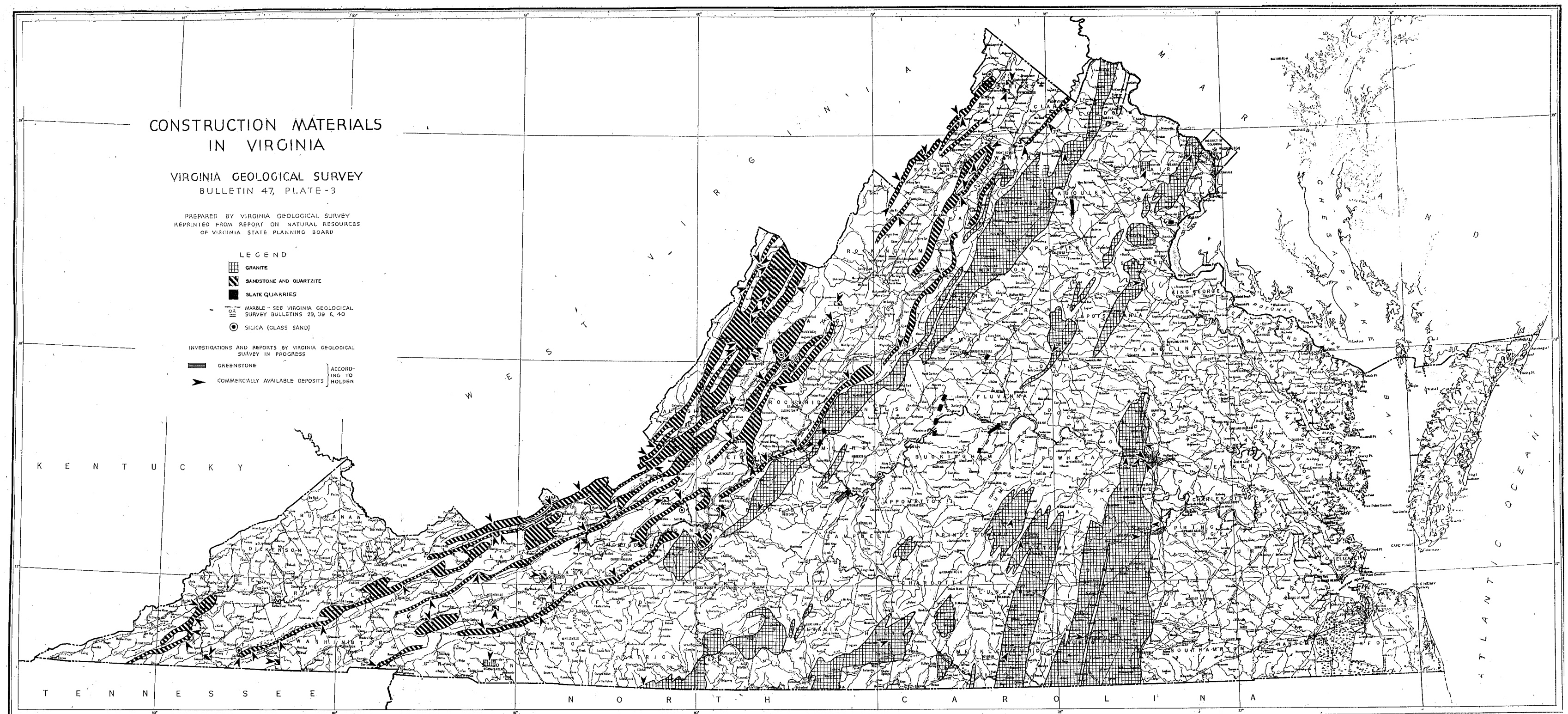
LEGEND

- GRANITE
- SANDSTONE AND QUARTZITE
- SLATE QUARRIES
- MARBLE – SEE VIRGINIA GEOLOGICAL SURVEY BULLETINS 29, 39 & 40
- SILICA (GLASS SAND)

INVESTIGATIONS AND REPORTS BY VIRGINIA GEOLOGICAL SURVEY IN PROGRESS

- GREENSTONE
- COMMERCIALLY AVAILABLE DEPOSITS

ACCORDING TO HOLDEN



grained dark blue-gray (Richmond-Fredericksburg) stone used extensively for monumental work, and a medium-grained, light-gray (Petersburg-Richmond) granite widely used for general building purposes.

In the Fredericksburg area, embracing an area west and north of that town in northern Spotsylvania and south-central Stafford counties, granite has been quarried on Hazel Run and along Rappahannock River, some 3 miles northwest of Fredericksburg. Two types of granite are reported in this area: A medium-grained, light-gray muscovite granite used only locally for building purposes, and a fine-grained, dark blue-gray stone, identical with the Richmond granite, used for monumental work.

OTHER PIEDMONT AREAS

Fairfax County.—A belt of granite of variable composition and texture extends from Potomac River southwesterly across Fairfax County, through McLean, Falls Church and Springfield, into Prince William County, near Occoquan. Stone from this belt has been quarried for local use at Falls Church, near Annandale, and on Occoquan Creek, near the village of Occoquan.

Prince Edward County.—An undeveloped but apparently promising area of massive gray granite of fine-grained texture occurs in the eastern part of Prince Edward, the northwestern corner of Nottoway, and the southeastern part of Cumberland, and the southwestern part of Amelia counties. A quarry has been opened near Rice in Prince Edward County and another near Jennings, in Nottoway County, for crushed stone for railroad ballast, bridge construction, and local use.

Nottoway, Lunenburg, and Mecklenburg counties.—An undeveloped zone of granite extends from southern Amelia County southwestward across Nottoway, Lunenburg, and Mecklenburg counties into North Carolina. Crushed stone, mainly for railroad ballast, has been obtained from quarries opened near Kenbridge in Lunenburg County, and near Burkeville, in Nottoway County. (See Pl. 4, A.)

Charlotte County.—A small area of granite of a pronounced red color occurs in southeastern Charlotte County, near the Southern Railway. A small quarry was opened in this granite on the State Farm near Saxe and the stone used for local bridge work.

Other undeveloped areas.—The Petersburg (Richmond-Petersburg) granite extends in a general southerly direction from the vicinity of Taylorsville in Hanover County, across Henrico County, through Chesterfield, Dinwiddie, western Greensville and most of Brunswick counties, into North Carolina. Other undeveloped areas occur in Halifax, Pittsylvania, Henry, and Patrick counties.

Other areas are known in a belt extending from western Albemarle, northeastward across Madison, Rappahannock, Fauquier, and Loudoun counties, and in the northwestern Piedmont region, just east of the Blue Ridge, from Warren County northeastward to Potomac River.

BLUE RIDGE REGION

Granites of variable texture and mineral composition occur in the Blue Ridge region, in belts of considerable length and of variable but generally narrow width, from Franklin and Bedford counties northeastward to Front Royal. In general they are light gray to pink in color.

One belt extends from the vicinity of Calloway in western Franklin County and Copper Hill in northeastern Floyd County northeastward to the vicinity of Fletcher in Greene County. This belt ranges in width from one to several miles and has a length of about 130 miles. Granite occurs also in Grayson County in the southwestern Blue Ridge Plateau region.

Production of granite has been reported from near Thaxton in Bedford County and from Skippers, near Roanoke. Although no quarries have been opened in the granite in the northeastern Blue Ridge region, it is stated that granite boulders have been used locally for construction purposes.

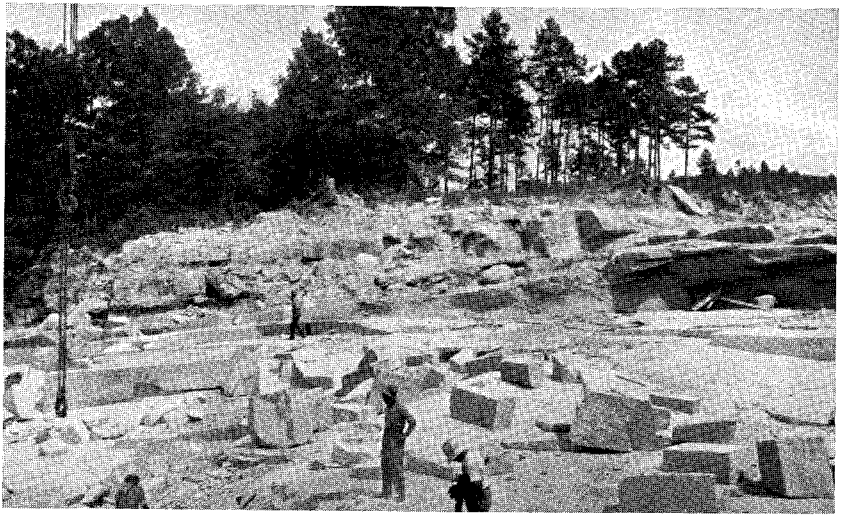
In addition to granite, more or less extensive, occurrences of granite-gneiss are known throughout the Blue Ridge region. Where the banding is not too conspicuous and the texture uniform, such stone may be adapted to construction uses, similar to that of granite.

UNAKITE

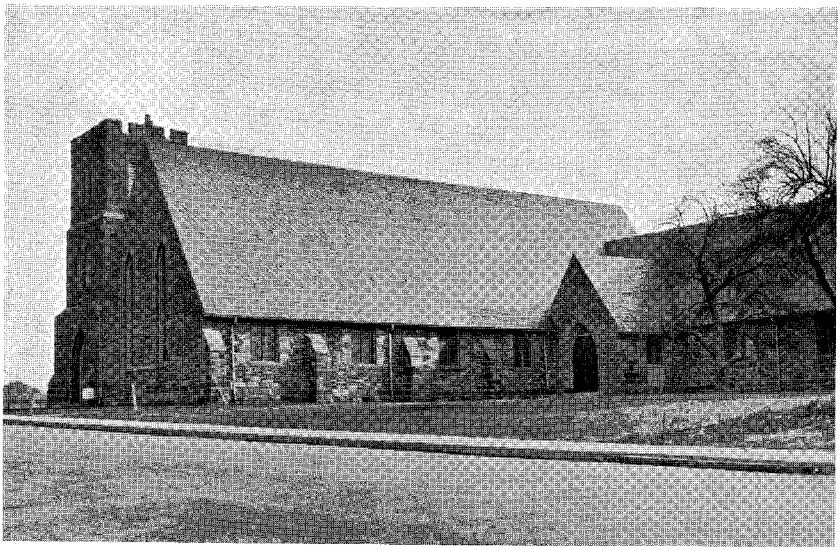
A particularly colorful and unique variety of granite, named unakite because of its discovery in the Unaka Mountains in North Carolina, has been found at several localities in the Blue Ridge region of Virginia. Good exposures are found near Browntown, at Milam Gap, and along the Skyline Drive in Warren, Madison, and Page counties, in the Irish Creek district in Rockbridge County, and about 3 miles south of Troutdale in Grayson County. Unakite is composed of pink feldspar, yellowish-green epidote, and quartz. Because of its distinctive and appealing color, particularly when polished, it may prove of value for ornamental stone.

GREENSTONE

Greenstone is a fine-grained, greenish or bluish-green, altered crystalline rock derived mainly from basic lava flows. Its name is derived

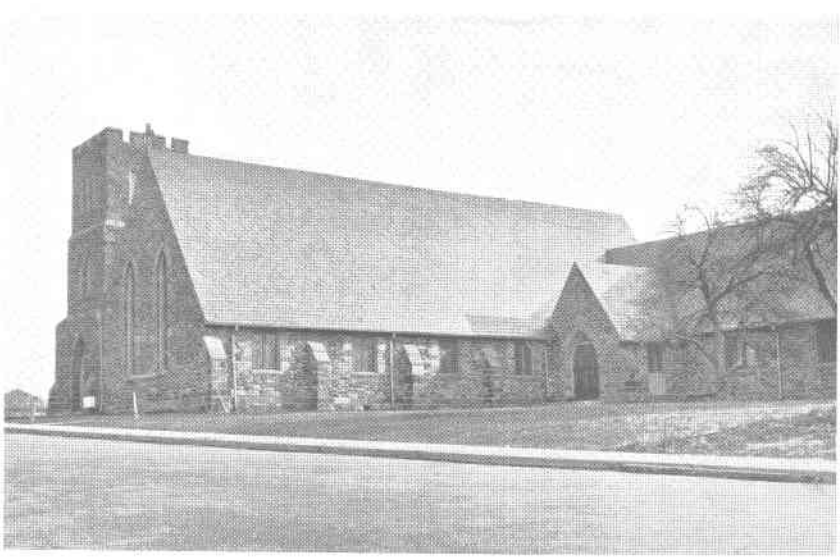


A. Granite quarry near Burkeville, Nottoway County, Virginia; owned by Pyramid Granite Company. Photograph by Edward Steidtmann.

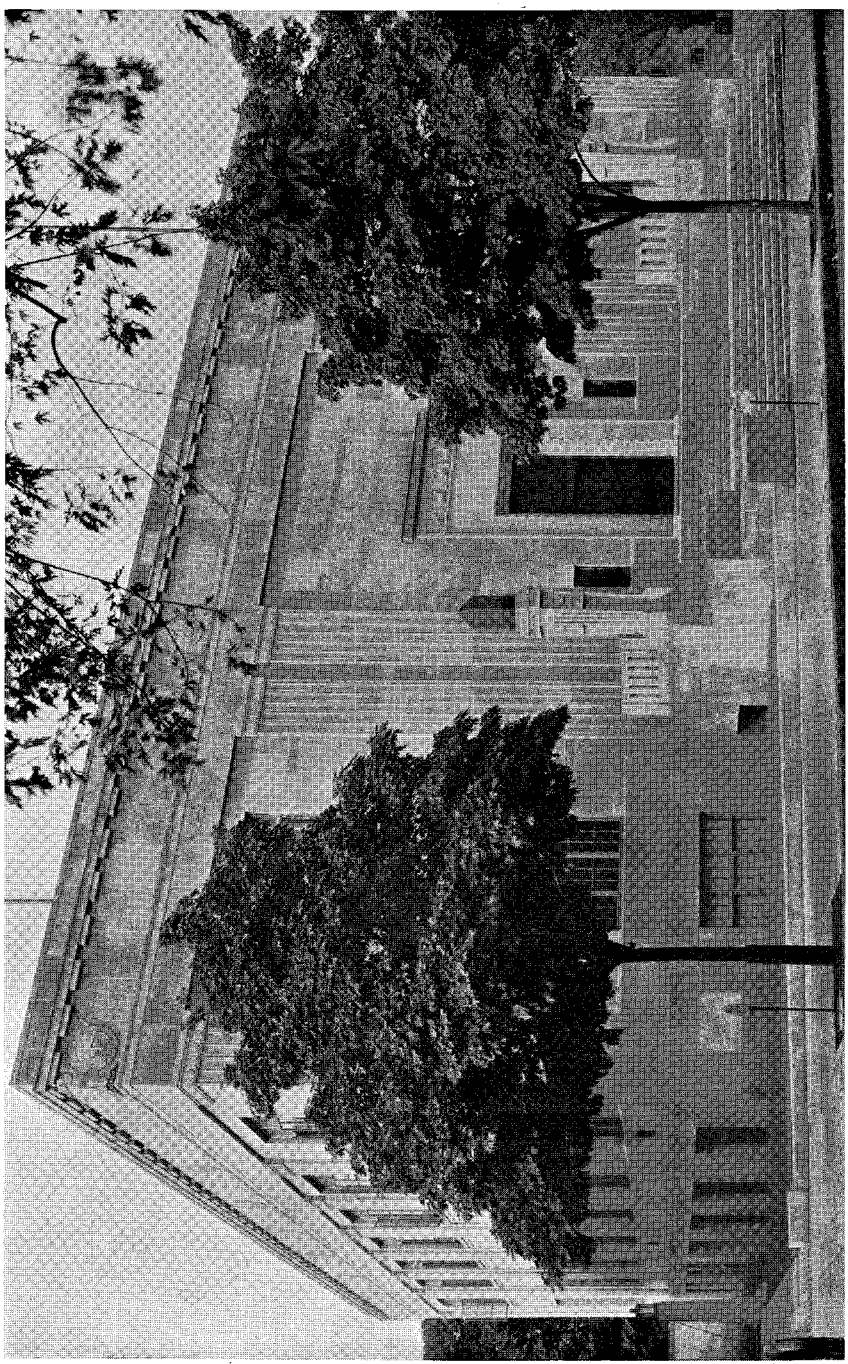


B. Grace Episcopal Memorial Church in Lynchburg, built of Virginia greenstone. Photograph by Edward Steidtmann.

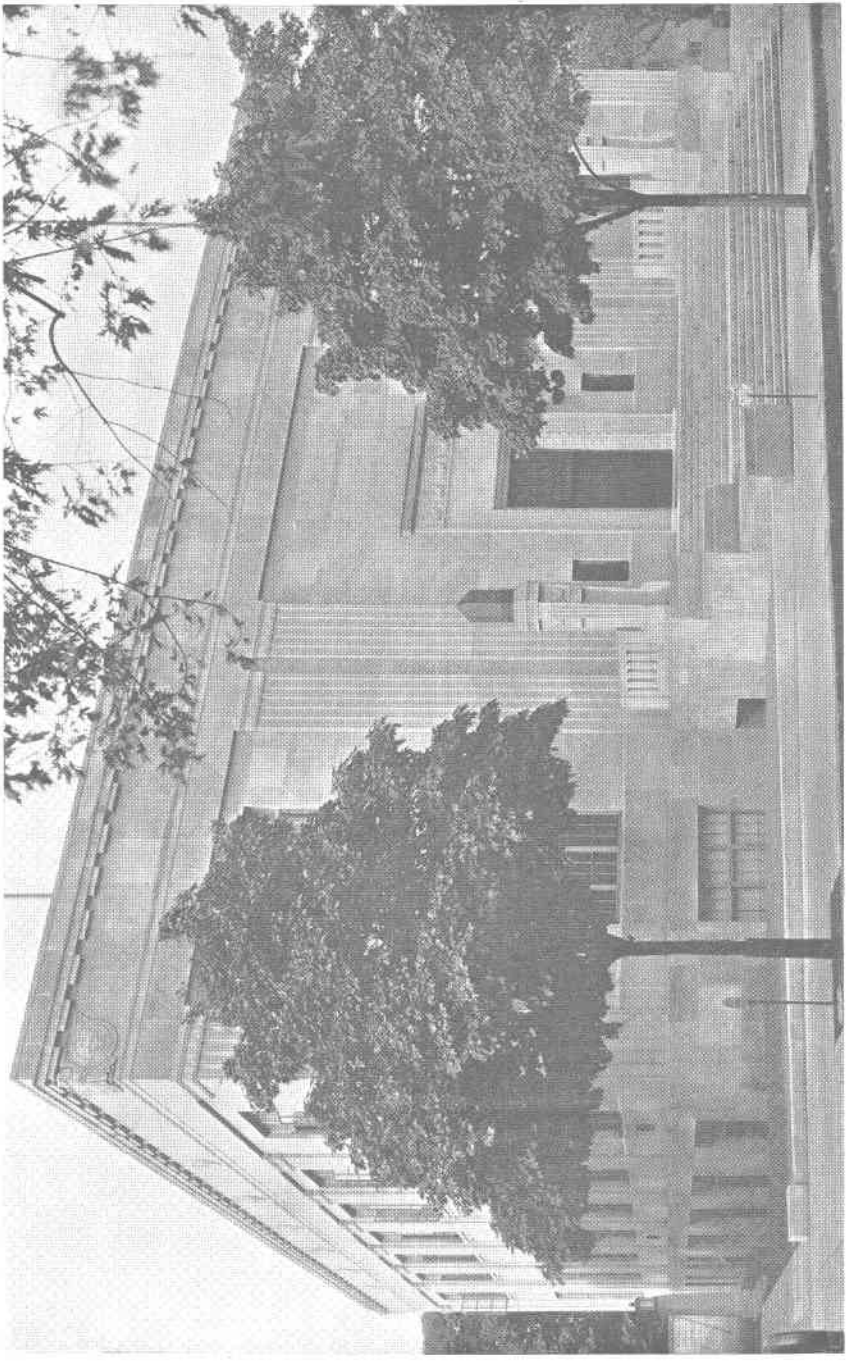
A. Granite quarry near Burkeville, Nottoway County, Virginia; owned by Pyramid Granite Company. Photograph by Edward Steidtmann.



B. Grace Episcopal Memorial Church in Lynchburg, built of Virginia greenstone. Photograph by Edward Steidtmann.



The Dooley Memorial Public Library in Richmond, built of Cretaceous (Aquia) sandstone.



The Dooley Memorial Public Library in Richmond, built of Cretaceous (Aquia) sandstone.

from its color which is due to epidote and chlorite, green minerals. Greenstone and greenstone-schist of pre-Cambrian age occur in the Virgilina and James River districts, in the Catoctin Mountain area and locally elsewhere in the Piedmont region.[16]

More or less extensive narrow belts of massive greenstone form the highest summits of the Blue Ridge throughout its extent across Virginia, from the vicinity of Vesuvius to Front Royal.[17]

Because of its resistance to erosion and the good polish it takes, massive greenstone makes a very fine building stone. The largest producer of greenstone is the Virginia Greenstone Company at Lynchburg. (See Pl. 4, B.)

OTHER CRYSTALLINE ROCKS

Gneiss is a banded metamorphosed rock, some of which is derived from granite and some from other rocks. It is of wide distribution throughout the Piedmont region and along the east slope of the Blue Ridge. Some varieties are adapted to the same uses as granite. Quarries have been opened and stone produced for general construction and other uses along James River near Lynchburg, in the vicinity of Columbia, and locally in Fairfax, Bedford, Pittsylvania, and other Piedmont counties.

Micaceous schist of variable composition is another type of crystalline rock that is of widespread occurrence throughout the Piedmont region. It has been quarried for local use at a number of places.

Diabase is a dense, fine- to coarse-grained crystalline igneous rock generally of a dark gray to green color. It occurs at several localities in the northeastern Piedmont region and along the northeastern portion of the Blue Ridge. Quarries have been opened locally in Culpeper, Fauquier, and Loudoun counties and the stone used for paving, rough construction work and road metal.

MARBLE

PIEDMONT PROVINCE

James River district.—In the south-central, or James River belt of the Piedmont region, occur local deposits of limestone and marble which recent studies indicate may be of commercial importance.[18] In years

[16] Keith, Arthur, Geology of the Catoctin belt: United States Geol. Survey 14th Ann. Rept., pt. 2, pp. 287-395, 1894.
Laney, F. B., The geology and ore deposits of the Virgilina district of Virginia and North Carolina: Virginia Geol. Survey Bull. 14, pp. 27-34, 1917.
Jonas, A. I., Geology of the kyanite belt of Virginia: Virginia Geol. Survey Bull. 38, pp. 6, 24, 28, 29, 1932.
Furcron, A. S., James River iron and marble belt, Virginia: Virginia Geol. Survey Bull. 39, pp. 47-50, 80, 1935.

[17] Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, pp. 12-13, 1919.

[18] Furcron, A. S., James River iron and marble belt, Virginia: Virginia Geol. Survey Bull. 39, 124 pp., 1935.

past quarries were operated at several places and the stone burned for agricultural lime and used for construction work. Bodies of stone of sufficient thickness and extent to warrant the development of large quarries are reported to occur in situations favorable to railroad and highway transportation.

Loudoun County.—A local deposit of green, white, and pink marble near Goose Creek was operated many years ago. In the vicinity of Leesburg, occurs a Triassic limestone conglomerate, termed "Potomac marble," which is reported to have yielded interesting specimens of ornamental stone and from which road material and agricultural lime have been obtained.[19]

APPALACHIAN VALLEY

Because of their crystalline texture, striking appearance when polished or ability to take a good polish, some limestones are used as marble. The Athens limestone has been worked for black marble near Harrisonburg and a pink fossiliferous marble bed occurs in the Ottosee limestone in Rich Valley in Smyth County. The Helderberg limestone in Panther Gap and along Marble Valley near Goshen in Rockbridge County offers several interesting varieties of marble, if blocks of sufficiently large size can be obtained. The Holston limestone in Russell, Scott, and Tazewell counties and in exposures near Lexington in Rockbridge County has the crystalline character of marble. This formation is the same as that which yields the well-known Tennessee marble. Recently discovered marble deposits in Giles County of probable future importance have been described by Mathews.[20] (See Pl. 6, A.)

SANDSTONE AND QUARTZITE

OCCURRENCE AND CHARACTER

Sandstones are bedded rocks composed of grains of sand cemented together by silica, iron oxide or lime. Quartzites are recrystallized and recemented sandstones. Both occur in the Piedmont region, along the western slope of the Blue Ridge, and through the Valley and Ridge province in Virginia. Because of some variation in mineral content, size of sand grains and character of cementing material, as well as varying degrees of metamorphism, both sandstones and quartzites of a wide range of color and physical properties are found in the State.

[19] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, pp. 10-13, 125, 130, 1928.

[20] Mathews, A. A. L., Marble prospects in Giles County, Virginia: Virginia Geol. Survey Bull. 40, 52 pp., 1934.

PIEDMONT REGION

Cretaceous sandstone.—Exposures of light-gray, white, or buff sandstone, of a character known or thought to be adapted to building stone, occur at several places along the eastern boundary of the Piedmont province. The sandstone is of varying degrees of coarseness in different localities, and generally occurs in nearly horizontal beds. It is generally sufficiently indurated and compact and occurs in beds thick enough to permit of quarrying large size blocks. In some places it has a fine-grained texture and it is mainly from such localities that building stone has been obtained.

The most extensive and best known quarries are in the vicinity of Fredericksburg and on Aquia Creek in Stafford County. It is from these localities that the major production of Cretaceous building stone has been obtained. According to Watson,[21] "The Aquia Creek quarries were purchased by the United States Government in 1791 for the purpose of using the stone in the construction of the public buildings in Washington. The material from these quarries was used in the construction of all of the important public buildings that were commenced in Washington prior to 1837. The list includes the Executive Mansion or White House, begun in 1792, the central or old part of the Capitol building, the old portion of the Treasury building, the old portion of the Patent Office building, and the foundation of the City Hall." The Dooley Memorial Library in Richmond, completed in 1930, was constructed from this sandstone. (See Pl. 5.)

Triassic sandstone.—Exposures of Triassic sandstones occurring in seven separate localities in the Piedmont region, have been described in detail by Roberts.[22]

The sandstone varies considerably in thickness and texture and to a less extent in color throughout the Virginia areas. It is reported, however, that at many localities the sandstone is of a uniform color and texture and of sufficient thickness to permit of quarrying a good grade of building stone. The stone is generally brown or brownish-red and is similar to that used so extensively for building stone in the northern and eastern states under the name of "brownstone." Quarries were worked in the vicinity of Manassas in Prince William County as early as 1867 and it is reported that by 1880 a total of 400,000 cubic feet of stone had been produced there. Red and brown sandstones have been quarried also near Leesburg and Oatlands in Loudoun County. Midway Mills in Nelson County was constructed of brownstone obtained from a small exposure near the site of the mill.

[21] Watson, T. L., Mineral Resources of Virginia, p. 54, Virginia-Jamestown Exposition Commission, Lynchburg, Va., J. P. Bell Co., 1907.

[22] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, pp. 117-120, 1928.

Quartzite.—Many exposures of quartzite of varied character occur throughout the Piedmont region, mainly along James River in Fluvanna, Buckingham, Albemarle, Amherst, Appomattox, Campbell, and Nelson counties. Other occurrences are reported in Orange, Prince William, and Fauquier counties. At several places the rock is more of a gneissic sandstone or a micaceous quartz-schist than it is a true quartzite. It is reported that stone from such exposures was used locally for building purposes and flagstones in the early days. More recently the production of quartzite has been mainly as crushed stone for concrete and locally for road metal.

Quartzite from an exposure at the east end of Fall Hill Mountain on the east side of Rockfish River in Albemarle County was used in the construction of the old James River Canal.

BLUE RIDGE REGION

Cambrian quartzite.—Along the northwest side of the Blue Ridge, practically throughout its extent across Virginia, occur one or more foothill ridges which generally parallel the mountain front. Most of these ridges are composed of the Erwin (also termed Antietam) sandstone and quartzite of early Cambrian age. In places in the northern part of the region, ledges or cliffs of hard, white quartzite or compact thick-bedded white to gray sandstone beds, commonly 40 to 100 feet thick, are exposed high up on the ridges.

Several spur ridges projecting into the Valley or ridges which locally are found some distance out in the Valley, contain Erwin quartzite. Three prominent examples are the series of narrow northeastward trending ridges which comprise the Brush Mountain group, between Marion and Sugar Grove in Smyth County, Iron Mountain in the Unaka National Forest, and a series of ridges forming the Lick Mountain group southeast of Wytheville in Wythe County.

It is thought that favorably located exposures of some of the sandstone and quartzite beds will be found satisfactory for use as building stone. In some exposures the beds are cut by closely spaced joints which probably would not permit of quarrying dimension stone, but in other places the joints are more widely spaced and thus would probably permit the obtaining of large size blocks. In some localities relatively massive beds of dense white quartzite as much as 15 to 20 feet thick without visible traces of bedding are reported. If the stone in such areas is not too hard, or two difficult and costly to quarry, it may be adapted to the production of large size blocks or dimension stone. Boulders of hard sandstone from the Erwin quartzite formation obtained along stream courses on the west slope of the Blue Ridge, are reported to have been used locally in rough, undressed condition as

foundation or building stones. Crushed stone from the same formation has been obtained from quarries along the Chesapeake and Ohio Railway at Pekin Siding and near Waynesboro in Augusta County, for ballast and concrete aggregate.

VALLEY AND RIDGE REGION*

Silurian sandstone.—Practically all of the ridges in the northwest part of the Appalachian Valley in Virginia are capped by sandstones and quartzites of the Clinch (also termed Tuscarora) and Clinton formations of Silurian age. In the central and northwestern parts of the Valley Ridges section, these two formations have a thickness of 300 to 500 feet of sandstone and quartzite. Because of the persistence and extensive occurrence of the Clinch and Clinton formations throughout the region and the predominance of sandstones in both, some exposures should offer building stone possibilities.

The Clinch-Tuscarora formation is decidedly a ridge-making formation and is exposed along the crests of most of the Valley ridges, from Clinch Mountain in Scott County northeastward to Great North Mountain in Shenandoah and Frederick counties.

The Clinton formation contains two prominent sandstone members; the lower "Cacapon sandstone," a distinctive dark red rock and the upper Keefer sandstone, a coarse-grained, thick-bedded gray sandstone, separated generally by green shale, thin green sandstone, and in places red shale. The Clinton is found in belts parallel to the Clinch-Tuscarora formation and forms benches along the northwest Valley ridges.

Silurian sandstone has been used for churches, private homes, foundations, retaining walls, and for ornamental uses, in Roanoke, Salem, and other Valley towns. Clinton sandstone from Catawba Mountain near Salem has been used also for glass sand.

Devonian sandstone.—In the lower part of the Devonian system occur sandstones which, since the Devonian rocks overlie the Silurian, are exposed in areas and belts generally parallel to and not far distant from the Clinch-Tuscarora and Clinton formations. The most conspicuous sandstone is the Oriskany, which immediately overlies the Helderberg formation, the bottom or lowest member of the Devonian. The Oriskany forms ridges or benches along the more prominent Valley Ridges, along which it is exposed in narrow belts from near Eagle Rock in Botetourt County, northeastward through Frederick County into West Virginia. The thickness of the Oriskany ranges from a few feet to 150 feet or more, generally being greatest from Highland County northeastward.

Near Gore in northwestern Frederick County and near Goshen in Rockbridge County, the Oriskany sandstone has been mined for glass

sand. At Gore the sandstone is generally light gray but in places is stained brown by iron. It is composed almost wholly of quartz sand (silica) in fine to medium, angular to subangular grains, which are in general rather firmly cemented. The thickness of the sandstone here is less than 100 feet.

Mississippian sandstone.—Of the several sandstone members of the Mississippian series in Virginia the Price (or Pocono) formation at or near the base of the series, is the most prominent and best developed. This formation is a ridge-maker and forms most of the ridges that bound the Valley coal fields on the northwest. In the southwestern portion of the region, where it is best developed, the Price formation forms conspicuous cliffs or ledges and the slopes of such ridges as Pine, Little Walker, Price, and Brush mountains. It is composed of sandstone and shale, both of which vary considerably in color and character from place to place.

According to Holden,[23] despite the fact that the Price-Pocono formation contains in places enough iron to produce a brown-gray color on weathering, the stone has been more extensively used than any other sandstone occurring west of the Blue Ridge. It is reported to have been quarried in two places in Pulaski County, one on New River and another near the town of Pulaski, and to have been used in the construction of public buildings in Pulaski and Roanoke. It has been used also for retaining walls and fences. Stone from quarries in the conglomerate or conglomeratic sandstone member near the base of the Price formation, on Brush Mountain, a few miles west of Blacksburg, has been used for a number of years for grindstones and millstones which are well known under the trade name of "Brush Mountain stone."

Pennsylvanian sandstone.—Of the five Pennsylvanian sandstone and shale formations exposed in southwestern Virginia, stone from the Gladeville formation has so far been used locally for building and construction purposes. It is possible, however, that local exposures of some of the other sandstone beds may yield satisfactory building stone.

SILICA

Silica in quantity and of sufficient purity to be used in making glass sand is found locally in the State. Numerous occurrences of vein quartz and bodies of quartzite in the Piedmont region, local exposures of basal Cambrian sandstones and quartzites along the west side of the Blue Ridge, and sandstones of Silurian and Devonian age throughout the Valley and Ridge region offer possibilities worthy of further investigation. Local occurrences of sand in the Coastal Plain

[23] Holden, R. J., Minerals and their exploitation, *in* Virginia: Economic and Civic, pp. 98-99, Whittet and Shepperson, Richmond, 1933.

region, including the area of sand dunes extending from Cape Henry southward, may be adapted to the production of glass sand.[24]

Glass sand has been produced from Cambrian quartzite near Stapleton in Amherst County, from the Clinton (Silurian) sandstone on Catawba Mountain near Salem in Roanoke County and near Kermit in Scott County, and Oriskany (Devonian) sandstone has been mined for glass sand near Gore in Frederick County, and near Goshen in Rockbridge County. Silurian sandstone which may contain silica of glass-sand quality occurs near Goshen.

SLATE

GENERAL STATEMENT

Deposits of slate of commercial importance are known to occur in five different areas and other undeveloped occurrences have been reported locally in the Piedmont region. The areas in which prospecting or development has shown the occurrence of slate adapted to the production of roofing slate, various mill products or other building uses are: The Arvonia area in Buckingham and Fluvanna counties, the Esmont area in Albemarle County, the Warrenton area in Fauquier and Culpeper counties, and the Quantico area in Prince William, Stafford and Spotsylvania counties. They have been described by Watson[25] and Dale.[26]

In his annual reports to the State Legislature during the period from 1835 to 1841, W. B. Rogers, then State Geologist of Virginia, called attention to the slate deposits east of the Blue Ridge in Rockingham, Fluvanna, and Fauquier counties. Of the Buckingham and Fluvanna area, from which slate had then been produced and was in use, he stated: "This [roofing slate] makes its appearance on both sides of the James River . . . . In Buckingham the bed is largely exposed in the neighborhood of New Canton, on Slate River . . . . In texture, density, and capacity of resisting atmospheric agents it can scarcely be excelled by a similar material in any part of the world."[27] In the same reports, Rogers referred to slate from the Warrenton-Fauquier White Sulphur Springs area in Fauquier County which was then used locally for roofing.

[24] Watson, T. L., Glass-sand resources of Virginia: Am. Ceramic Soc. Jour., vol. 2, no. 10, pp. 794-803, 1919.

[25] Watson, T. L., Mineral Resources of Virginia: pp. 41-52, Virginia-Jamestown Exposition Commission, Lynchburg, Va., J. P. Bell Co., 1907.

[26] Dale, T. N., and others, Slate in the United States: U. S. Geol. Survey Bull. 586, [Virginia] pp. 146-164, 1914.

[27] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, p. 79, New York, D. Appleton and Co., 1884.

OCCURRENCE AND CHARACTER

Buckingham and Fluvanna counties.—The most important developed area in Virginia at this time, is the Arvonia belt which extends from near Arvonia in Buckingham County in a northeasterly direction along Hunts Creek, through Arvonia, across James River west of New Canton to a point about 2 miles northwest of Bremo Bluff in Fluvanna County. The belt varies in width from less than a mile in the southern part to 1½ miles on the north side of James River, and has a length of about 18 miles.

In this area the most extensive development has been in the vicinity of Arvonia, particularly at a location about 2 miles northeast of that place, and at Penlan, about 2 miles southwest of Arvonia. There are two distinct belts in the area immediately northeast of Arvonia, which appear to represent two different limbs of a fold along which the slate occurs. Most of the quarries are on the southeast limb of the fold. Some of the quarries are large, being as much as 400 feet by 400 feet and worked to a depth of 350 feet.

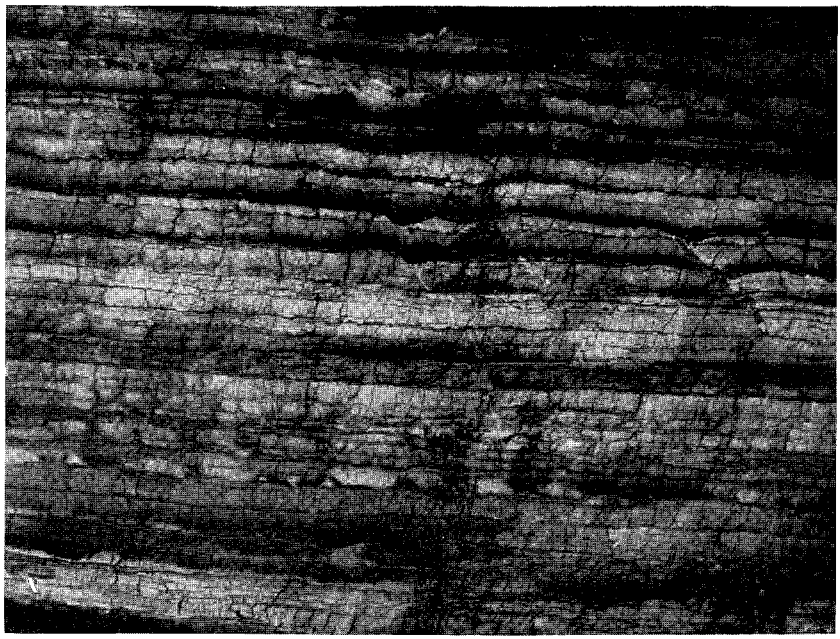
The slate of the Arvonia belt is of outstanding quality and has a ready market for roofing slate. One of its outstanding qualities is its sonorousness. Formerly slate from this district was used for various mill products, such as interior decoration, stair treads, and other building uses but more recently it has been in more or less constant and exclusive demand for roofing. It is reported that roofing slate from this area which has been on houses in the vicinity of the quarries for about a century is still in good condition. (See Pl. 6, B.)

In the Arvonia belt, quarries have been opened also at Ore Bank, a short distance northeast of Arvonia and locally in Fluvanna County near Bremo Bluff.

Albemarle County.—In Albemarle County slate has been prospected in a narrow belt which trends northeasterly along Ballinger Creek in the vicinity of Esmont, along Buck Island Creek and at Keswick. The belt is reported to extend as far southwest as Manteo, near which on James River exposures of slate occur. This belt or district is about 10 to 12 miles west of the Arvonia belt. The slate of the Albemarle County belt is also exposed along the limbs of a fold.

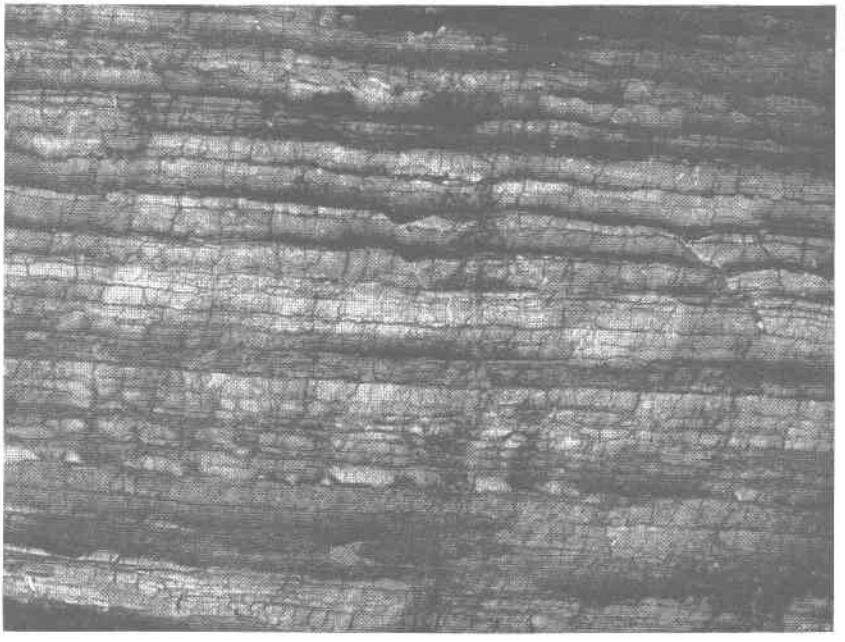
In the Albemarle County district a commercial quarry has been developed at Esmont and recently an old prospect was opened and worked a short time at the northeast base of Carters (Monticello) Mountain. Recent prospecting has been reported near Keswick where it is said some slate has been obtained for local use, mainly for flagstone and road work.

Amherst and Bedford counties.—A belt of slate of undetermined extent occurs in a valley between Rocky Row Mountain on the north-

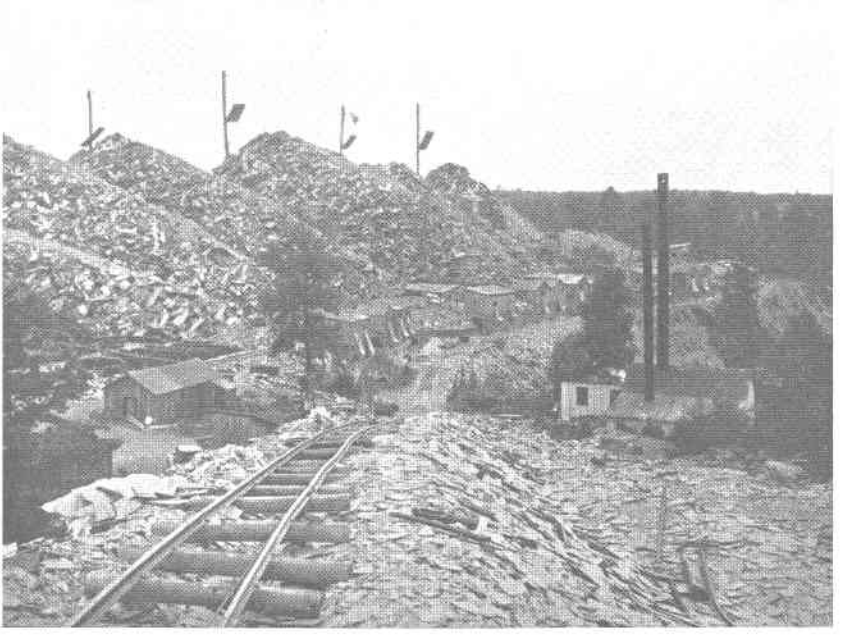


A. Marble beds in Giles County, Virginia. From Geological Survey Bulletin 40, by A. A. L. Mathews.

B. Part of operations of Buckingham-Virginia Slate Corporation near Arvonia in Buckingham County, Virginia. Photograph courtesy of Buckingham-Virginia Slate Corporation.



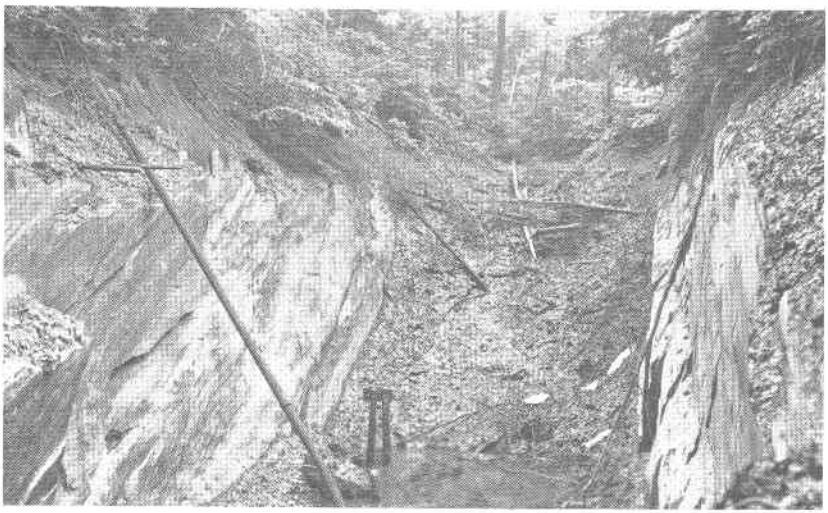
A. Marble beds in Giles County, Virginia. From Geological Survey Bulletin 40, by A. A. L. Mathews.



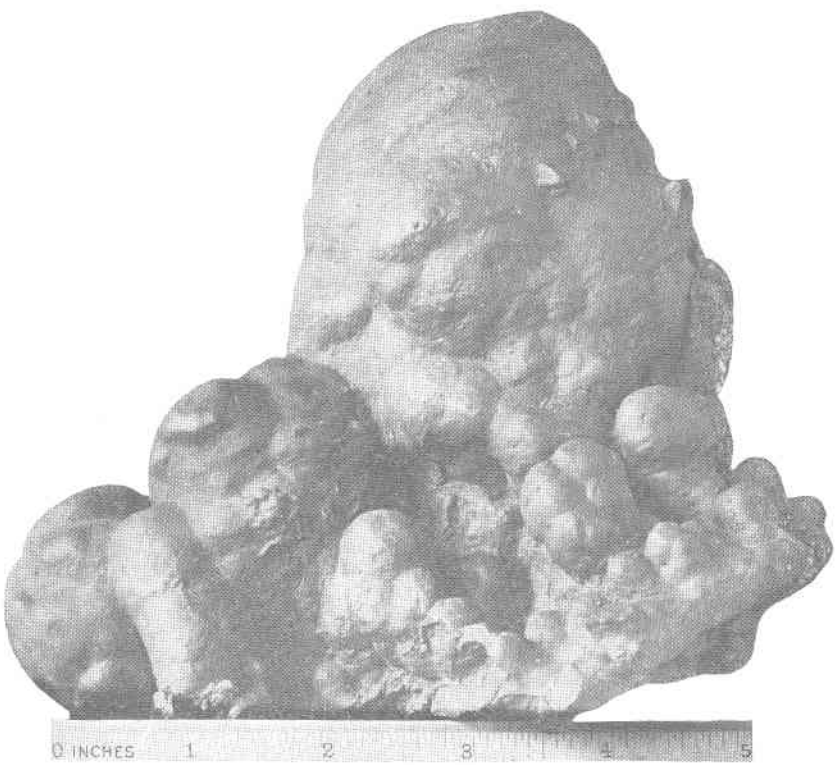
B. Part of operations of Buckingham-Virginia Slate Corporation near Arvonia in Buckingham County, Virginia. Photograph courtesy of Buckingham-Virginia Slate Corporation.

A. Open cut at old Vaucluse gold mine in Orange County, Virginia. Photograph by Charles J. Park, Jr.; from Geological Survey Bulletin 44.

B. Manganese ore from Wythe County, Virginia. From Geological Survey Bulletin 17, by G. W. Stose and others.



A. Open cut at old Vaucluse gold mine in Orange County, Virginia. Photograph by Charles J. Park, Jr.; from Geological Survey Bulletin 44.



B. Manganese ore from Wythe County, Virginia. From Geological Survey Bulletin 17, by G. W. Stose and others.

west and Big Piney Mountain on the southeast, extending from James River along the Bedford County line northeastward through the vicinity of Snowden to the northeast end of Bluff Mountain in Amherst County. A thickness of about 250 feet of slate is reported along a flat-topped anticlinal fold. A quarry was formerly operated about 3 miles northeast of Snowden, from which it is reported that a dark-gray roofing slate of a superior quality but less crystalline than that of the Arvonia district was obtained.

Fauquier and Culpeper counties.—Slate prospects occur in the vicinity of Fauquier White Sulphur Springs, about 6 miles southwest of Warrenton along the Fauquier-Culpeper county line, but mainly in Fauquier County, in a belt which trends from the vicinity of the Springs northeastward towards Warrenton. In the vicinity of Fauquier White Sulphur Springs the slate belt is reported to be half a mile wide. It was in this vicinity that the production of roofing slate in Fauquier County in 1837 was reported by Rogers. Of the slate of this area Holden[28] says, "While its extent is not known, its properties and possibilities as to quantity are such as to warrant further exploration."

Prince William, Stafford, and Spotsylvania counties.—A relatively narrow belt of black slate, termed "Quantico slate" from the name of the creek along which it occurs, forms part of the easternmost belt of rocks of the Piedmont province along the Fall Zone in northern Spotsylvania, Stafford and Prince William counties. It crops out in places as much as a half to three quarters of a mile in width, over a northeast extent of about 10 miles. Exposures occur along Accotink Creek, along Aquia Creek near Garrisonville, and on Austin River in Stafford County; in the vicinity of the old Cabin Branch pyrite mine and northeast of Dumfries in Prince William County. The slate is reported by Watson[29] to be highly graphitic in places.

The slate of this belt has not been quarried to any extent and little is known regarding its qualities and commercial possibilities. It is reported to resemble the roofing slate of the Arvonia district.

[28] Holden, R. J., Minerals and their exploitation, *in* Virginia: Economic and Civic, p. 95, Richmond, Whittet and Shepperson, 1933.

[29] Watson, T. L., Mineral Resources of Virginia, p. 51, Virginia-Jamestown Exposition Commission, Lynchburg, Va., J. P. Bell Co., 1907.

GOLD DEPOSITS[30]

HISTORICAL

Gold mining is not a new industry in Virginia. Some of the earliest known attempts at mining for iron and gold in North America were made in Virginia. The history of the earlier operations, particularly the search for gold, is therefore interesting since recently renewed explorations have been made in the vicinity of several of the old mines which were opened up or operated between 1835 and the outbreak of the War between the States. (See Pls. 7, A, and 8.)

The earliest accredited reference to gold in Virginia was by Thomas Jefferson in his "Notes on the State of Virginia", in 1782, in which he described a lump of ore found on the north side of the Rappahannock River about 4 miles below the falls. The gold "was interspersed in small specks through a lump of ore about four pounds weight, which yielded seventeen pennyweight of gold of extraordinary ductility."

According to Watson,[31] gold in place was first found in 1806 at the site of the famous Whitehall mine in western Spotsylvania County. He states that this property was worked from 1848 until just before the War between the States and again as late as 1884 and that returns from the Philadelphia mint show it yielded $1,800,000 in gold. A pocket encountered at a depth of 28 feet is reported to have yielded $160,000 in gold.[32] The Waller mine in Goochland County was opened in 1831.

According to records of the United States mint, the first actual production of gold in Virginia was obtained in 1829, from placer operations in Goochland County, although there may have been some earlier production that was not recorded. This first deposit of Virginia gold amounted to $2,500. It is possible that some of it came from the Grasty tract in the Wilderness area in Orange County, since the deed books of that county show that a one-half interest in a 20-year lease on a part of this mining tract dated 1829, was sold in 1831 for $30,000 cash.[33]

The first gold mining company incorporated in Virginia was the Virginia Mining Company of New York, which between 1831 and 1834 operated the Grasty tract. This company was incorporated on March 10, 1832. At the Tellurium mine, about 7½ miles north of Columbia, partly in Goochland and partly in Fluvanna counties, gold was discovered in 1832. This mine was worked continuously from the date of its opening until 1857 and again at a later date. It is reported that it

[30] See "Selected References" at end of this report.
[31] Watson, T. L., Mineral Resources of Virginia: Virginia-Jamestown Exposition Commission, p. 555, Lynchburg, Va., J. P. Bell Co., 1907.
[32] Idem.
[33] Watson, T. L., op. cit., p. 549.

yielded approximately $1,000,000 in gold.[34] The Vaucluse mine south of the Rapidan River in northern Orange County was opened in 1832 and was one of the most prominent mines in that county. In 1848 its plant was valued at $70,000 and in 1847 it was reported to have had one of the most elaborate plants for the separation of gold from quartz and pyrite in North America.[35] The Moss vein was discovered in 1835 and mining was begun on the Moss property in Goochland County in that year.[36]

About 2 miles northeast of the Vaucluse, in southeastern Culpeper County between the Rappahannock and the Rapidan rivers is the old Culpeper mine, which was in operation in 1838. About half a mile northeast and south, respectively, of the Culpeper, are the Love and Embry mines, which are believed to be on the same mineralized zone and both of which have histories similar to that of the Culpeper. Other prominent mines operated in Virginia in the early days were those of the Virginia Mining Company in Orange County, the United States Mining Company and the Whitehall properties in Spotsylvania County, the Franklin in Fauquier County, the Eagle in Stafford County, the Moss and Waller mines in Goochland County, the Hughes in Fluvanna County, and the Morrow (or Booker) and the London and Virginia properties in Buckingham County.

Placer gold was discovered on the Collins tract in Goochland County prior to 1830.[37] Dams had been built across the branch and gravel deposits were being worked in 1830. Little if any vein-mining was attempted on this tract. Other near-by placers were the Eades, the Big Byrd, and the Lowry. The Tinder Flat placer in Louisa County was probably the best known and most extensive of the placer operations in the early days. The Rattlesnake mine in Stafford County was also operated as a placer.

Operations were carried on continuously throughout the Virginia districts until about 1850 when the discovery of the rich gold deposits in California caused many of the local operators and miners to trek westward.

There was a resumption of activity locally in the early fifties but with the outbreak of the War between the States practically all mining ceased in Virginia and elsewhere in the South. Operations were again resumed shortly after the close of the war and from about 1875 to about 1900 there was considerable activity in the Virginia districts. In this later period milling and treatment plants were erected at several properties and many "secret processes" were tried out. But little success attended these attempts at further development and although some

[34] Watson, T. L., op. cit., p. 559.
[35] Watson, T. L., op. cit., pp. 555-556.
[36] Taber, Stephen, Geology of the gold belt in the James River basin, Virginia: Virginia Geol. Survey Bull. 7, p. 144, 1913.
[37] Taber, Stephen, op. cit., p. 141.

slight production was reported until 1926, active gold mining in Virginia may be said to have ceased from about 1910 until the renewal of explorations, discussed later, in 1930.

DISTRIBUTION

The principal gold deposits of Virginia occur in the eastern part of the Piedmont region in a belt of crystalline rocks extending from the vicinity of Great Falls on Potomac River southwesterly across the State through Chancellorsville, Mineral and Tabscott into Buckingham County. Another belt southwest of this embraces the Virgilina district of Virginia and North Carolina. The gold belt ranges in width from 15 to 25 miles, and has a length of about 200 miles, embracing an area of some 4,000 square miles. Its best developed portion is in Fauquier, Stafford, Culpeper, Orange, Spotsylvania, Louisa, Fluvanna, Goochland, and Buckingham counties. Gold is found also in Appomattox, Prince Edward, Pittsylvania, Charlotte, Halifax, and Franklin counties in the southwestern portion of the principal belt. There is a smaller belt on the west side of the Blue Ridge in Montgomery, Floyd, and Grayson counties. (See Pl. 8.)

OCCURRENCE AND ORIGIN

Although studied for more than one hundred years, since William B. Rogers was appointed, in 1835, as the first State Geologist of Virginia, the geology of the Virginia Piedmont is not well known. The rocks are all deeply weathered and natural exposures are rare except in the major stream valleys and along the deeper road cuts.

The principal rocks of the gold belt are micaceous gneisses and schists, including both altered sedimentary and igneous masses. The gold-bearing bodies are mainly lenses and veins of quartz which occur generally in a dark greenish gray schist or gneiss. Locally gold occurs in beds of quartzite in the schist. The quartz varies in texture from large crystalline masses to very fine sugary grains. Granite bodies and basic igneous rocks occur in the gold-bearing areas. Some gold occurs locally in the granitic rocks, although the deposits are more commonly in the schist.

At times during the long, varied and complex geologic history of the Piedmont region fractures were developed in the rocks as a result of various earth movements, such as folding, faulting and uplift. Shear zones, as areas or zones of numerous closely spaced fractures are termed, occur in the gold-bearing rocks. Some of them are traceable for considerable distances in the schist. The gold ores are generally found along the shear zones, and where the crushing and breaking have been most extensive the better ores are likely to be found.

GOLD DISTRICTS OF VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

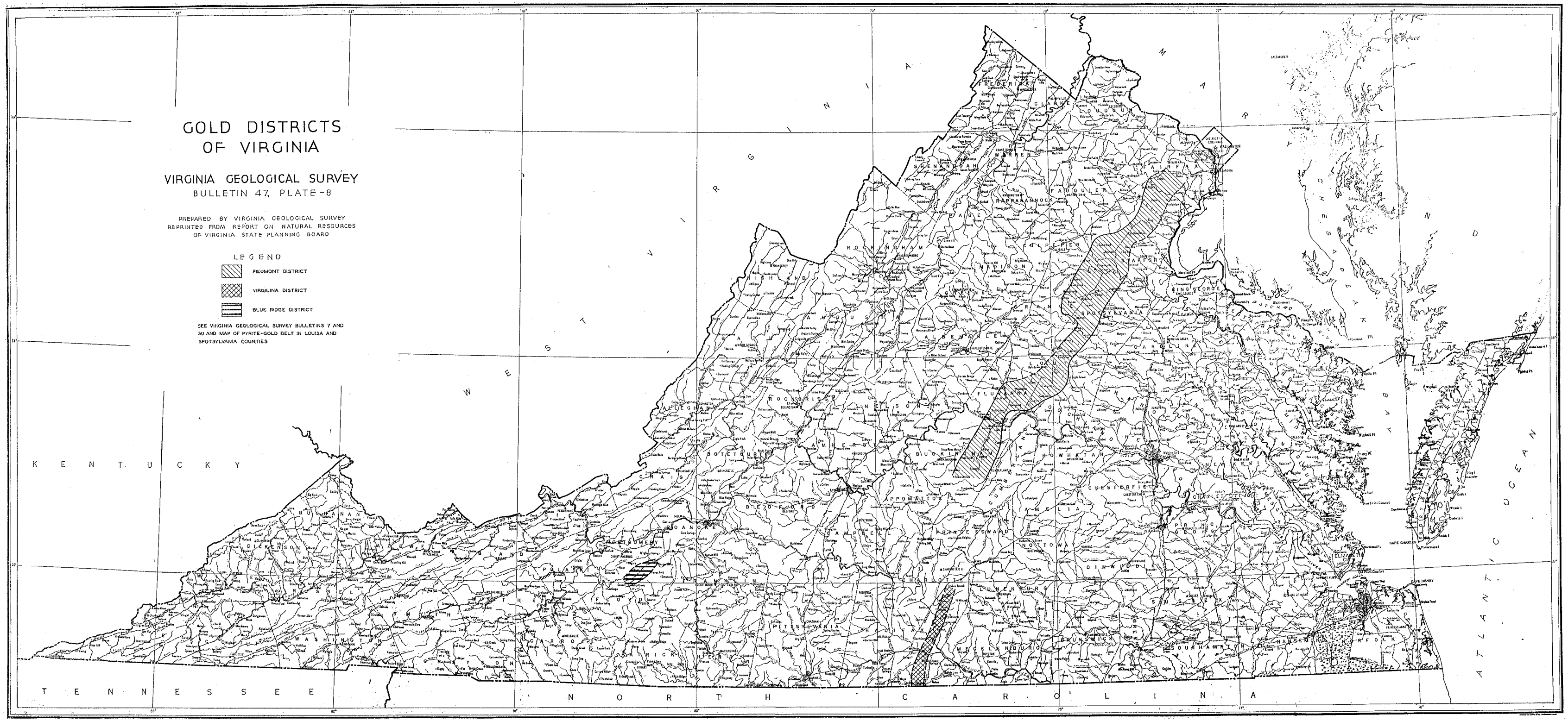
BULLETIN 47, PLATE-8

PREPARED BY VIRGINIA GEOLOGICAL SURVEY
REPRINTED FROM REPORT ON NATURAL RESOURCES
OF VIRGINIA STATE PLANNING BOARD

LEGEND

- PIEDMONT DISTRICT
- VIRGILINA DISTRICT
- BLUE RIDGE DISTRICT

SEE VIRGINIA GEOLOGICAL SURVEY BULLETINS 7 AND 30 AND MAP OF PYRITE-GOLD BELT IN LOUISA AND SPOTSYLVANIA COUNTIES



The results of a recent study of operations during the past four years in the Piedmont region of Virginia,[38] show that the gold ores may be classed into three types, which locally grade into one another. They are deposits formed by replacement or impregnation of the sheared rock by quartz, well-defined persistent quartz veins, and irregularly distributed quartz lenses or pockets, generally in schist.

In addition to the above types, which may be termed lode or vein deposits, accumulations of gold were formed as flakes or masses of free gold dispersed through clay and decomposed surface rock overlying and derived from the underlying bedrock, and relatively coarse particles of free gold of variable size in gravel along streams or old stream courses. The first type is termed saprolite deposits and the second, placer deposits. Both are or were derived from the disintegration and decomposition of quartz and vein-bearing material in the original bedrock. The placer deposits represent similarly derived material that has been further disintegrated by running water and atmospheric agencies and the particles transported down hill or streamward by surface waters. Thus the particles or nuggets of gold were deposited in eddies and shoals in gravel along streams where the transporting force of the water was retarded.

EARLY OPERATIONS

In the early history of gold mining in Virginia, the gravel or placer deposits were first worked, and it is reported that in many places they were very rich. From the gravel deposits the miners or operators worked upstream or uphill in search of the veins from which the placer gold was derived and as they were discovered "vein mining" was begun. At first primitive methods and crude devices were used and it is very probable that these early operations were successful only because of the high percentage of free gold contained, the thickness of the decayed mantle rock overlying the bedrock, and the low cost of mining. Gold in quartz veins was recovered by crushing the ore and using various chemical processes for separating the free-milling native gold. Later, stamp mills of more efficient types were installed at a number of mines.

The more successful operations were the earlier ones on placer deposits or on the free-milling decomposed material above the original bedrock or surrounding eroded vein outcrops. Activities were curtailed and in many instances entire operations abandoned as workings penetrated below the water level and the removal of water from the workings by pumping became too difficult or too costly, the rock became harder and the ores too lean, or the separation of the gold from the

[38] Park, C. F., Jr., Preliminary report on the gold deposits of the Virginia Piedmont: Virginia Geol. Survey Bull. 44, 44 pp., 1936.

sulphide ores encountered below the weathered zone near the surface required a different kind of treatment from any of the processes then in use.

PRODUCTION

From 1829, the first year for which mint returns are available, to 1926, the production of gold in Virginia was valued at $3,298,542.00.[39] Approximately one-half of this was obtained in the period from 1829 to 1879 and about $9,200.00 was produced during the last 20 years.

Of the producers among the Virginia gold mines the following are reported to have yielded the amounts given: Whitehall Mine, Spotsylvania County, $1,800,000.00; Tellurium Mine, Goochland and Fluvanna counties, $1,000,000.00; Marshall Mine, Spotsylvania County (up to 1854), $300,000.00.

Since many of the early mines were owned by English operators it is probable that a part, in instances perhaps a considerable amount, of the gold produced in the early days of mining in Virginia was shipped abroad instead of being sent to the United States mint. It is therefore probable that the reported production data now available will not check with reports of production of individual mines or that such data as can now be obtained do not reveal "all of the story."

RECENT OPERATIONS

Few of the earlier explorations penetrated beneath the level of ground water. Since 1929, however, there has been much interest in gold mining throughout most of the gold-producing countries and considerable prospecting and exploratory work has been done. Partly because of this and partly because of the history of many of the old mines and the belief held by many that "pay ore" was still to be found in portions of the southern Appalachian region, explorations have been renewed on several of the old properties in the Virginia districts. The recent operations have had as their objective the exploration of deeper ground in search of gold-bearing sulphides carrying a sufficient value in gold to warrant extensive deep-mining.[40]

The most extensive of the recent explorations have been those on the Waller and Moss properties, between Tabscott and Columbia, in Goochland County; on the Melville, Vaucluse, and Laird tracts in northern Orange County, near Wilderness Store; on the Franklin tract near Morrisville in Fauquier County; and on the old United States tract in western Spotsylvania County. Prospecting has also been done on the Grasty and adjoining tracts in Orange County, on the old

[39] Lonsdale, J. T., Geology of the gold pyrite belt in northeastern Piedmont Virginia: Virginia Geol. Survey Bull. 30, pp. 8-9, 1927.

[40] McGill, W. M., Gold mining operations in northern Virginia: Min. Cong. Jour., vol. 20, no. 10 pp. 12-16, 23, October, 1934.

Liberty and Randolph mines in Fauquier County and on the Culpeper and Love tracts in Culpeper County. Placer explorations have been in progress on the Collins (Fisher-Knutzen) and the adjoining long-abandoned Young American properties in Goochland County, locally along Byrd Creek in the same county, in parts of Louisa County, and on the Crawford tract a few miles north of Dumfries in Prince William County. (See Pl. 8, A.)

The occurrence of sulphide ores carrying gold has been found in all of the recent lode operations and although detailed sampling has not been done in any of the present operations, enough has been done to indicate that the deeper sulphide ores are with few exceptions of low grade. The margin of profit being small, the success of operations of deposits of this type will depend largely upon capable experienced management.

LIMESTONE, DOLOMITE, AND CALCAREOUS MARL[41]

GENERAL STATEMENT

Extensive thick beds of limestone and dolomite throughout the Appalachian Valley in Virginia constitute probably the most important mineral resources of the State and offer practically inexhaustible reserves of building stone, road and construction materials, and ready sources of chemical and agricultural lime. Local bodies of more or less crystalline limestone, in the Piedmont province and relatively extensive beds of calcareous marl in the Coastal Plain provide additional sources of limestone and lime for various uses.[42] (See Pls. 9 and 12.)

Because of their widespread occurrence, range in character and composition, accessibility to railway and highway transportation, and the favorable situation of many extensive outcrops with respect to quarrying, the limestones and dolomites of the Appalachian Valley should provide materials adapted to a wide variety of uses.

The annual production of limestone and related lime materials in Virginia consists of crushed stone for concrete, road metal and railway ballast, building lime, agricultural lime, hydrated lime and chemical lime. Normally more than 50 limestone plants are in operation in the State and the total annual value of limestone products exceeds $1,000,000. Of the 1,685,260 short tons of limestone, valued at $1,570,359 produced or sold in Virginia in 1932, 1,381,860 short tons with a value of $1,218,180 were used for concrete, road metal and railway ballast and 55,410 short tons, valued at $71,474, were used for agricultural lime.

LIMESTONE

DISTRIBUTION AND CHARACTER

Valley and ridge province.—From Potomac River on the northeast, throughout its southwesterly extent across Virginia, 360 miles to the Tennessee line on the southwest, much of the Appalachian Valley is a limestone region. The main lowland areas in the eastern part and most of the narrow valleys between the mountain ridges on the northwest are underlain mainly by limestone, dolomite, and shale. These occur in belts of variable width which extend in a general northeasterly direction.[43] The lands in the Valley counties are among the most productive in the State which

[41] See "Selected References" at end of this report.
[42] See also sections on "Construction Materials" and "Nonmetallic Resources."
[43] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, 56 pp., and map, 1933.

fact is to be attributed to the fertility of the limestone and dolomite soils. Practically every county in the Appalachian Valley region contains readily available deposits of limestone that have been used, at least locally, as sources of crushed stone or agricultural lime.

Many of the limestone and dolomite formations extend in narrow belts nearly the full length of the Valley, whereas others crop out in several parallel belts of variable extent, as along both sides of many of the Valley ridges. Some limestones have considerable areal surface extent locally.

The limestones vary in physical character and chemical composition. The high-calcium beds are commonly white, light gray, or dove-colored. Some of the limestones are fine-grained and others are coarsely crystalline.

Of the numerous limestone formations in the Appalachian Valley region, the following, ranging in age from Late Cambrian (Ozarkian) to Mississippian, are known to be of importance for the commercial development of limestone and lime materials: Limestone members of the Shady dolomite, the Conococheague, Chepultepec, Stonehenge, Mosheim, Lenoir, Holston, Athens, Lowville, Chambersburg, Tonoloway, Helderberg, and St. Louis and Ste. Genevieve. The distribution of these formations is shown on the geologic map of the Appalachian Valley of Virginia.[44]

The Mosheim and Lenoir limestones across the State are particularly high-grade limestones, especially the Mosheim which in most places is almost 100 per cent calcium carbonate. The Holston limestone in southwestern Virginia is also a very high-grade limestone.

Piedmont province.—In the south-central or James River section of the Piedmont region occur local deposits of limestone and marble which recent studies indicate may be of commercial importance. In years past quarries were operated at several places and the stone has been burned for agricultural lime and used for construction work. Bodies of limestone of sufficient thickness and extent to warrant the development of large quarries are reported to occur in areas favorably situated with regard to railroad and highway transportation.[45]

In the vicinity of Leesburg in Loudoun County occurs a Triassic limestone conglomerate, termed "Potomac marble," from which road material and agricultural lime have been obtained. A

[44] Idem.

[45] Furcron, A. S., James River iron and marble belt, Virginia: Virginia Geol. Survey Bull. 39, pp. 27-31, 60-77, 1935.

deposit of similar material on the north side of Potomac River is reported to have been worked extensively for ornamental stone for exterior use.[46]

USES

There is probably no other mineral commodity with as wide and varied a field of use for its products as limestone. A wide range of limestone satisfactory for building or dimension stone is available throughout the Appalachian Valley region. Limestone has been used for private homes, retaining walls and other constructional uses locally, mainly in the Valley region. In recent years such stone has been used for public buildings. The buildings of the State Teachers College at Harrisonburg and the recently constructed buildings at the Virginia Polytechnic Institute at Blacksburg are built of limestone.

In recent years the major production of limestone in Virginia has been as crushed stone, used for concrete, road metal and railway ballast; agricultural lime including ground lime and hydrated lime; and lime for various building, chemical and metallurgical uses.[47] Considerable limestone for furnace flux in iron smelting was formerly quarried near Clifton Forge and at Pulaski. A Portland cement plant at Fordwick uses local Devonian limestone and shale. Carbide is made from a limestone member of the Shady dolomite at the plant of the National Carbide Corporation at Ivanhoe. The Mathieson Alkali Works at Saltville uses large quantities of Holston limestone in the manufacture of soda products and the General Electric Co. consumes additional large amounts of limestone in its sulphuric acid plant at Pulaski.

There are large limestone operations at Riverton in Warren County, Stephens City in Frederick County, Indian Rock and Eagle Rock in Botetourt County, Pearisburg and Ripplemead in Giles County, Saltville in Smyth County, and at numerous other localities. Lime kilns producing high-grade building and chemical lime are widely distributed in the Appalachian Valley region. Numerous plants throughout the Valley and Piedmont regions produce crushed stone for road metal. (See Pl. 12, A.)

[46] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, pp. 10-13, 1928.

[47] Steidtmann, Edward, Chemical limestones and dolomites of Virginia: Bull. Virginia Section, Am. Chem. Soc., Richmond, vol. 11, no. 8, pp. 112-115, and vol. 11, no. 9, pp. 126-127, 1934.

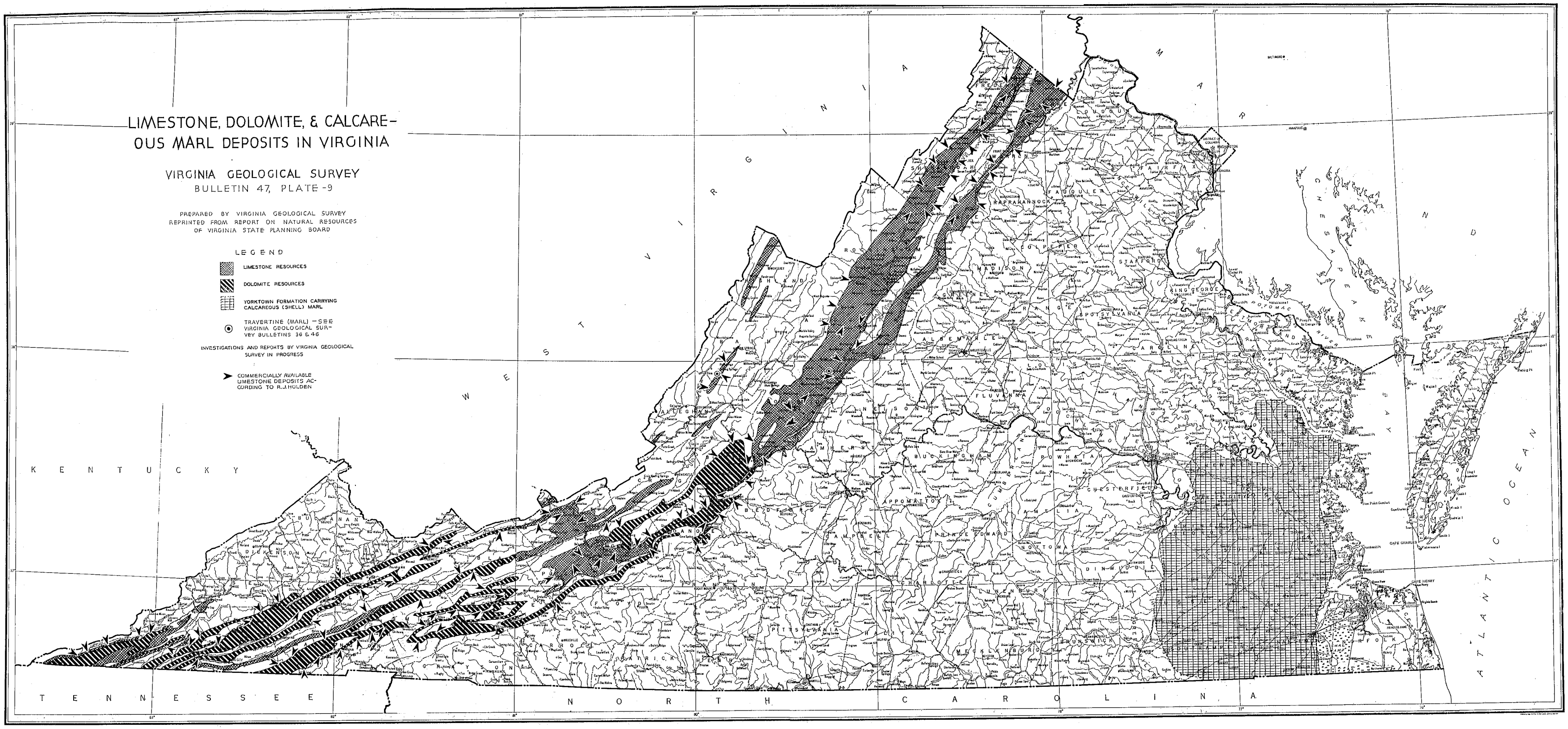
LIMESTONE, DOLOMITE, & CALCAREOUS MARL DEPOSITS IN VIRGINIA

VIRGINIA GEOLOGICAL SURVEY
BULLETIN 47, PLATE-9

PREPARED BY VIRGINIA GEOLOGICAL SURVEY
REPRINTED FROM REPORT ON NATURAL RESOURCES
OF VIRGINIA STATE PLANNING BOARD

LEGEND

- LIMESTONE RESOURCES
- DOLOMITE RESOURCES
- YORKTOWN FORMATION CARRYING CALCAREOUS (SHELL) MARL
- TRAVERTINE (MARL) — SEE VIRGINIA GEOLOGICAL SURVEY BULLETINS 36 & 46
- INVESTIGATIONS AND REPORTS BY VIRGINIA GEOLOGICAL SURVEY IN PROGRESS
- COMMERCIALLY AVAILABLE LIMESTONE DEPOSITS ACCORDING TO R.J. HOLDEN



DOLOMITE

CHARACTER AND OCCURRENCE

Dolomites, like limestones, are well developed in the Appalachian Valley region, where they occur in several extensive narrow belts.[48] They vary considerably in character, composition, and thickness. Limestones are composed principally of calcium carbonate ($CaCO_3$), and are therefore generally classed according to their magnesian content, which distinguishes between a limestone and a dolomite. Where the calcium carbonate content is 95 per cent or more and the magnesium carbonate content 5 per cent or less, the rock is considered a more or less pure limestone; where the magnesium carbonate content ranges from 5 to 45 per cent, the rock is termed a magnesium or dolomitic limestone; and where the magnesium carbonate comprises 45 per cent or more of the rock it is called a dolomite.

Some of the formations, such as the Athens, in the Appalachian Valley in Virginia, vary in different parts of the region from limestone to shale. Likewise variations in the calcium and magnesium carbonate content of the magnesium limestone or dolomite formations yield dolomites of normal to high-grade quality. The Beekmantown formation varies from a limestone or dolomitic limestone in one locality to a dolomite in some other area.

The dolomites include the Shady-Tomstown, Elbrook, and Honaker formations of the Cambrian; the Copper Ridge dolomite of the Ozarkian; and the Beekmantown formations of the Canadian systems. From information now available it seems most probable that the Copper Ridge and Nittany dolomites offer the most abundant supplies of high-grade dolomite.

USES

Dolomite is used for many of the same purposes as is limestone, and although it is not well adapted to certain uses for which limestone is particularly suited, dolomite also has certain special uses for which it is more satisfactory than limestone. It is used as building stone, both for exterior and interior use, for statuary, tombstones, and other ornamental purposes. It is also being more widely used in place of magnesite by various industries for heat insulation.

Dolomite is used in fluxing iron ore but probably not now as widely so as is limestone, although recent studies show that dolomite has certain advantages over limestone for this use. It is being more extensively used in open-hearth furnaces, for lining

[48] Butts, Charles, Geologic map of the Appalachian Valley of Virginia with explanatory text: Virginia Geol. Survey Bull. 42, 56 pp., and map, 1933.

and for mending floors. Finely ground or burned and hydrated dolomite is also used in the manufacture of agricultural lime or fertilizer.[49]

Among the particular uses for high-grade dolomite are the manufacture of basic magnesium carbonate and magnesia. A by-product of this operation of importance is pure calcium carbonate especially adapted for whiting. Magnesia products are used for heat insulation, rubber filler, certain kinds of cement and other construction materials, and drugs or pharmaceutical preparations.

CALCAREOUS MARL

OCCURRENCE AND CHARACTER

Deposits of calcareous (shell) marl and soft unconsolidated limy materials occur in the Coastal Plain region. They are especially prominent in the Yorktown formation.

It is thought that owing to the extensive area in which deposits are known to occur and their high lime content,—some of the marls are reported to contain locally, as much as 97 per cent calcareous matter—, they may be of especial promise for the future manufacture of Portland cement and fertilizers, for which uses local deposits have been operated.

USES

One of the first plants constructed in the South to manufacture Portland cement from shell marl is that of the Lone Star Cement Company of Virginia, Inc., located in Norfolk. It is using material from calcareous marl deposits along tributaries of James River near Chuckatuck in Nansemond County and near Smithfield in Isle of Wight County. Other deposits have been dug and used locally for agricultural lime. It is also possible that other uses will be found for these materials.

TRAVERTINE

At several places in the Valley region occur deposits of travertine or fresh water marl formed by springs and streams.[50] One large travertine deposit in Alleghany County is being operated for the manufacture of agricultural lime and similar material from this region has been shipped to Norfolk for use in the manufacture there of artificial fertilizers. (See Pl. 12, B.)

[49] Steidtmann, Edward, Chemical limestones and dolomites of Virginia: Bull. Virginia Section, Am. Chem. Soc., Richmond, vol. 11, no. 8, pp. 112-115, and vol. 11, no. 9, pp. 126-127, 1934.

[50] Steidtmann, Edward, Travertine-depositing waters near Lexington, Virginia: Science, n. s. vol. 82, pp. 333-334, 1935.

MANGANESE[51]

DISTRIBUTION AND CHARACTER

Manganese is of wide distribution in the Valley Ridges section of western and southwestern Virginia and along the northwest slope of the Blue Ridge. Other deposits, several of which have been more or less extensively worked in the past, occur in certain belts in the Piedmont region on the east side of the Blue Ridge and pockets of manganese of small extent have been found in the Coastal Plain region. The latter are not now considered to be of commercial value.[52]

In general the manganese deposits are masses of oxides, mainly psilomelane and pyrolusite, occurring in residual clay in or overlying limestone and sandstone and in sandstone. Some are of sufficient extent and of such purity as to permit of mining and shipping the manganese ore with but little or no preliminary treatment. Most of the deposits, however, are either accumulations of nodules of manganese oxide in beds or lenses of clay or mixtures of iron and manganese oxides, both of variable composition and character, commonly also in bodies of clay. These require washing, crushing, screening, and separation of the ore from the clay, to yield manganese ore of marketable grade. Many contain silica and other impurities which require refining and concentration of the manganese ore to produce ore of shipping grade. Some deposits occur as fillings in fissures or fractured zones in sandstone and limestone. Many deposits of this type contain too much silica to be of commercial value.

Whereas many deposits of known or probable commercial importance are favorably situated with regard to development and transportation facilities, others are at the present time less readily accessible. Owing to its use in the manufacture of steel, manganese is one of a group of minerals which has been classed as "strategic minerals." Other specific uses annually require varying amounts of manganese. With improved market conditions, increased demands or new uses, and improved extraction, separation or recovery methods, many deposits of manganese or manganiferous iron ore which are not now considered of development value, may become of commercial importance. (See Pl. 10.)

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[51] See "Selected References" at end of this report.

[52] Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, 166 pp., 1919.

....., and Miser, H. D., Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, 206 pp., 1922.

Furcron, A. S., James River iron and marble belt, Virginia: Virginia Geol. Survey Bull. 39, pp. 104-109, 1935.

OCCURRENCE

PIEDMONT REGION

In the Piedmont region manganese deposits occur mainly in residual clay derived from the weathering of crystalline (Wissahickon) schist or limestone (Cockeysville marble), generally near quartzite. Some deposits are reported to consist of high-grade manganese oxide only, whereas others are associated with iron oxide, mainly limonite. Manganese is reported to have been mined in Nelson County as early as 1868 and other mines were in operation in Campbell and Nelson counties from about 1880 to 1885 and at later intervals. Workable deposits have been reported in Amherst, Albemarle, Appomattox, Buckingham, Campbell, Louisa, Nelson, Pittsylvania and Spotsylvania counties.

BLUE RIDGE REGION

Along the northwest base of the Blue Ridge, deposits of manganese of variable character and extent occur in bodies of clay, generally either in the basal part of the Shady dolomite, which marks the eastern margin of the Valley, or in the upper part of the underlying Cambrian sandstone (Erwin quartzite), which forms many foothill ridges along the northwest base of the Blue Ridge. The larger deposits occur in local clay-filled basins or basin-shaped folds (synclines) where apparently structural conditions have been favorable for accumulation. At several places along the foothill ridges, siliceous deposits of manganese, generally too limited in extent and too siliceous in character to be of commercial value, occur in crevices in sandstone. Commercially workable deposits have been operated or reported to occur locally in Page, Rockingham, Augusta, Rockbridge, Botetourt, Wythe and Smyth counties. (See Pl. 7, B.)

VALLEY AND RIDGE REGION

Deposits of manganese occur throughout the extent of the Valley Ridges across western and southwestern Virginia. Some are quite extensive. They are found at varying elevations along the ridges or along the valley slopes in clay, generally either in the Oriskany sandstone or in the underlying Helderberg limestone. The deposits, particularly those in the sandstone, are in places associated with deposits of iron oxide, which have been termed "Oriskany iron ores." Many are high grade, adapted to chemical uses. Deposits occur in Alleghany, Bath, Bland, Botetourt, Craig, Frederick, Giles,

MANGANESE DEPOSITS IN VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

BULLETIN 47, PLATE-10

PREPARED BY VIRGINIA GEOLOGICAL SURVEY
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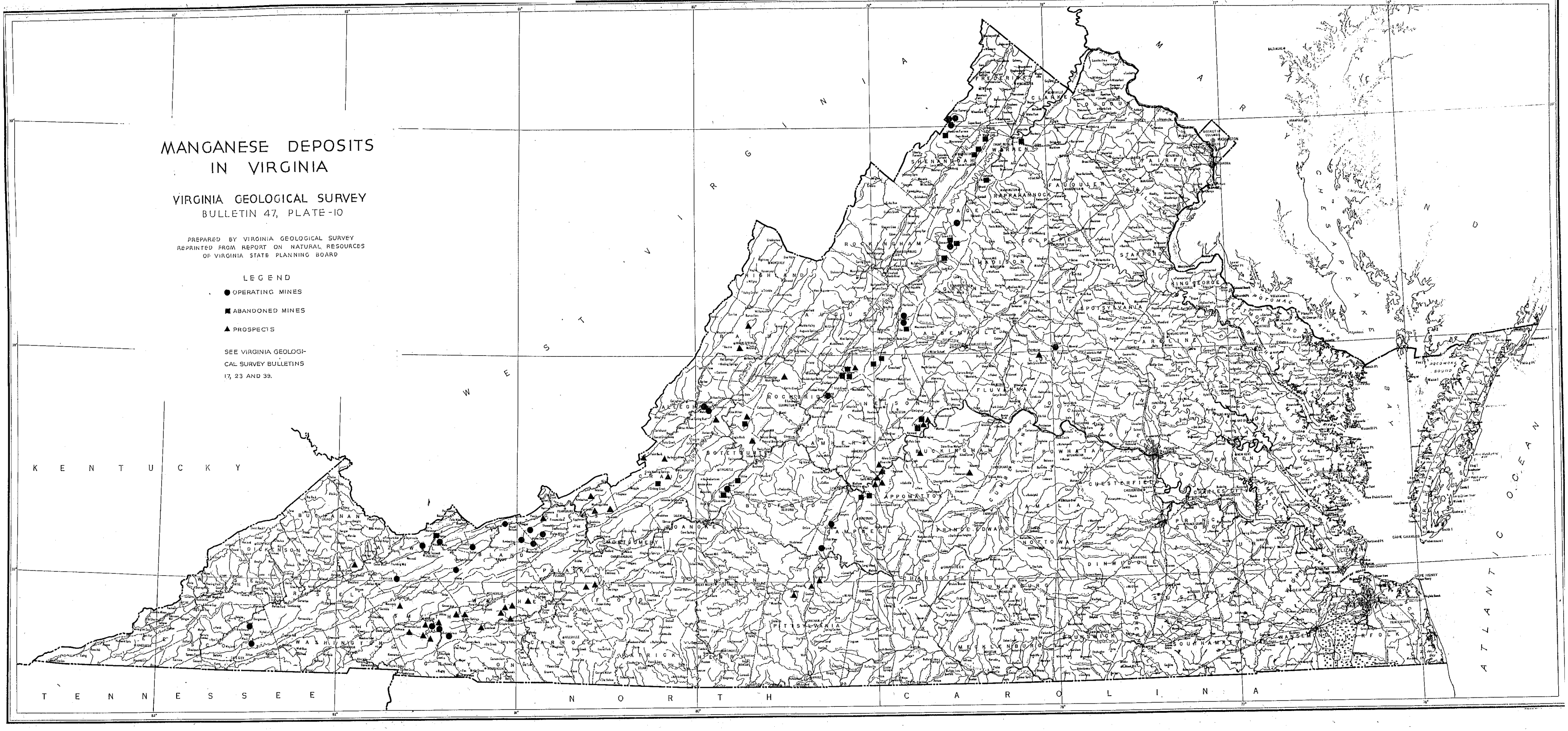
LEGEND

- ● OPERATING MINES
- ■ ABANDONED MINES
- ▲ PROSPECTS

SEE VIRGINIA GEOLOGICAL SURVEY BULLETINS 17, 23 AND 39.



Highland, Montgomery, Russell, Scott, Shenandoah, Tazewell, Washington, and Wise counties.

EARLY OPERATIONS

According to available information the earliest manganese mining in Virginia was in 1834 in the Fort Valley area in Massanutten Mountain in Shenandoah County and in the Paddy's Mill or Paddy's Run area in Frederick County. The Bonnet Hill mine, in northwestern Shenandoah County, about 2 miles southwest of Paddy's Mill mine, is said to have been in operation in 1848, and the near-by Godlove mine is reported to have been in operation in 1847. The first operations reported in the Blue Ridge region were at the Lyndhurst mine, near Lyndhurst, in 1859.[53] The Kennedy tract, near Stuarts Draft in the same county, is said by Weeks to have produced 300 tons of ore in the same year. Gowans Bank near Lithia in Botetourt County is said to have been worked before the War between the States and the Frank Cabell mine near Warminster in Nelson County in 1868. The famous Crimora mine, at Crimora, also in Augusta County, was operated prior to 1867. The Glade Bank near Max Meadows in Wythe County, the Garrison Bank near Shenandoah in Page County, the Houston mine near Nalle in Botetourt County, the Leet or Whitman mine near Mt. Alto in Campbell County, and the Simpson and Davis mines in Nelson County, were in operation between 1880 and 1885.

PRODUCTION

During the period from 1867 to 1879, Virginia is credited with the production of 18,000 long tons of manganese ore. In 1880, the first year for which official annual production records are available, 3,661 tons were produced. According to Holden, the maximum production was obtained in 1925 when 23,000 tons of ore having a manganese content of 35 per cent and higher, and 47,000 tons of lower grade ore were produced. Holden[54] states that, "Records running from 1880 . . . to 1925, show that Virginia produced 380,000 tons or approximately 26 per cent of the 1,440,000 tons from American mines during the forty-five year period."

The renowned Crimora mine in Augusta County is reported by Stose to have yielded 161,000 tons of manganese ore from the date of its opening ("prior to 1869") through 1917,[55] and this from

[53] Weeks, J. D., Manganese, *in* Mineral Resources of the United States: U. S. Geol. Survey, pp. 303-356, 1885.

[54] Holden, R. J., Minerals and their exploitation, *in* Virginia: Economic and Civic, p. 132, Richmond, Whittet and Shepperson, 1933.

[55] Stose, G. W. and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, pp. 83-86, 1919.

an area of about 20 miles in extent. This property, which long enjoyed the distinction of being the largest producer of manganese in the United States, was listed as a producer again in 1933.

The Piedmont or Lerner mine, 8 miles southeast of Lynchburg in Campbell County, is reported to have yielded a total of about 30,000 tons.

RECENT OPERATIONS

During the World War, manganese was in great demand for increased steel, machinery, equipment and munitions manufacture. As a result many of the abandoned mines in Virginia were worked and new ones opened. Several new properties in Bland, Giles and Tazewell counties were more or less extensively developed. Some of these, together with some of the old, reopened mines in Frederick, Shenandoah, Page, and Augusta counties and two mines in the Piedmont region have maintained intermittent, though variable, production up to the present time.

Whereas recent official reports do not show any marked increase in the production of ore in the United States in 1933 over 1932, shipments of manganese ore from Virginia in 1933, are reported as being 4,882 long tons, the greatest since 1918. Of this amount 4,184 tons were for steel manufacture and 698 tons for miscellaneous uses. Shipments were reported from properties in Augusta, Bland, Campbell, Giles, Page, and Shenandoah counties. Among the producing mines were the Old Dominion and Crimora in Augusta County; the Stange, and the Bruce and Horne properties in Bland and Giles counties; the Stanley Mine in Page County; Hy-Grade Mining Company's mines in Shenandoah County; and the mine of Southern Mines and Metals, Inc., in Campbell County.

USES

The principal use of manganese is in the manufacture of alloys of spiegeleisen and ferro-manganese which are the forms in which manganese is usually added to steel. Another important use is in the manufacture of dry batteries. Manganese ore is also consumed in chemical, ceramic, and glass industries; as a drying agent for paints and varnishes, for decolorizing and coloring glass, and for glazing bricks and pottery. In recent years manganese ore has been used as a filler in a certain kind of fertilizer for which encouraging claims are being advanced. Other uses for manganese are probable.

OTHER METALLIC DEPOSITS[56]

GENERAL STATEMENT

Among the metallic mineral deposits of Virginia which are of known or probable commercial importance are iron, lead and zinc, manganese, pyrite and pyrrhotite, and titanium minerals. The importance of these minerals and their products or alloys in industrial, community, national and everyday family life is generally far less realized than it should be. There is scarcely any field of human activity in which one or more of these minerals in some form is not a matter of vital and daily necessity. (See Pls. 7, 8, 10, 11, and 13, A.)

ARSENIC

Arsenopyrite, a double sulphide of arsenic and iron, occurs near Rewald along the crest of the Blue Ridge in Floyd County, in the Irish Creek tin district, in the northeast corner of Rockbridge County, and has been reported from copper deposits in Carroll and Grayson counties. The deposit in Floyd County, which occurs as veins in quartz in sericite schist, is the only one which has been mined commercially. It is reported to have been worked at various times between 1903 and 1919, the last operation, in 1918, being for arsenic for war supplies, as the United States government obtained most of the production.[57]

Arsenic has a variety of uses in the chemical industry. It is used in calico printing, dyeing, in the manufacture of pigments, of fine-grade glassware, of special enamels, in arsenical soap, and in the preparation of salts of arsenic. It is also used in the manufacture of war supplies, particularly poison gas.

COPPER

Copper occurs in three different areas in the Piedmont region and in two areas in the Blue Ridge. No extensive deposits have been developed and the actual resources are therefore not known. The known deposits are confined principally to the older crystalline rocks, chiefly schists and massive igneous rocks. In the Piedmont region copper occurs in the form of sulphides and oxides and a small amount of native copper, in quartz veins in schist and greenstone, in the Virgilina area in Halifax County; mainly as sulphides in the James River section, in Buckingham, Appomattox and

[56] See "Selected References" at end of this report.
[57] Holden, R. J., Minerals and their exploitation, *in* Virginia: Economic and Civic, p. 110, Richmond, Whittet and Shepperson, 1933.

Albemarle counties; and mainly as coatings of oxides and carbonates in greenstone, related igneous rocks or greenstone schist in the northeastern Piedmont region.

In the Great Gossan Lead in Floyd, Carroll, and Grayson counties, sulphides of copper are reported associated with pyrrhotite in a belt of crystalline schist for a distance of 18 miles. This area appears worthy of further investigation as some of the deposits have been worked for copper.[58] (See also "Pyrite and Pyrrhotite.")

In the northern Blue Ridge region scattered deposits and showings of copper have led to many attempts at commercial development locally. It is not thought that these occurrences are of commercial promise.

IRON

DISTRIBUTION

The first iron ore mined in America was by the Jamestown settlers in Virginia in 1609, and the first iron furnace in Virginia, if not in the entire United States, was erected in 1620 in the vicinity of Falling Creek, near U. S. Highway No. 1, midway between Richmond and Petersburg. The iron ores are distributed over the western half of the State, occurring in the Valley Ridges, the Valley, along the Blue Ridge and the western part of the Piedmont regions.

TYPES OF DEPOSITS

For convenience and on the basis of the different types of ore, the iron deposits of Virginia are divided by Holden[59] into four main types with further subdivisions of two of these in accordance with the geological occurrence of the deposits. The four main types are as follows: Limonite, hematite, magnetite, and carbonate deposits.

OCCURRENCE AND CHARACTER

Limonite deposits.—The limonite ores are the most widely distributed and the most important. Shallow, irregular or pocket deposits of limonite occur in residual clay overlying the Shady dolomite, and locally the Elbrook dolomite, throughout the Appalachian Valley region, mainly on the east side of the Valley of Virginia and in southwestern Virginia. Similar deposits occur in residual material overlying the Erwin quartzite and in pockets and

[58] Ross, C. S., Origin of the copper deposits of the Ducktown type in the southern Appalachian region: U. S. Geol. Survey, Prof. Paper 179, 165 pp., 1935.
Laney, F. B., The geology and ore deposits of the Virgilina district of Virginia and North Carolina: Virginia Geol. Survey Bull. 14, 176 pp., 1917.
[59] Holden, R. J., op. cit., pp. 119-122.

SOME METALLIC DEPOSITS OF VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

BULLETIN 47, PLATE-II

PREPARED BY VIRGINIA GEOLOGICAL SURVEY
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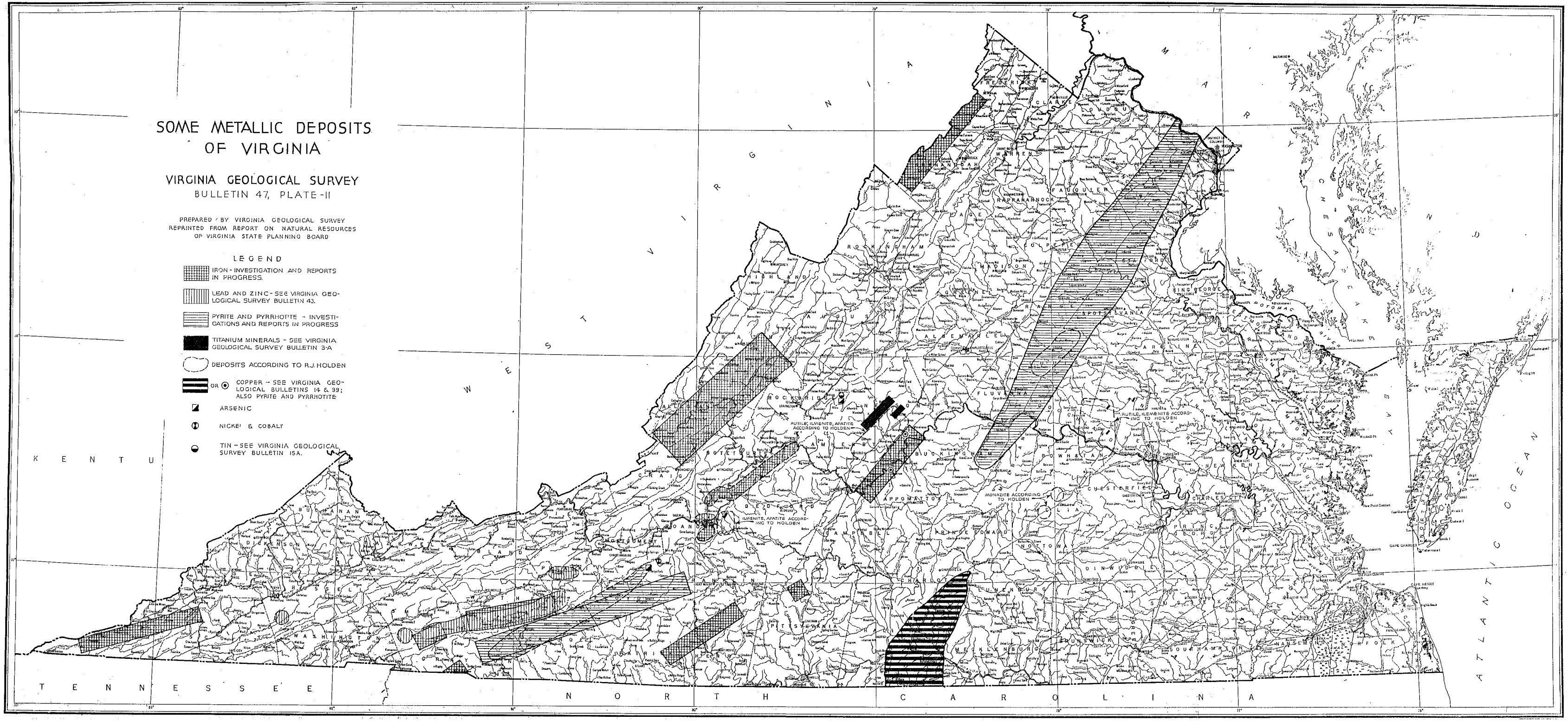
LEGEND

- IRON - INVESTIGATION AND REPORTS IN PROGRESS.
- LEAD AND ZINC - SEE VIRGINIA GEOLOGICAL SURVEY BULLETIN 43.
- PYRITE AND PYRRHOTITE - INVESTIGATIONS AND REPORTS IN PROGRESS
- TITANIUM MINERALS - SEE VIRGINIA GEOLOGICAL SURVEY BULLETIN 3-A
- DEPOSITS ACCORDING TO R.J. HOLDEN
- OR ⊙ COPPER - SEE VIRGINIA GEOLOGICAL BULLETINS 14 & 39; ALSO PYRITE AND PYRRHOTITE
- ARSENIC
- NICKEL & COBALT
- TIN - SEE VIRGINIA GEOLOGICAL SURVEY BULLETIN 15A.



as crevice fillings in sandstone in the ridges along the northwest side of the Blue Ridge.

The sandstone or ridge deposits are reported to be more massive, to occur in more definite bodies, to be more widely distributed than the limonite ores in limestone and, in places, to require no washing.

Deposits of limonite in limestone have been extensively mined and smelted in Wythe County and considerable production of the sandstone limonite or "mountain ore" has been obtained from Pulaski and Wythe counties.

Important deposits of limonite which because of their definite association with Oriskany sandstone, have been termed "Oriskany iron ores," occur in the Valley Ridges section of Alleghany, Augusta, Botetourt, and Craig counties. The Oriskany ores are the most extensive and most valuable of the limonite deposits. According to Burchard, "The iron content of the Oriskany ore ranges between 35 and 50 per cent, the silica from 10 to 25 per cent, the phosphorus from 0.06 to 0.5 per cent, and manganese less than 1 to 3 or 4 per cent."[60]

The largest production of Oriskany ore has been obtained in the Clifton Forge area in Alleghany County from the Oriskany, Longdale, Low Moor, Rich Patch, Dolly Ann, Stack, Potts Valley, Wilton, and Fenwick mines. Several of these are reported to have yielded about 1,000,000 tons each and the Oriskany is credited with having produced about 2,000,000 tons.[61]

In the plateau section of Carroll, Floyd, and Grayson counties, occur extensive deposits of pyrrhotite in a belt about 60 miles long, in crystalline schists, to which the name "Great Gossan Lead" has been applied. As a result of oxidation, the pyrrhotite to depths of 30 feet and more, has been changed into limonite. In Louisa County and elsewhere in the Piedmont region, portions of deposits of pyrite, also generally in crystalline schists or related rocks, have undergone oxidation and conversion into limonite.

Hematite deposits.—In the Clifton Forge area in Alleghany County in the Valley Ridges section and in Lee and Wise counties in southwestern Virginia occur deposits of Clinton hematite, related to the well-known Clinton ore of widespread distribution throughout the Appalachian region from New York to Alabama. The Clinton ore is different from any other iron ore in the State and is easily recognized by its two distinctive types: "Oolitic ore,"

[60] Burchard, E. F., Iron ore [in Virginia], *in* Official industrial and shippers directory of the Chesapeake and Ohio Railway Co., p. 40, Richmond, Chesapeake and Ohio Railway Co., 1929.

[61] Holden, R. J., op. cit., p. 121.

composed of small rounded or flattened granules; and "fossil ore," composed largely of fossil fragments in which the lime of the various fossil organisms has been replaced by hematite. Above the water level the hematite is reported to be soft and leached whereas below the water level it is limy.

Clinton hematite has been mined near Low Moor and near Iron Gate in the Clifton Forge area, and in the Big Stone Gap area in southwestern Virginia. In the Clifton Forge area the hematite is reported to have contained about 45 per cent of metallic iron equivalent and in the Big Stone Gap area some of the ore is reported to carry 50 per cent of metallic iron equivalent.[62]

A deposit of hematite about 16 miles long occurs in the lower Cambrian (Chilhowie group) along the west base of the Blue Ridge in Roanoke and Botetourt counties northeast of Roanoke. On and near the surface, the hematite is hard and red, but at depth it is reported to be of a deep purplish-green color. The hematite contains 35 to 40 per cent metallic iron equivalent and from 30 to 40 per cent silica.[63] It is classed as a low-grade ore.

Deposits of high-grade, low-phosphorus, red hematite of limited extent occur in limestone locally in Bland and Giles counties in southwestern Virginia. They are associated either with deposits of magnetite or iron carbonate, in such a manner as to suggest that the hematite is of recent replacement origin.

In the central-western portion of the Piedmont region, hematite of both red and specular varieties, occurs in several places in schist and quartzite, in places in association with magnetite. A deposit near Riverville in Amherst County was worked in 1880-1881, and other mines containing "specular ore" were operated about the same time near Greenway in Nelson County, near Stapleton in Amherst County, and at Mount Athos in Campbell County.[64]

Magnetite deposits.—In the Piedmont region deposits of magnetite occur mainly as lenses of variable extent in schist, or between schist and limestone, in Franklin and Patrick counties, in Grayson County, in Pittsylvania County and in the James River district.

The old Hairston and Rocky Mount mines in the Franklin and Patrick counties district are reported to have produced and shipped magnetite of high quality (Bessemer grade). The Pittsylvania County deposits have been the most worked of all the Piedmont

[62] Holden, R. J., op. cit., p. 123.
[63] Woodward, H. P., Geology and mineral resources of the Roanoke area, Virginia: Virginia Geol. Survey Bull. 34, p. 106, 1932.
[64] Furcron, A. S., James River iron and marble belt, Virginia: Virginia Geol. Survey Bull. 39, pp. 86-96, 1935.

magnetite areas and this district is credited with a production of probably more than 100,000 tons. From 1880, when first exploited, for several years, the James River district was the largest iron-producing area in the State.[65]

Magnetite also occurs locally in limestone, in several places in the Valley and Ridges section, in Giles County and in Washington County. Deposits of Bessemer grade have been mined in Giles and Washington counties.

Carbonate deposits.—Although no mines have been opened in deposits of iron carbonate, occurrences of carbonate have been reported and obtained in commercial quantities from the deeper workings of mines in Oriskany and fault deposits; from the Grubb mine in Botetourt County, the Longdale mine in Alleghany County, and the Indian Camp mine in Wythe County. Iron carbonate has been reported associated with magnetite in a mine in Washington County.

PRODUCTION

It has been estimated that 26,000,000 long tons of iron ore has been produced in Virginia. This has yielded about 11,000,000 tons of pig iron valued at about $200,000,000. However, as a part of the iron produced here has been converted into finished products within the State, the iron industry has made a still larger contribution to the wealth of the State.[66]

USES

The major use of iron ores is for making pig iron, which is converted into cast iron, wrought iron, steel and various alloys of iron and steel. Some low-grade ores of limonite and hematite are used for the manufacture of cheap paint. The total production of iron from Virginia in 1933, 287 tons of Oriskany ore from the Oriskany mine in Botetourt County, was used in the manufacture of hydrogen gas.

LEAD AND ZINC

DISTRIBUTION

The ores of lead and zinc occur so generally in association in nature that they are nearly always discussed together and it would be difficult to discuss them separately. In Virginia, lead

[65] Furcron, A. S., op. cit., pp. 82-83.
[66] Holden, R. J., Minerals and their exploitation, *in* Virginia: Economic and Civic, p. 119, Richmond, Whittet and Shepperson, 1933.

and zinc ores occur sparingly in two localities in the Piedmont region, and at several places in the Appalachian Valley or Valley and Ridge region.

The lead ores include galena (unoxidized sulphide), cerussite (oxidized carbonate), and anglesite (oxidized sulphate); those of zinc are sphalerite (unoxidized sulphide), smithsonite (oxidized carbonate), and calamine (oxidized silicate). Sphalerite and calamine are probably the most abundant zinc ores. (See Pl. 13, A.)

OCCURRENCE

Piedmont region.—Only two deposits of lead and zinc of workable quantity have been found in the Piedmont region. One is near Faber in Albemarle County where lead is reported to have been discovered in 1849. This deposit was worked for lead soon after its discovery, by Confederate soldiers during the War between the States, and again about 1905-1906, since which time it has been abandoned. Sphalerite and galena were reported in fluorite-quartz lenses in schist. The other operations were at the Louisa mine in Louisa County, where sphalerite in vein or lens form, also in schist, was mined about 1914.

Valley and ridge region.—In the Appalachian Valley region occurrences of lead and zinc have been known or reported at many localities and much prospecting has been done locally. The most extensive and commercially important deposits occur in a mineralized belt, about 50 miles in length and from 2 to 7 miles in width, in Wythe and Smyth counties. Other deposits are known locally in parts of Roanoke, Montgomery, Pulaski, Smyth, Russell and Scott counties. The deposits occur mainly in fractured or fissured zones in the Shady dolomite and comprise both sulphide and oxidized ores. Local structural conditions in the dolomite are probably largely responsible for the deposition and concentration of the rich deposits.[67]

PRODUCTION

The main production of lead and zinc in Virginia has been in Wythe County where in 1750 operations were commenced at the Austinville mines by Colonel Chiswell. In the beginning and until the opening of the Bertha mine in 1879, mining was for lead only. The zinc ores were either not recognized or if so were considered of no value. Total production statistics are not available

[67] Currier, L. W., Zinc and lead deposits of southwestern Virginia: Virginia Geol. Survey Bull. 43, 122 pp., 1936.

but records for the 20-year period beginning in 1848, as cited by Holden,[68], show that during that time the Austinville mines produced 14,427,296 pounds of lead. These mines and the Faber mine in Albemarle County furnished most of the lead used in making bullets for the Confederate troops during the War between the States. The Austinville mines, after producing for more than 180 years, are now being operated on a larger scale. Galena and sphalerite are produced separately in large modern mills where a by-product of dolomite, now being used as agricultural lime, is also obtained.

The Osborne mine in Russell County has produced both lead and zinc and has yielded a little cadmium sulphate, greenockite, which, so far as known, has not been reported elsewhere in the State.

USES

Lead and zinc are both used in the manufacture of paints. Ores of lead are used in making alloys of solder, pewter, type metal, babbit metal; for making shot, water pipes, fusible alloys for various electrical fixtures, and for covering electric cables. Red lead is used as a pigment, as a cement for pipe joints, and in the manufacture of glass. Litharge is used as a fluxing agent.

Zinc is used in making roofing, galvanized iron, brass and imitation gold, alloys of copper and zinc, white metal, German silver, electric batteries, and for other purposes.

NICKEL AND COBALT

The occurrence of nickel and cobalt, generally in association, has been reported locally in the pyrrhotite areas of the Great Gossan Lead in Floyd, Carroll, and Grayson counties, from near Lynchburg in Amherst County, and from other localities in the Piedmont region. Cobalt has been reported to occur associated with some of the manganese found along the northwest slope of the Blue Ridge.

PYRITE AND PYRRHOTITE

GENERAL STATEMENT

Both pyrite, sulphide of iron, and pyrrhotite, a double sulphide of iron, are of wide distribution in Virginia, both have been mined in considerable commercial quantities, mainly as sources of sulphur and for the manufacture of sulphuric acid, respectively.

[68] Holden, R. J., op. cit., p. 131.

OCCURRENCE

Pyrite.—Pyrite is of widespread occurrence throughout Virginia, particularly in the gold belt and locally elsewhere in the Piedmont region. Large deposits of pyrite near Louisa in Louisa County were worked as a source of sulphur from about 1882 to about 1905. The Arminius, the Smith, and the Sulphur mines in the Louisa district and the Cabin Branch mine, near Dumfries in Prince William County, have contributed the main production of pyrite in the State.

Pyrrhotite.—Extensive and commercially valuable deposits of pyrrhotite occur in the Great Gossan Lead area in the plateau region of Floyd, Carroll, and Grayson counties. Lenses and veins from a few to several feet in width and of considerable extent occur in crystalline schist in a mineralized belt of at least 60 miles in length extending through portions of these counties.[69] The deposits contain some copper, and a little lead and zinc, mainly as sulphides. They have been worked at three different periods for three different minerals: First for copper alone, next the oxidized or weathered portions of the pyrrhotite (limonite gossan) were mined for iron alone, and now they are being operated for pyrrhotite which is used as a source of both iron and sulphur. The sulphur is used in the manufacture of sulphuric acid.

The Betty Baker and the Chestnut Yard mines are two properties which have been worked in this region. The Gossan mine of the General Chemical Company near Cliffview in Carroll County, producing pyrrhotite for sulphuric acid manufacture, has been in continuous operation for a number of years.

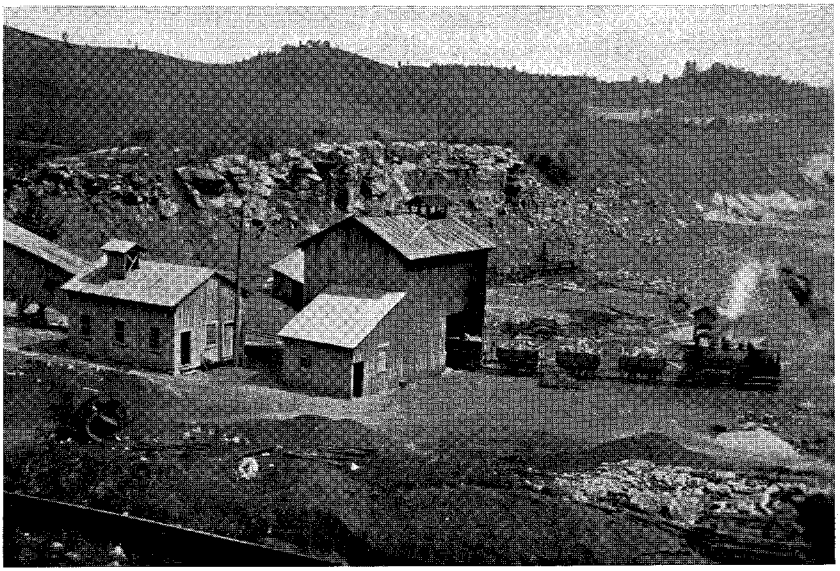
PRODUCTION

Detailed or complete production statistics are not available for either pyrite or pyrrhotite, but it is known that nearly 250,000 tons produced in Virginia in 1905 represented approximately half of the aggregate production of the United States. From 1880 to 1885, the production of pyrite was but a few thousand tons; however, it increased annually until 1905 when the maximum was reached. Pyrite was then worth approximately $3.50 per ton, so that the value of pyrite production that year was about $875,000.

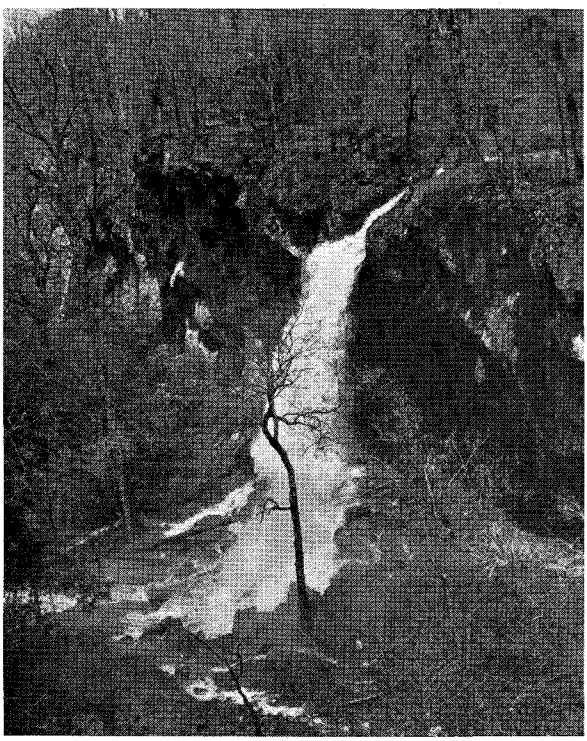
TIN

The occurrence of tin in the Irish Creek district in northeastern Rockbridge County has been known for a long time and has led to

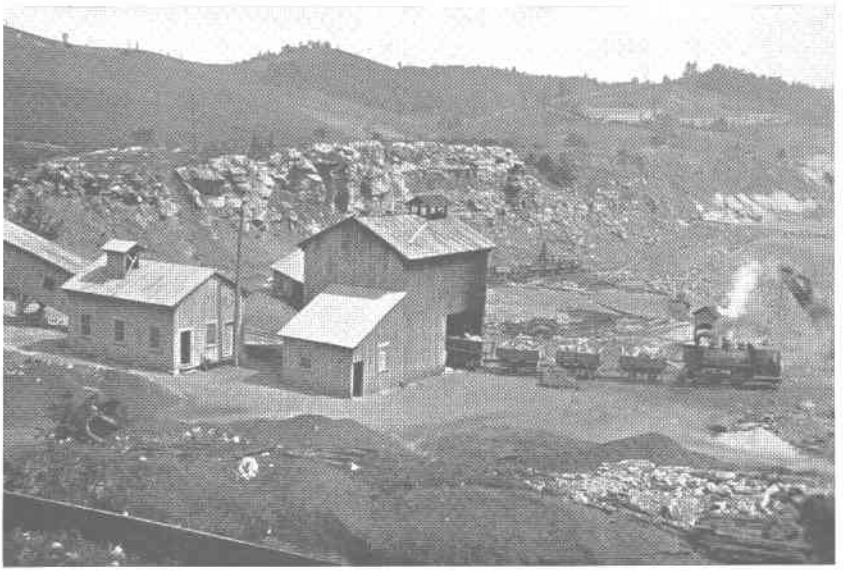
[69] Ross, C. S., The origin of the copper deposits of the Ducktown type in the southern Appalachian region: U. S. Geol. Survey Prof. Paper 179, 165 pp., 1935.



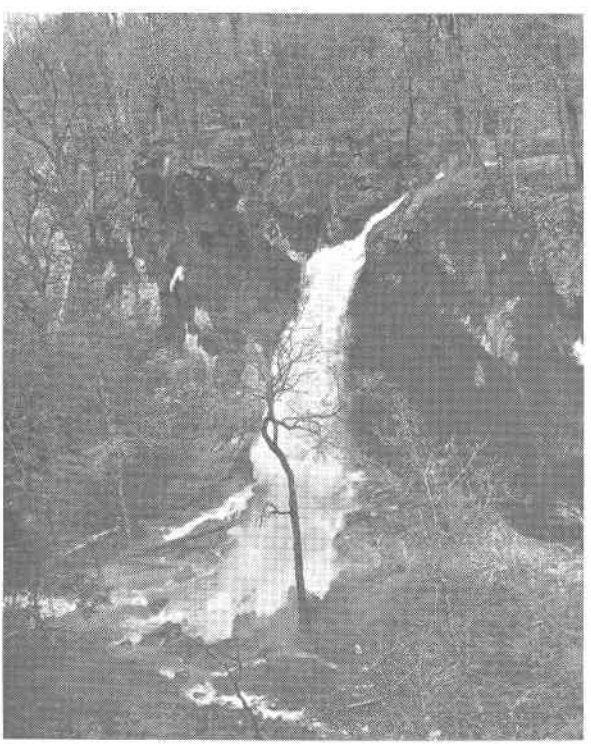
A. Limestone quarry and plant in Tazewell County, Virginia. Photograph by Arthur Bevan.



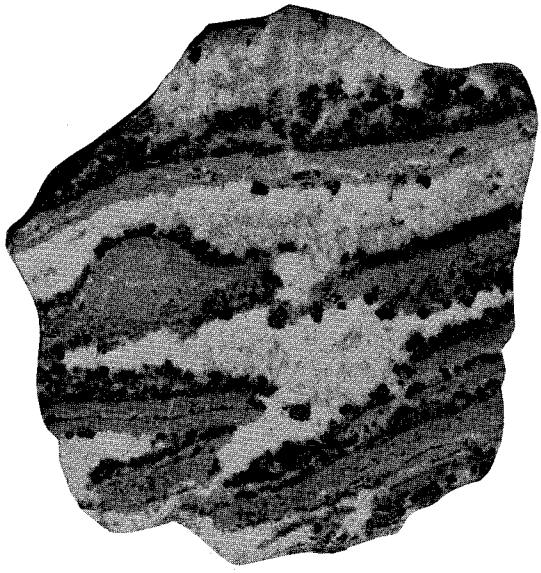
B. Travertine and cascades on Falling Springs Creek. On U. S. Highway 220 northeast of Covington. Photograph by Arthur Bevan.



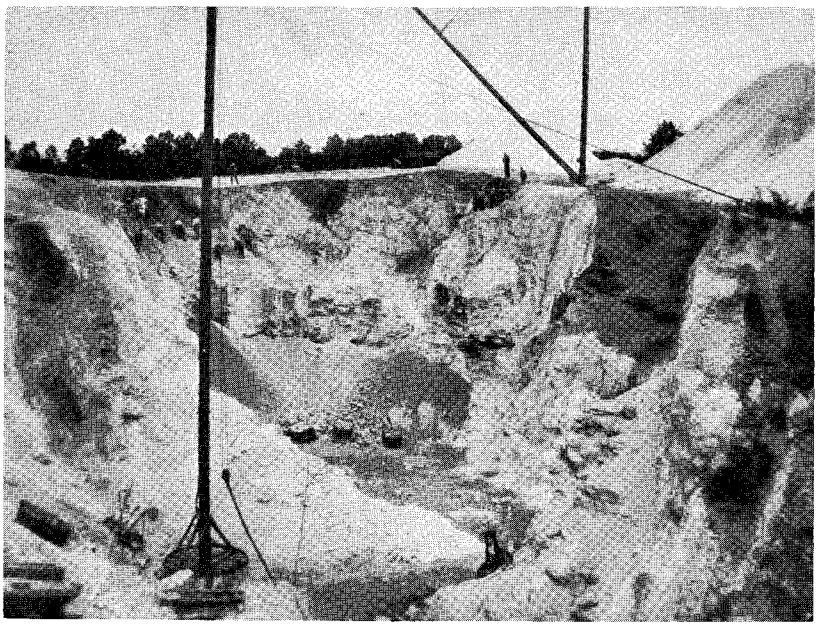
A. Limestone quarry and plant in Tazewell County, Virginia. Photograph by Arthur Bevan.



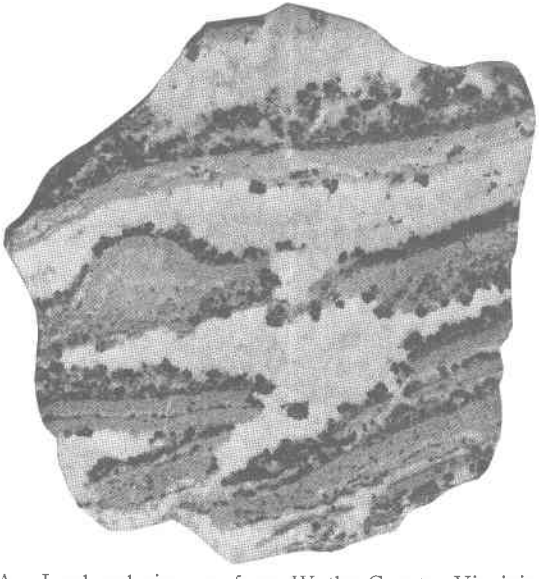
B. Travertine and cascades on Falling Springs Creek. On U. S. Highway 220 northeast of Covington. Photograph by Arthur Bevan.



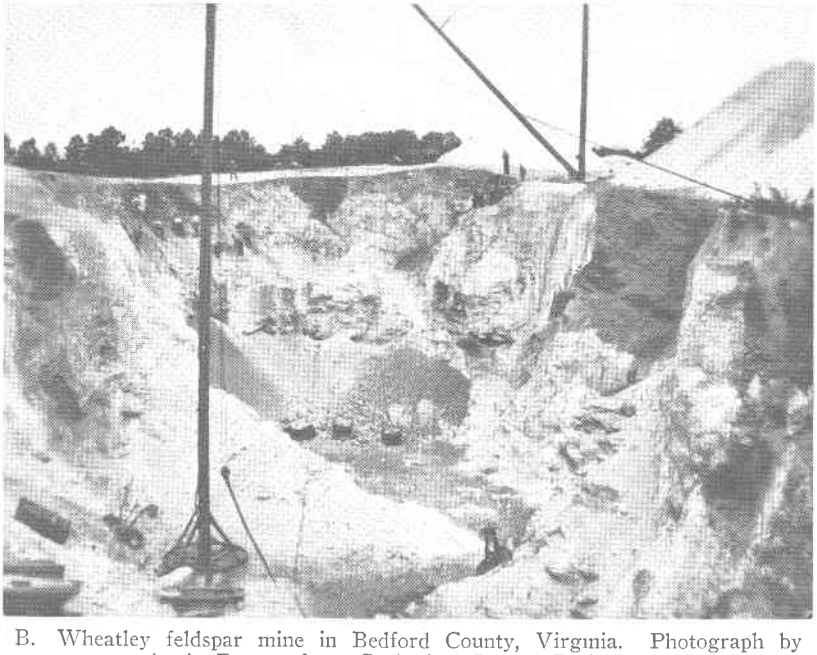
A. Lead and zinc ore from Wythe County, Virginia. From Geological Survey Bulletin 43, by L. W. Currier.



B. Wheatley feldspar mine in Bedford County, Virginia. Photograph by A. A. Pegau; from Geological Survey Bulletin 33.



A. Lead and zinc ore from Wythe County, Virginia. From Geological Survey Bulletin 43, by L. W. Currier.



B. Wheatley feldspar mine in Bedford County, Virginia. Photograph by A. A. Pegau; from Geological Survey Bulletin 33.

several attempts to develop the deposit. The ore, cassiterite, occurs chiefly in narrow quartz veins in granitic rock near the crest of the Blue Ridge. Pyrite and pyrrhotite and arsenopyrite are associated with the cassiterite. Some high-grade specimens of tin have been reported from the Irish Creek deposits.[70]

TITANIUM MINERALS

DISTRIBUTION

Deposits of titanium-bearing minerals, rutile (oxide of titanium) and ilmenite (oxides of titanium and ferrous iron) occur in Amherst, Goochland, Grayson, Hanover, Roanoke and Nelson counties.[71] The most extensive deposit is in the Amherst-Nelson counties area, where large developments have recently been made by the Southern Minerals Products Corporation at Piney River. A deposit of rutile near Roseland in Nelson County has been operated by the American Rutile Company for about 30 years. This company has for a long time supplied a large amount of the rutile consumed annually in the United States.

OCCURRENCE AND CHARACTER

In both the Amherst-Nelson and Roanoke county areas rutile and ilmenite occur intermixed with apatite, generally in pegmatite dikes in crystalline rock. The Amherst-Nelson counties area covers a belt about 13 miles long in a northeast direction and about 2½ miles wide. Roseland is situated about in the center of the area. The Roanoke County deposit is near Vinton. The Goochland-Hanover counties area comprises two small areas, one near Gouldin and the other about midway between Dover Mills and Rockville.

Showings of titanium minerals have been found a short distance south of Lynchburg in Campbell County and in the Irish Creek tin district in Rockbridge County.

USES

The chief use for titanium minerals is in the manufacture of ilmenite- and titanium-base paints and titanium-steel. Titanium oxide produced from ilmenite and to a lesser extent from rutile is used in the ceramic and chemical industries.

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[70] Ferguson, H. G., Tin deposits near Irish Creek, Virginia: Virginia Geol. Survey Bull. 15-A, 19 pp., 1918.

[71] Watson, T. L., and Taber, Stephen, Geology of the titanium and apatite deposits of Virginia: Virginia Geol. Survey Bull. 3-A, 308 pp., 1913.

Ross, C. S., Titanium deposits of Roseland district [Virginia]: XVI Internat. Geol. Cong. Guidebook 11, pp. 29-36, 1932.

Ryan, C. W., The ilmenite-apatite deposits of west-central Virginia: Econ. Geology, vol. 28, no. 3, pp. 266-275, 1933.

NONMETALLIC RESOURCES[72]

GENERAL STATEMENT

Virginia contains a large variety of rocks and nonmetallic minerals, which upon consideration of their physical and chemical composition, and particularly their use in engineering, construction, chemical, and related industries, are of considerable economic importance. Among those known to occur in quantity and quality of commercial value are: Barite, diatomite, feldspar, gypsum, kyanite, salt, soapstone and talc. Deposits of each of these have been mined or produced commercially in the past and there is production of most of them in the State today.[73] (See Pls. 13, B, 14, 15, and 16.)

ASBESTOS

Asbestos is a fibrous variety of silicate minerals, which is distinguished for heat-resisting properties. The fibers are flexible and easy to separate. There are two varieties—amphibole, a silicate of calcium and magnesium, and serpentine, a hydrous magnesium silicate. Amphibole asbestos occurs in pockets or veins at several localities in the older crystalline rocks, usually granite or schist, in Virginia.

Amphibole asbestos has been mined south of Bedford in Bedford County and about 2 miles east of Rocky Mount in Franklin County. It has been reported in the lead and zinc mines of Wythe County, near the copper deposits in Grayson County, from other localities in the Piedmont region and along the northeastern Blue Ridge. No commercial operations have been developed.

BARITE

DISTRIBUTION

Barite (sulphate of barium), frequently termed heavy spar, occurs in several places in the Piedmont and Appalachian Valley regions. The production of barite in Fauquier County, in the northeastern Piedmont, in 1845 was probably among the first attempts to mine barite in the United States. Barite has been reported in Amherst, Bedford, Buckingham, Campbell, Fauquier, Louisa, Nelson, Orange, Pittsylvania and Prince William counties in the Piedmont region; in Augusta, Bland, Botetourt, Frederick, Montgomery, Roanoke, Rockingham, Russell, Scott, Smyth, Tazewell, Warren and Wythe counties in the Appalachian Valley region; and deposits of probable commercial value have recently

[72] See "Selected References" at end of this report.

[73] Other mineral commodities used in building and construction work, which would come under the classification of "Nonmetallic Resources" are discussed in the sections on "Construction Materials" and "Limestone, Dolomite and Calcareous Marl."

been reported in Grayson County in the plateau section of the Blue Ridge province.

The principal production has been from Campbell and Pittsylvania counties, although barite has been mined in Bedford, Fauquier, Louisa, Russell, Smyth, and Tazewell counties. From information now available, it is thought that the most promising commercial deposits are those of the Campbell-Pittsylvania counties area, the Russell-Tazewell-Smyth counties area, and the Grayson County area.

OCCURRENCE AND CHARACTER

Campbell and Pittsylvania counties.—The most extensive known area of barite in the Piedmont region occurs in Campbell and Pittsylvania counties. It extends from a point about 3 miles south of Toshes in Pittsylvania County northeastward to a point about 7 miles southeast of Lynchburg, a distance of approximately 40 miles. The deposits occur in Cockeyville marble and its residual clay. The barite is generally white or gray, of good quality, and variable texture. The most important producer in this area has been the Hewitt mine, and it is reported that much of the material shipped from that property averaged better than 95 per cent barium sulphate. Among other mines in this area are the Ramsey, Berger, Bennett, Parker, and Thompson.

Grayson County.—In the Blue Ridge plateau section deposits of barite which appear worthy of further investigation occur along the southern slope of Iron Mountain in northern Grayson County. Others occur also in the vicinity of Independence in the south-central part of the county. The barite is reported to occur as irregular veins and replacement bodies in the Grayson granite-gneiss and the Unicoi quartzite.

Russell, Tazewell, and Smyth counties.—In the southwestern section of the Appalachian Valley region deposits of barite which have been mined and which appear to be of future commercial importance occur in Russell, Tazewell, and Smyth counties. In Smyth County, barite occurs in a narrow zone from a point about 2 miles southwest of Marion, northeastward, more or less parallel to U. S. Highway No. 1, for a distance of 5 miles. Other deposits occur west of Marion. The Russell-Tazewell belt begins about 2 miles north of Lebanon and extends in a northeasterly direction along Clinch River to North Tazewell, a distance of about 35 miles.

The barite occurs mainly as small veins or replacement masses in Beekmantown limestone and dolomite. There have been a number of operations in all three counties and it is probable that considerable barite has been mined in this area; however, the showings of barite in bedrock locally should stimulate additional prospecting.

PRODUCTION

Barite has been mined in Virginia for more than 80 years. According to Holden[74] the annual production of barite in Virginia, from 1900 to 1907, ranged from about 5,000 to 10,000 tons, compared with a total annual production of 100,000 to 225,000 tons for the United States during the present century. Although production statistics for Virginia for the past few years are not available, it is believed that as a result of renewed operations in the Piedmont region in the past two years, the recent production from Virginia will compare favorably with that above referred to, even though in 1932 the total production of the United States had decreased to 117,801 tons. In 1933, the total United States production was 152,297 tons.

USES

Barite has several chemical uses. It is used in the manufacture of lithophone, paint, enamel, lacquers, rubber, wall paper, asbestos cement, in tanning leather, in sugar refining, in enameling iron ware, in glazing pottery, and in the manufacture of barium chemicals.

CERAMIC MATERIALS

Virginia contains a variety of mineral resources adapted to the manufacture of clay and ceramic products. Among these are barite, clay and kaolin, feldspar, kyanite, limestone and dolomite, and shale. Among the ceramic and allied products for the manufacture of which natural mineral resources are available are brick, tile, sewer pipe, terra cotta, refractories, tableware and kitchenware, pottery, porcelain, paper filler and other uses. The barite, feldspar, kyanite, and limestone and dolomite are discussed separately elsewhere in this report.

CLAY

Deposits of clay of known or probable brick-making quality occur throughout the State. Many deposits are as yet undeveloped. The clays of the Coastal Plain region have been described by Watson[75] and similar studies of clay areas in the Piedmont region and clay and shale resources west of the Blue Ridge have been made by Ries and Somers.[76]

Deposits of brick clay occur in Princess Anne County, in the vicinity of Norfolk, at Suffolk in Nansemond County, in the vicinity of City

[74] Holden, R. J., Minerals and their exploitation, *in* Virginia: Economic and Civic, p. 111, Richmond, Whittet and Shepperson, 1933.

[75] Watson, T. L., Economic products of the Virginia Coastal Plain *in* Physiography and geology of the Coastal Plain province of Virginia: Virginia Geol. Survey Bull. 4, pp. 223-239, 1912.

[76] Ries, H., and Somers, R. E., The clays of the Piedmont province, Virginia: Virginia Geol. Survey Bull. 13, 86 pp., 1917.
....., The clays and shales of Virginia west of the Blue Ridge. Virginia Geol. Survey Bull. 20, 118 pp., 1920.

NONMETALLIC RESOURCES OF VIRGINIA

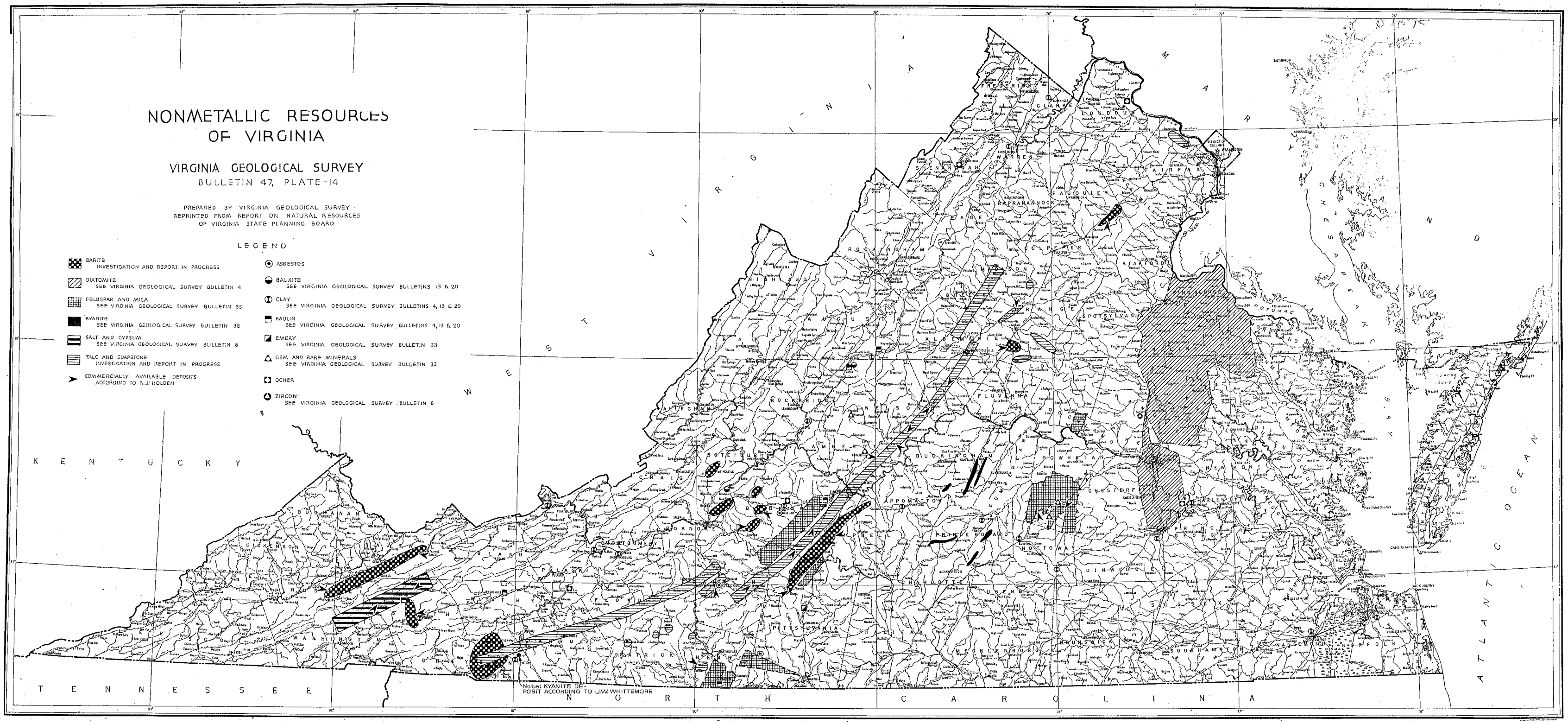
VIRGINIA GEOLOGICAL SURVEY

BULLETIN 47, PLATE -14

PREPARED BY VIRGINIA GEOLOGICAL SURVEY
REPRINTED FROM REPORT ON NATURAL RESOURCES
OF VIRGINIA STATE PLANNING BOARD

LEGEND

- BARITE
  INVESTIGATION AND REPORT IN PROGRESS
- DIATOMITE
  SEE VIRGINIA GEOLOGICAL SURVEY BULLETIN 4
- FELDSPAR AND MICA
  SEE VIRGINIA GEOLOGICAL SURVEY BULLETIN 33
- KYANITE
  SEE VIRGINIA GEOLOGICAL SURVEY BULLETIN 38
- SALT AND GYPSUM
  SEE VIRGINIA GEOLOGICAL SURVEY BULLETIN 8
- TALC AND SOAPSTONE
  INVESTIGATION AND REPORT IN PROGRESS
- COMMERCIALLY AVAILABLE DEPOSITS
  ACCORDING TO R.J. HOLDEN
- ASBESTOS
- BAUXITE
  SEE VIRGINIA GEOLOGICAL SURVEY BULLETINS 13 & 20
- CLAY
  SEE VIRGINIA GEOLOGICAL SURVEY BULLETINS 4, 13 & 20
- KAOLIN
  SEE VIRGINIA GEOLOGICAL SURVEY BULLETINS 4, 13 & 20
- EMERY
  SEE VIRGINIA GEOLOGICAL SURVEY BULLETIN 33
- GEM AND RARE MINERALS
  SEE VIRGINIA GEOLOGICAL SURVEY BULLETIN 33
- OCHER
- ZIRCON
  SEE VIRGINIA GEOLOGICAL SURVEY BULLETIN 8



Point in Prince George County, at Petersburg in Dinwiddie County, at Bermuda Hundred in Chesterfield County, and in other Coastal Plain counties.

In the Piedmont province deposits of clay of known or tested brick quality are found at Blackstone and Burkeville in Nottoway County, in the vicinity of Farmville in Prince Edward County, near Appomattox in Appomattox County, in the Bedford-Thaxton area in Bedford County and at other places.

Other clay deposits of probable brick-making qualities occur near Berryville in Clarke County, Riverton in Warren County, Christiansburg in Montgomery County, Galax in Grayson County, Marion in Smyth County, and Narrows in Giles County.

KAOLIN

Deposits of kaolin, possibly of a quality suitable for pottery manufacture, occur at Lofton, Cold Spring and Sherando in Augusta County, near Oak Level and Ridgeway in Henry County, at Forest in Bedford County, near Rye Valley in Smyth County, and near Wytheville in Wythe County.[77]

Deposits of weathered feldspar have been mined as kaolin locally in some of the Piedmont counties. Occurrences of fire-clay or kaolin of probable fire-brick quality have been reported to occur at Stuarts Draft in Augusta County, near Buena Vista in Rockbridge County, at Radford in Montgomery County and at Christiansburg in Montgomery County.

SHALE

More or less extensive bodies of shale adapted to the manufacture of shale brick or for mixing with clay in making clay-shale brick are found throughout portions of the Appalachian Valley region.[78] The distribution of the shale formations and the location of accessible bodies in the neighborhood of local clay-bearing areas are shown on the geologic map of Virginia, and in more detail on the geologic map of the Appalachian Valley in Virginia, issued by the Virginia Geological Survey in 1928 and 1933, respectively.

DIATOMITE

OCCURRENCE AND CHARACTER

Diatomite, or diatomaceous earth, is a fine-grained, earthy to chalky material composed of numberless skeletons of microscopic plants (diatoms). When pure, the material is white, porous, of low specific

[77] Ries, H., and Somers, R. E., op. cit.
[78] Ries, H., and Somers, R. E., The clays and shales of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 20, 118 pp., 1920.

gravity, and of varying degrees of induration. In Virginia deposits of diatomite occur in the Calvert formation of Miocene age in a broad belt, extending from Petersburg northeastward to Potomac River. In places the beds are reported to have a thickness of 30 feet. The Virginia deposits are generally of a brownish or yellowish color and contain variable amounts of impurities, mainly iron oxides, alumina, lime, and magnesia.

The best exposures occur in the city of Richmond, in the vicinity of Petersburg, at Bermuda Hundred on James River, along the Rappahannock River, near Wilmont in King George County, and near Layton in Essex County. The exposures along the Rappahannock River are reported to be of higher purity than most of the others. The American Diatom Co. is reported to have shipped several hundred tons of diatomite from a deposit near Leedstown in 1933, which is the first known attempt to rework the Virginia deposits since previous operations ceased some years ago as a result of the discovery and exploitation of deposits of higher quality in some of the western states.

As no detailed studies have yet been made of the deposits in Virginia, information on the extent, character, and probable economic value of the deposits is not available.

USES

The principal uses of diatomite are as a heat, cold, and sound insulating material; as a filter medium for filtering oils and liquids, in the refining of cane sugar, an admixture in concrete, and as lightweight filler. Diatomite was first used mainly as an abrasive or polishing agent, as a constituent of polishing preparations. Other uses include the manufacture of sealing wax, fireworks, Swedish matches, oil cloth, linoleum and insecticides.

EMERY

A deposit of emery near Whittles in Pittsylvania County in the southern Piedmont region has been operated on a small scale for grindstones or abrasives. This is the only occurrence of emery in the State that has been mined.

FELDSPAR AND MICA

DISTRIBUTION

The term feldspar includes several species, all of which are silicates of aluminum with varying amounts of lime, potash, and soda. In color feldspars vary from white to pink or red, and green. The alkali feldspars, those known as orthoclase, microcline, and albite are the most im-

portant commercially. Feldspar occurs in many of the granitoid rocks of the Piedmont region. (See Pl. 13, B.)

Mica is likewise a silicate of aluminum, with several varieties designated in accordance with the percentages or amounts of other elements, such as potassium, magnesium, fluorine, and iron, contained. Two varieties, muscovite or white mica, and biotite or black mica, are of common occurrence in many of the sedimentary and crystalline rocks of the Piedmont region, mainly in mica schist and micaceous granite-gneiss. Muscovite is the only mica occurring in Virginia in quantities or quality of commercial value.

Although both feldspar and mica are of wide distribution in the Piedmont region the results of recent detailed studies of the Virginia deposits show that known deposits of probable commercial importance are more or less restricted to pegmatite and syenite areas.[79] The most promising deposits of feldspar and mica occur in Amelia, Amherst, Bedford, Franklin, Henry and Pittsylvania counties.

PRODUCTION

Feldspar.—Prior to 1907, feldspar was produced largely from the Amelia area in Amelia County, as a result of mica mining, although in the same year quarries were also reported in operation near Bells in Bedford County and near Prospect in Prince Edward County. Since then, there has been annual production from these and other counties in the Piedmont region with the exception of the period from 1917 to 1922. As a result of the legalizing of beer and the increased demand for bottles, glass-lined tanks, enameled vessels and allied specialty products, the production of feldspar throughout the United States increased greatly in 1933 and since. The total production of feldspar in Virginia in 1933, was 13,459 long tons, valued at $52,758, nearly double in quantity that of 1932, which was reported as 6,759 tons with a value of $31,990.

Mica.—Mica has been mined intermittently in Virginia over a long period of time. It is claimed by the early settlers in that neighborhood that mica was mined in Amelia County, by the Indians, prior to the white man's arrival there. The first record of actual mining, however, was from 1867 to 1870, in Hanover County. The Jefferson mine in Amelia County was opened in 1873 and other mines in that area were started soon after. Owing to the development of several other mines in this area and stimulated production, the most productive deposits were exhausted. The mines were abandoned and allowed to fill with water, there having been but few attempts made to rework any of them, except for a brief period of small production during the World War.

[79] Pegau, A. A., Pegmatite deposits of Virginia: Virginia Geol. Survey Bull. 33, 123 pp., 1932.

Mines were first opened in Goochland County in 1880 and operated until about 1885. There was little production of mica from 1885 until about 1900, but there was a resumption of activity in 1900 to 1902. In 1907 the deposits near Ridgeway in Henry County were operated and after another quiet period, mines were opened in 1913-1923 in the Ridgeway area in Henry County, the Axton area in Pittsylvania County, and the Goochland area in Goochland County.

In 1918, the production of sheet mica in Virginia reached its greatest value, $46,200. The greatest quantity of sheet mica, 179,339 pounds, which was more than twice that of 1918 (78,500 pounds), was produced in 1920, although its value was only $26,189. As a result of the decrease in price there was a considerable reduction of production in Virginia in 1921. There has been some production annually since then; however, the production of scrap and sheet mica, for 1931, the last year for which figures are available, was 371 short tons and 6,554 pounds, respectively, valued at $4,044 and $601, respectively (a total of $4,645.)

USES

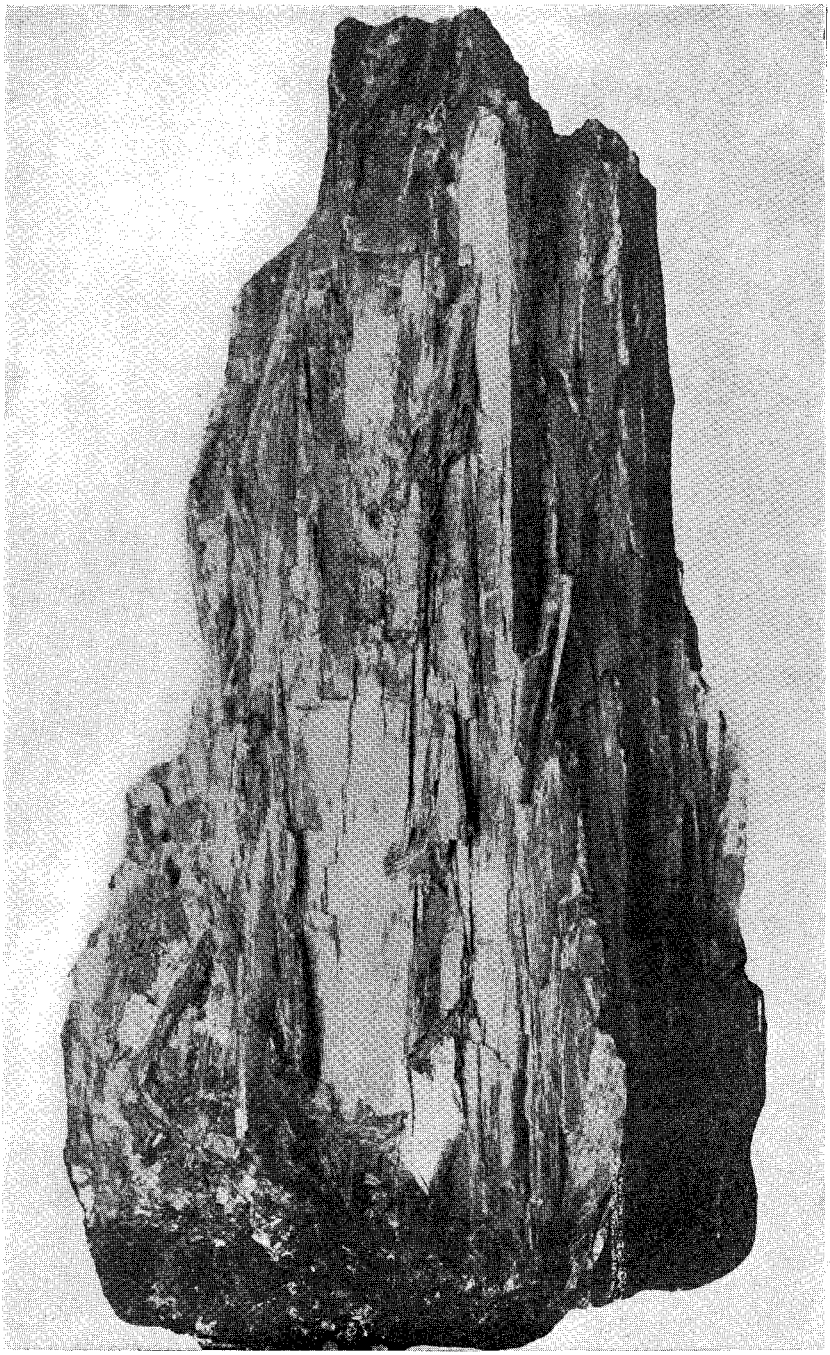
Feldspar.—Feldspar is used mainly in the ceramic industry for making pottery, enamel ware, enamel brick, vitrified sanitary ware, and electrical porcelains. It is also used as a flux or binder in the manufacture of emery and corundum wheels. The glass industry has become an important consumer of feldspar in recent years, accounting for about 30 per cent of the total United States production. Some feldspar is used in the manufacture of wood filler and scouring soaps.

Mica.—Muscovite is used for many purposes, the most extensive, in sheet form, being in the electrical industry for insulators in dynamos, motors, switchboards. It is also used for transparent stove doors, safety lamps, automobile curtains, in arc lights, incandescent lamps, and X-ray apparatus. Sheet and "built-up" mica are used for decorative purposes, as lamp shades, Christmas-tree snow, on postcards, and for wall paper, and plasters. Scrap mica from mines is ground and used in giving lustre to wall paper, in making various paints, in rolled roofing, asphalt shingles, as a filler in rubber goods, and for dusting automobile tires. Finely ground and mixed with oil, mica makes an excellent lubricant.

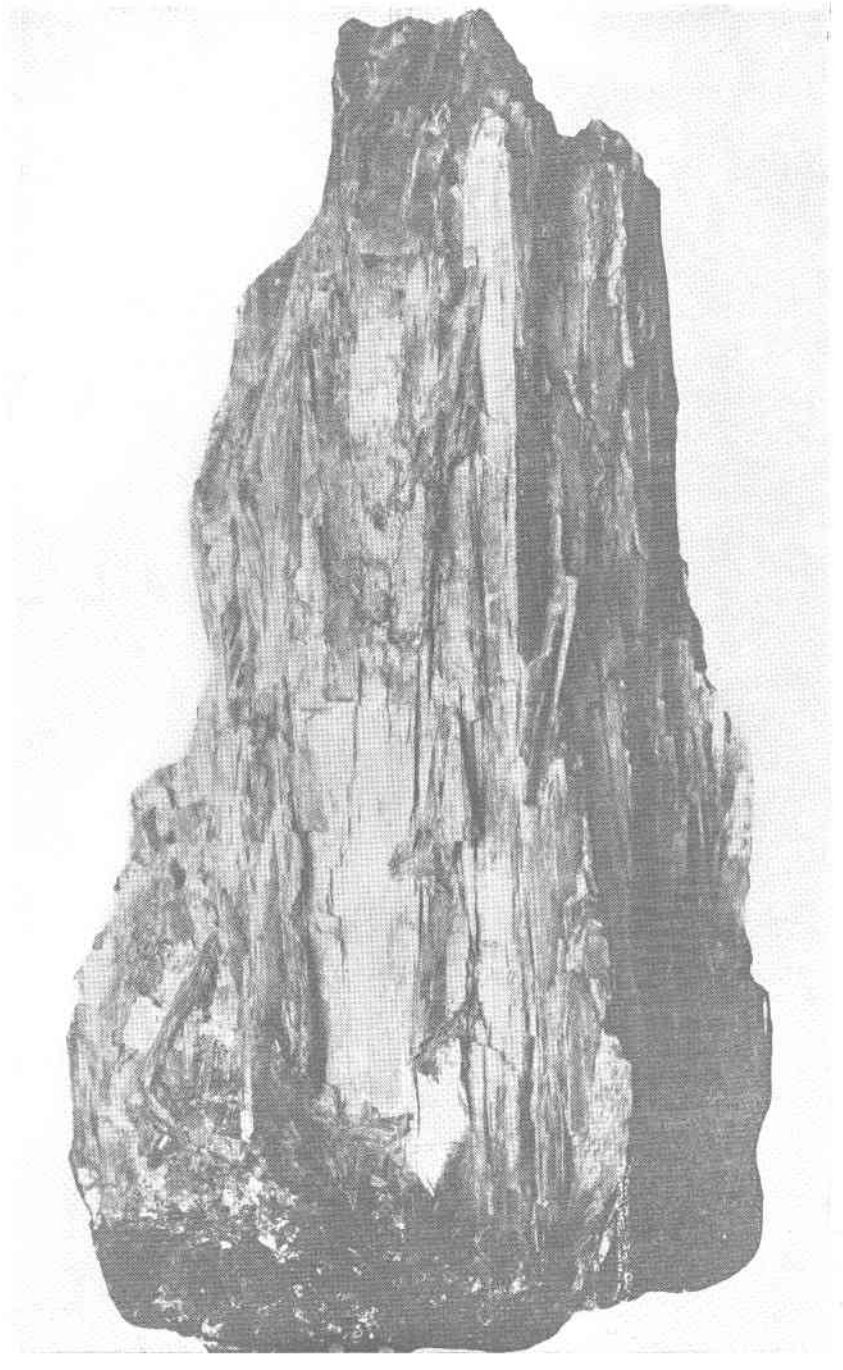
FERTILIZER MATERIALS

Fertilizer materials include cave earth, dolomite and limestone, gypsum, marls—both calcareous and greensand—potash and phosphorus-bearing rocks. The limestone, dolomite and calcareous marl deposits of Virginia have been described separately in a previous section,[81] and

[81] See section on "Limestone, Dolomite and Calcareous Marl."



Kyanite from a deposit near Galax, Virginia. From Geological Survey Bulletin 38, by A. I. Jonas.



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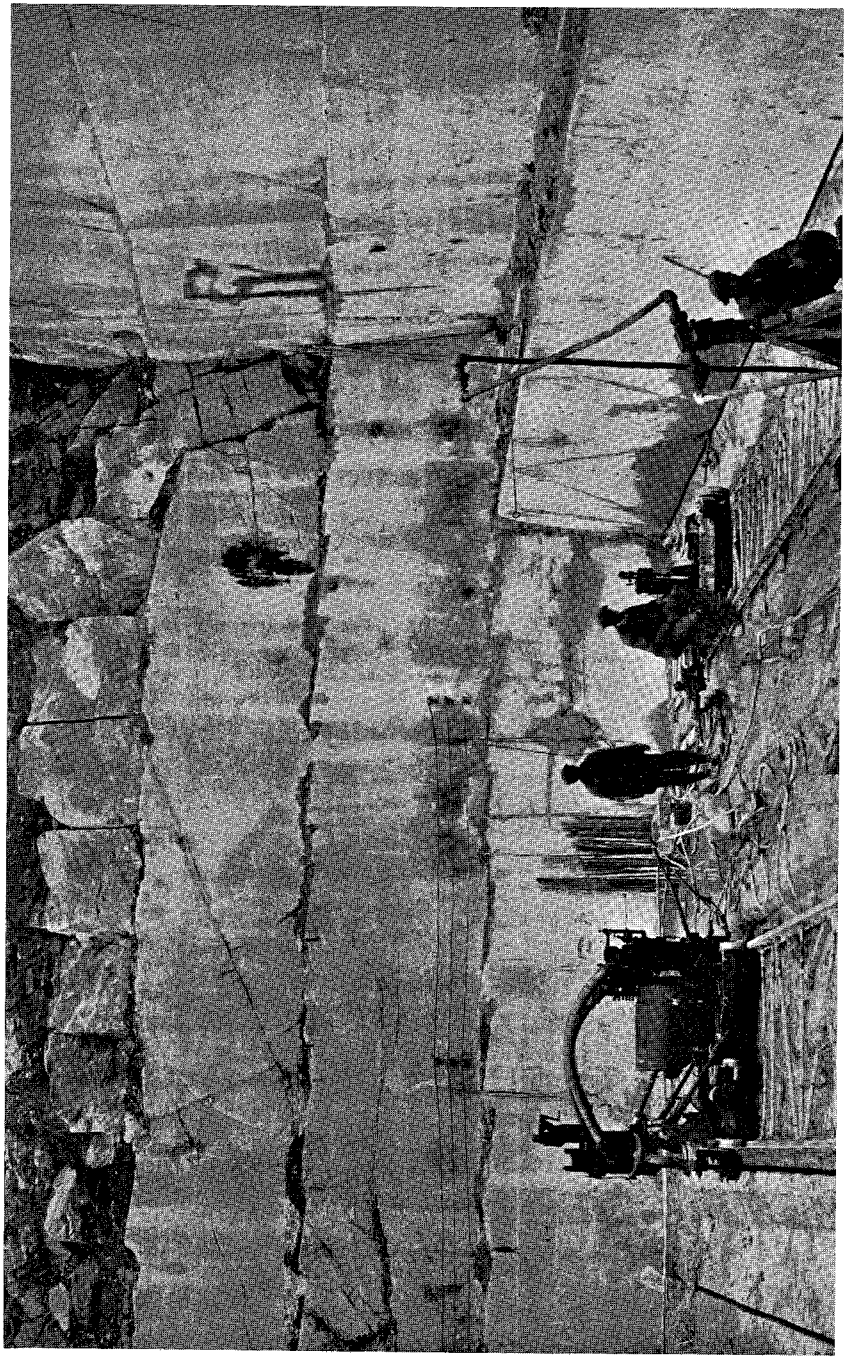
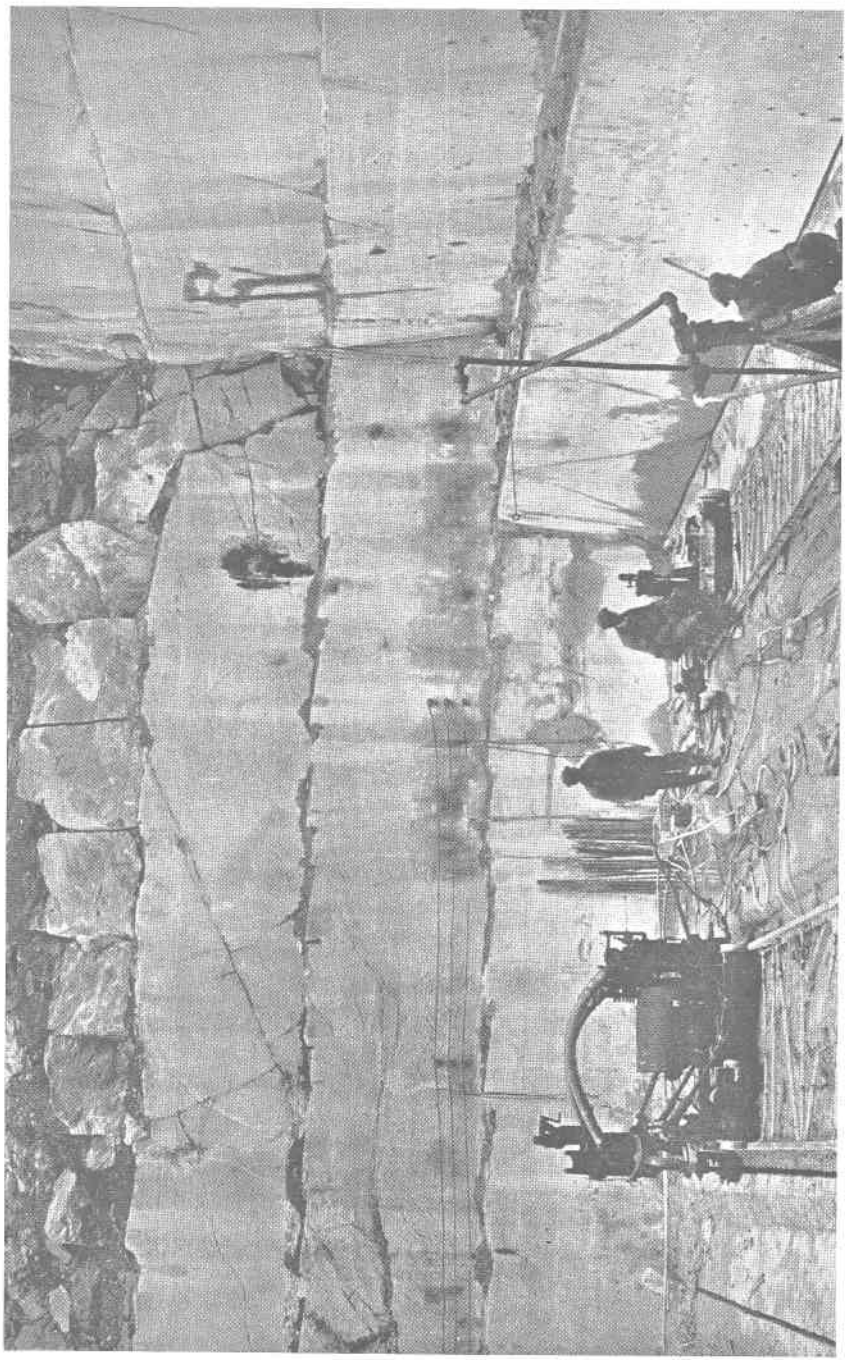


Soapstone quarry near Schuyler, Albemarle County, Virginia. Photograph courtesy of Alberene Stone Corporation of Virginia.



Soapstone quarry near Schuyler, Albemarle County, Virginia. Photograph courtesy of Alberene Stone Corporation of Virginia.

will not therefore be again discussed here. The gypsum deposits are also treated of separately later in this section. Occurrences of cave earth, some of which are reported to have been worked for saltpeter used in the manufacture of gunpowder by the Confederate soldiers during the War between the States, have been noted in caves in the limestones of the Appalachian Valley region.

GREENSAND MARL

Deposits of greensand marl occur extensively in Eocene and Miocene formations of the Coastal Plain of Virginia. The green color of these marl deposits is due to the glauconite which occurs as fine grains. Greensand marl is composed principally of potash and lime. A small variable percentage of phosphate of lime is shown in many analyses of greensand. Greensand marl has been slightly used locally as a natural fertilizer but it is more frequently used as a base in the manufacture of artificial fertilizers. Small deposits have been worked at a few places.[82]

PHOSPHORUS-BEARING ROCKS

Three forms of phosphorus-bearing material are known to occur in Virginia. They comprise the greensand marls of the Coastal Plain above described, nelsonite deposits of the Vinton area in Roanoke County, and the more extensive deposits of Amherst and Nelson counties, and the pebble phosphate deposits found in the Devonian shales west of the Blue Ridge Mountains. Phosphate minerals have also been reported from Rockbridge County in central western Virginia and from Floyd and other counties in southwestern Virginia. Nelsonite is a dikelike igneous rock composed principally of ilmenite and apatite. Rutile is frequently associated with the ilmenite (nelsonite). Ilmenite and rutile are sources of titanium (see Titanium minerals). Apatite is composed chiefly of calcium and phosphorus in the form of a calcium phosphate. It is a source of phosphate, and phosphorus. The apatite deposits of Virginia have been described by Watson and Taber.[83]

But slight local production of phosphate or phosphorus from these deposits has been attempted and they are largely undeveloped. The variety of uses of phosphate in chemical industries should prove a stimulus for the future development of some of the known Virginia deposits.

[82] Watson, T. L., Economic products of the Virginia Coastal Plain, *in* Clarke, W. B., and Miller, B. L., Physiography and geology of the Coastal Plain province of Virginia: Virginia Geol. Survey Bull. 4, pp. 247-249, 1912.
Roberts, J. K., Greensand and diatomite deposits of Virginia: Bull. Virginia Section, Am. Chem. Soc., vol. 11, no. 9, pp. 130-132, 1934.

[83] Watson, T. L., and Taber, Stephen, Geology of the titanium and apatite deposits of Virginia: Virginia Geol. Survey Bull. 3-A, 308 pp., 1913.

KYANITE

CHARACTER AND DISTRIBUTION

Kyanite is silicate of aluminum, which has bladed structure and good cleavage. It is a member of the sillimanite group of aluminum silicate minerals. Although the occurrence of kyanite has been known for a long time, it is only in recent years that the members of this silicate group have attained prominence, as a result of the discovery of many uses for them in the ceramic industry. Of the three members of the sillimanite group, kyanite is of more widespread distribution and occurrence, although but few deposits of commercial importance have been found. In Virginia, kyanite is found mainly in Buckingham, Charlotte, and Prince Edward counties in the Piedmont region and in Carroll and Grayson counties in the Blue Ridge plateau section. Kyanite has been reported also in Spotsylvania and Patrick counties.[80] (See Pl. 15.)

OCCURRENCE

In the Piedmont region kyanite occurs mainly in the Wissahickon schist, a crystalline schist in a belt of ancient crystalline rocks. Where most abundant the kyanite is generally in the quartzite beds of the schist. Leigh and Baker mountains in Prince Edward County and Woods and Willis mountains in Buckingham, each of which is a prominent local feature, are formed of kyanite-bearing quartzite. In the Carroll-Grayson counties area, the kyanite occurs in pegmatite.

Kyanite has been mined on a commercial scale at only one locality in Virginia, in a deposit on Baker Mountain. Here the kyanite content of the unaltered kyanite quartzite is reported to range from 20 to 80 per cent, probably averaging well above 40 per cent.

USES

Until a relatively few years ago, there was no commercial demand for kyanite. Recent experiments and tests have proved, however, that kyanite is especially well adapted to use in the manufacture of electrical porcelain, for which it is to some extent replacing feldspars. It is also used for spark plug porcelain. It is reported that as a result of detailed experiments and tests, the Champion Porcelain Company since 1919 has been using in all of its spark plug cores, andalusite, one of the three members of the sillimanite group, from California. Other uses for which kyanite or its equivalents, have been found well suited are: Glass house refractories, crucible furnaces, saggers, high-temperature cements, boiler furnaces, cement kiln linings, and other special applications.

[80] Jonas, A. I., Geology of the kyanite belt of Virginia: Virginia Geol. Survey Bull. 38, pp. 1-38, 1932.
Watkins, J. H., Economic aspects of kyanite: Idem, pp. 39-45, 1932.

OCHER

Ocher is a term commonly applied to pulverized or earthy forms of hematite or limonite (oxides of iron) more or less admixed with kaolin or clayey material. Natural ochers are commonly red, brown and yellow. The chief use of ocher is in the manufacture of paints.

Ocher of varying degrees of purity and of many different colors is known to occur locally throughout the State, in the Coastal Plain, the Piedmont, and the Appalachian Valley provinces. Ocher has been mined near Bermuda Hundred in Chesterfield County, near Bedford in Bedford County, in the vicinity of Woodstock in Shenandoah County, at Stanley in Page County, near Pulaski in Pulaski County, and locally in Augusta and Rockingham counties. Other occurrences are known near Max Meadows in Wythe County and at several localities in Roanoke County.

A paint or pigment manufacturing plant has been in operation at Bedford for a number of years and a second mine and mill are now operating near Hiwassie in Pulaski County.

SALT AND GYPSUM

DISTRIBUTION AND EARLY HISTORY

Deposits of salt (sodium chloride), both as rock salt and as salt brines, and gypsum (hydrous calcium sulphate) are found in association in the valley of the North Fork of Holston River, in an area about 30 miles long and about 5 miles wide, extending northeasterly through parts of Washington and Smyth counties. The town of Saltville, in the southwestern corner of Smyth County, is situated near the center of the area. The best known and largest developed deposits occur in the part of the area from south of Plasterco in northeastern Washington County on the southwest to North Holston in southwestern Smyth County, on the northeast. Other deposits, several of which have been worked in the past, are found near Chatham Hill in Smyth County, and southwest of Plasterco.

Salt seeps in the vicinity of Saltville have been known for a long time. Wild animals frequented the seeps in the swampy flats in Holston Valley and here it was that the Indians and pioneer hunters and trappers sought them. The early settlers in this region dug shallow wells to obtain the brine from which they extracted the salt. Two wells were reported in operation in 1836. During the War between the States the wells at Saltville, of which there were several in operation, were the main source of salt for the Confederacy.

It is not known when gypsum was first discovered or produced in southwestern Virginia, although the value of using "gypsum plaster"

as a fertilizer on poor farm land in Virginia was known as early as 1835. Watson[84] stated that between 1815 and 1857, a number of borings were made on the property, later operated by the Buena Vista Plaster and Mining Company at Plasterco, to determine the thickness of the gypsum and the presence of brine or rock salt. According to the same authority, gypsum was produced about 1892 from a mine on the (then) Barnes tract, about 8 miles northwest of Saltville. The large dump pile at this mine when Watson visited it in 1906 indicated that the gypsum mined there was of good quality.[85]

OCCURRENCE AND CHARACTER

The commercial salt and gypsum deposits occur along a narrow belt of Mississippian rocks extending along the northwest side of the Saltville fault from the vicinity of Plasterco to Chatham Hill, a distance of about 16 miles. They have been described by Stose.[86]

Gypsum occurs in lenses and masses of variable thickness and extent, generally in massive form. Some selenite (a cleavable platy or strip variety) occurs locally associated with the more massive variety. The purer forms of gypsum are white or gray; brown, black or other colors are due to impurities.

Salt occurs both as salt brine and as rock salt. In several places salt has been found below beds or lenses of gypsum. A large number of salt wells has been drilled in the Saltville area, to depths ranging from a few hundred to more than 2,000 feet.

PRODUCTION AND USES

Salt has been produced commercially only near Saltville, where large properties are owned and operated by the Mathieson Alkali Works. This company has maintained operations since 1895, when it acquired the properties. It is a large producer of soda products. The salt is obtained from the brine and made into sodium carbonate by a modern improved ammonia-soda process. The sodium carbonate is used in the manufacture of baking soda, soda water, caustic soda, soda ash, chlorine, and other chemical products. Soda ash is used in the manufacture of glass and pottery, and caustic soda, put up in large hermetically sealed containers for chemical and medicinal purposes.

Plaster of Paris was made (by roasting) from gypsum in this area about 1900. The production, however, was small and it only has been since then that the successful field of use of gypsum products in construction, architectural, and related lines, has been developed. The

[84] Watson, T. L., Mineral Resources of Virginia, p. 331, Virginia-Jamestown Exposition Commission, Lynchburg, Va., J. P. Bell Co., 1907.
[85] Watson, T. L., op. cit., p. 330.
[86] Stose, G. W., Geology of the salt and gypsum deposits of southwestern Virginia: Virginia Geol. Survey Bull. 8, pp. 51-73, 1913.

United States Gypsum Company's plant at Plasterco and that of the Beaver Products Company at North Holston are the largest producers of gypsum in Virginia, and are reported to be the largest operations south of the Ohio and east of the Mississippi rivers.

In 1933, the Mathieson Alkali Works acquired the holdings of the Beaver Products Co. (formerly a subsidiary of the Certainteed Products Co.)

Uncalcined ground gypsum is used as a land plaster and, when finely ground, as an adulterant in cheap paints. Ground and calcined gypsum is used in large amounts in building and construction work, as plaster of Paris, base coat and wall plaster, in wall or plaster boards, in the manufacture of Keene's cement and in the manufacture of plate glass. Crude uncalcined gypsum is now being rather extensively used in Portland cement. Finely ground and calcined gypsum produces a plastic medium which by the addition of water may be cast and molded in any form.

Production statistics are not available for either the quantity or value of salt or gypsum produced in Virginia in recent years.

SOAPSTONE AND TALC

GENERAL STATEMENT

Soapstone is a medium- to fine-grained, bluish-gray, greenish-gray, or grayish-green, generally massive, variety of talc, showing varying degrees of schistosity and possessing the quality of being easily sawed or cut. Several grades or varieties occur. Commercially, soapstone is the most important and the most widely distributed variety of talc in Virginia. (See Pl. 16.)

Talc is a hydrous silicate of magnesia. It has a soapy feel, is very soft, being easily cut with a knife, and varies in color from apple-green, to white or yellowish. It occurs as small veins or as massive, generally lenticular, bodies. There are several varieties, based on their chemical composition and physical properties.

Steatite is a coarse- to fine-grained massive variety of talc which may be as hard as 2.5, depending upon kind, nature, and amount of impurities contained. The best grade of steatite appears to be an interwoven mass of talc flakes with about 1 per cent of chlorite and a few grains of magnetite.

Steatite, soapstone, and deposits of pure talc have been found in Virginia. The deposits have been described by Burfoot.[87]

[87] Burfoot, J. D., Jr., The Origin of the talc and soapstone deposits of Virginia: Economic Geology, vol. 25, no. 8, pp. 805-826, 1930.

OCCURRENCE AND DISTRIBUTION

Soapstone and talc occur as lenses or irregularly shaped bodies, in or along dikelike bodies of altered crystalline rocks trending northeasterly across the central and west-central parts of the Piedmont region. The most extensive deposits occur in a belt extending from Madison County southwestward to Grayson County, a distance of more than 200 miles. This has been termed the Albemarle-Nelson county belt. Other commercial deposits occur in Fairfax and Franklin counties. Small deposits, some of which have been worked locally, occur near the main belts and it is probable that other deposits will be found.

Albemarle and Nelson counties belt.—Soapstone has been quarried at places over a distance of more than 25 miles in Albemarle and Nelson counties in the main developed soapstone belt. The operations at Schuyler and Alberene show these deposits to be 1,200 and 2,000 feet long, respectively, as much as 300 feet wide, and as yet of unknown depth. Some of the quarries 200 feet or more deep, still show good stone at that depth. The soapstone generally always grades into the enclosing rock type. These are the largest operations in the United States and are reported to produce more soapstone than any other locality in the world. (See Pl. 16.)

Fairfax County.—There are a number of scattered deposits in Fairfax County, which are operated mainly for talc. These yield the largest production of talc in the State. The talc is produced almost entirely in ground or pulverized form.

Other areas.—Other local deposits of talc and soapstone of probable commercial value occur in the vicinity of Orange, Barboursville and Locust Grove in Orange County, between Louisa and Melton, and Zion and Poindexter in Louisa County, west of Bassetts in Henry County, and near Fayerdale, Elamsville, and Meadows of Dan in Patrick County.

PRODUCTION

The largest production of soapstone in Virginia in 1932 and 1933 was from the important operations at Schuyler, in Nelson County, with the Franklin County area second. The Fairfax County area was reported as the largest producer of talc. Figures are not available for soapstone, but those for talc show that the production of ground talc in Virginia for 1932 amounted to 90 short tons, valued at $1,260, and for 1933, 9,343 tons, having a value of $40,058.

USES

Although geologically closely related and considered together, because of the different form in which soapstone and talc are produced, prepared, and used commercially, these materials and their products are classed separately by consumers. Practically 95 per cent of the talc produced is sold in ground or pulverized form. On the other hand, the greater portion of the soapstone produced is sold as cut or dimension stone, and used in the form of blocks, slabs, and special shapes.

Soapstone because of its physical properties, easy workability, light color, and resistance to chemical and water action, is particularly adapted to a variety of structural and architectural uses, for which purposes it is mainly utilized. Commercial soapstone operations involve not only the production of the stone but the cutting, sizing, and finishing of the stone, and the manufacture of salable products at the quarries.

Soapstone in cut or sized forms is used for laundry tubs, aquariums, laboratory table tops, sinks, shower stalls, ovens, acid tanks, trays, developing tanks for photographs, retort and furnace linings, switchboards, insulators, fuse guards, griddles, fireplaces, hearths, mantels, wainscoting, baseboards, floors, steps, and other purposes. In granular form, hardened by heat treatment, soapstone has recently been used as an admixture and as a filler in concrete.

Talc in pulverized form is used in paint, paper, rubber, textile, and other products; in foundry bearings, in various lubricants, in toilet preparations, particularly talcum powder, in the ceramics industry, in glass manufacture, as a polishing agent, as an insecticide, and as an insulating material for underground conduits. Purer forms of massive talc are used mainly for electrical insulation and in the manufacture of crayons, pencils, and French (tailor's) chalk. Among new uses for ground talc are as a dusting material, to keep down dust and thus aid in preventing explosions in coal mines, and as an admixture in concrete.

OTHER RESOURCES

BAUXITE

Deposits of bauxite, hydrated oxide of aluminum, have been reported at the Cold Spring mine and other localities in Augusta County and from the old Houston iron mine in Botetourt County, a short distance northeast of Roanoke. The deposits occur associated with iron and manganese oxides in residual clays along the western base of the Blue Ridge.

Bauxite is one of the chief sources of aluminum, a metal of increasing importance in the manufacture of various light weight, aluminum alloy products. Bauxite is also used in the manufacture of bauxite bricks, artificial abrasives and aluminum salts.

GEM MINERALS

A large number of rare or gem minerals have been reported from Virginia, generally in occurrences of scientific interest only. The best known and most exploited occurrences are associated with pegmatite dikes in the vicinity of Amelia Court House, in Amelia County, although other occurrences are known locally in other crystalline rocks in the Piedmont region. Rare and gem minerals in Virginia have been described by Pegau.[88] Among the gems and minerals are allanite, amethyst, Amazon stone, apatite, beryl, columbite, fluorite, kyanite, microlite, moonstone, several varieties of smoky or colored quartz, sipylite, and spessartite. The best known deposits of allanite occur near Alhambra, in Amherst County, in association with the very rare mineral sipylite.

MINERAL WATERS

Natural mineral springs and mineral waters of known medicinal and domestic value occur in Virginia, chiefly in the mountainous sections on the west of the Great Valley, though a number are known in the Piedmont region. The number of spring resorts now in operation is not as great as in former years, but water from several properties is shipped for table or mineral water to many places in the United States. The beautiful natural scenic location of many of the mineral springs and local climatic conditions make their sites attractive for development into recreational and health resorts.

ZIRCON

A deposit of zircon-bearing sandstone occurs along the western boundary of the Coastal Plain province, a short distance west of Ashland in Hanover County. The zircon crystals are reported to be mostly of the short, stout form although elongated forms also occur. Quartz, garnet, ilmenite, rutile, staurolite, and other heavy minerals have been found in association with the zircon.[89] Zircon is used in the manufacture of special alloys, high-grade porcelain, and electrical apparatus.

[88] Pegau, A. A., Pegmatite deposits of Virginia: Virginia Geol. Survey Bull. 33, 123 pp., 1932.

[89] Watson, T. L., and Hess, F. L., Zirconiferous sandstone near Ashland, Virginia: Virginia Geol. Survey Bull. 8, pp. 40-50, 1913.

NATURAL GAS AND PETROLEUM[90]

Despite popular opinion to the contrary it is a well-established fact that certain geological conditions are essential to the occurrence of commercial quantities of natural gas and petroleum. First there must be source beds such as fossiliferous sandstones, limestones or carbonaceous shales, of marine origin from which natural gas or petroleum can be formed, by the decomposition of organic material contained in such beds. Second, there must be some satisfactory reservoir bed, such as a thick porous sandstone, or a fractured or fissured limestone, dolomite or shale, in which the gas or petroleum may accumulate in quantity for commercial production. Third, since both natural gas and petroleum migrate, there must be some impervious bed or caprock, such as a shale, above the reservoir bed, and also a favorable structure, such as an anticline, to trap or hold the moving gas or petroleum.

There are in the Coastal Plain and Appalachian Valley regions in Virginia marine beds that may have been satisfactory source beds for natural gas or petroleum, and in both regions there are favorable reservoir beds. But favorable structural conditions are lacking in the Coastal Plain region and even though natural gas or petroleum might have been formed in that region, it is most probable that neither is present at this time. This is borne out by a deep test hole that was drilled to a depth of 2,325 feet near Mathews in Mathews County about 5 years ago. No indication of either natural gas or petroleum of commercial importance was encountered.

In the Appalachian Valley the rocks have been greatly folded and in many places broken by faults. In these disturbed or deformed areas occurs coal. The coal was formed from plant remains in the rocks and in part has been carbonized by the heat and pressure generated by the disturbances. Had petroleum been present in the rocks, the chances are that the heat and pressure which affected the coal would have distilled or driven it off.

No commercial quantity of petroleum or natural gas has been found in areas of crystalline rocks, such as underlie the Piedmont region.

Thus, in general, the geology and structural conditions throughout Virginia are not considered favorable to the occurrence of commercial quantities of petroleum. It is possible, however, that occurrences of natural gas may be found locally in areas which have not been too extensively or too intensively deformed or where favorable structural conditions prevail. It is also possible that minor showings of oil, not of commercial importance, may likewise be found in such areas. Minor

[90] McGill, W. M., Prospecting for natural gas and petroleum in Virginia, *in* Contributions to Virginia geology: Virginia Geol. Survey Bull. 46, pp. 11-21, 1936.

seepages of gas and "showings" of petroleum have been reported from several localities in the Valley and southwestern Virginia regions.[91]

A test well drilled in 1930-31 on a favorable but small anticlinal structure near Early Grove in Scott County[92] resulted in the "bringing in" of the first natural gas well in Virginia.[93]

A second test near the completed well was abandoned in 1930 as a dry hole at a depth of about 2,900 feet, with no indications of either natural gas or petroleum having been found. A third hole, commenced during the summer of 1935, near the first well, is reported to have been completed early this year as a "second gas well." Three other unsuccessful test wells have been drilled in southwestern Virginia in the past few years and it is reported that others are to be drilled in the Early Grove area. Other wells have been drilled or tests projected in other parts of the Appalachian Valley region in the State, but no other indication of natural gas and no evidence of petroleum of commercial importance have been reported.

[91] Butts, Charles, Oil, *in* Fensters in the Cumberland overthrust block in southwestern Virginia: Virginia Geol. Survey Bull. 28, pp. 3, 10, 12, 1927.

[92] Butts, Charles, Oil and gas possibilities at Early Grove, Scott County, Virginia: Virginia Geol. Survey Bull. 27, 18 pp., 1927.

[93] McGill, W. M., Possibilities for oil and gas in southwestern Virginia: The Mountain Empire, Southwestern Virginia, Inc., Wytheville, Va., vol. 1, no. 3, pp. 10-11, 16, 1932.

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[94] See also "General References" above.

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[97] See also "General References" above.
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[100] See also "General References" above.
[101] See also "General References" above.

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